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Green Engineering and the Automobile Infrastructure

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by

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Abstract

This project is intended to determine the impact of automobiles on society and the environment. The impacts of fuel consumption, mining, fabrication, and road construction are explored, and improvements are recommended. We recommend making better use of replaceable and reusable parts, as well as improving fuel economy.

Executive Summary

The impact of automobiles on American society is varied and significant. A large amount of the average American's income goes to buying and maintaining automobiles. The resources that the United States expends on its fleet of automobiles are a monumental burden on the economy. The amount of natural resources consumed by automobiles, along with the damage done to the environment through use of the vehicles, will be a detrimental legacy for future generations to cope with. In order to lessen this financial and environmental impact, the processes through which automobiles consume resources should be streamlined to greater degree of efficiency.

About 11% of all energy spent on a vehicle in a typical life cycle is spent on material acquisition and manufacturing. Reusing parts from defunct vehicles can lessen this energy consumption. In order to facilitate reuse of parts, vehicles should be designed with disassembly and interchangeability of parts in mind. If all automobiles shared parts, and it was easy to remove them from broken cars, then there would be less need for newly manufactured materials.

Other damage done by manufacturing processes should be controlled. The largest damage in manufacturing and procurement activities is habitat destruction. Most habitat destruction is the result of poor methods resulting in pollution of an ecosystem. There are green engineering based improvements being implemented to reduce this negative output. Effort must continue to reduce pollution, and laws should be made stricter concerning poor practices.

Nearly 89% of the energy consumed by a vehicle is spent supplying and burning gasoline. Fuel efficiency of modern cars is poor, and internal combustion is an inefficient process. Reduction of this need for gasoline would greatly reduce the demands placed on the economy by the automobile infrastructure. Most pollution generated by vehicles is generated through vehicle exhaust and oil procurement. We must make more efficient automobiles, and experts agree that current internal combustion technology could be made nearly twice as efficient through streamlining.

Alternative fuels are viable, and many are more clean burning than gasoline; many are even zero emission fuels. The efficiency lost by making an engine alternative fuel ready is inconsequential (2-5% of the total power captured by the engine). Industries should support alternative fuel ready engines, and the government should entice them to do so.

If gasoline consumption is reduced by half, 40% of the trade deficit will disappear, the average American will have more money, and the environment will be saved from absorbing a huge amount of pollution.

The government should take steps to ensure that such efficiency is attained, and should more carefully regulate the emissions caused by auto-manufacturing.

Aknowlegements

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Authorship

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1 Introduction

The automotive industry has the power to influence the minds of the consumers. The fact is that the automotive industry can control the way that consumers view their products. This enables the automotive industry to advertise an automobile according to what they believe is appealing to the consumer. When most automobile companies produce their products they do not take into consideration the full effect that their product will have on the environment. Automobiles should be designed as environmentally friendly as possible while still economically profitable. There are so many ways that automobiles create waste throughout their entire life cycle.

The automobile industry does not give consumers all the information regarding waste generated and how it is exposed when consumers are buying a car. The truth of the matter is that most consumers are not extremely interested in this when purchasing a car. The automotive industry does not discuss the problems that may come with a particular car when advertising their product otherwise consumers would think twice about purchasing that particular vehicle. Most people will not even think about the environmental impact that automobile will have on the environment. People in general will look at the fuel economy of that automobile but will not look further than that. Companies that are the best at designing environmentally safe cars without loosing any quality can advertise this fact with the hope that consumers reward their efforts.

Green engineering is environmentally conscious design while still economically profitable and can be extremely important to a number of major industries. The automobile industry has made a number of strides with respect to green engineering but there still exists plenty of room for improvement. There are so many different times where waste is created during the life cycle of an automobile. Most of the waste comes while the automobile is being used but improvements in all areas during the automobiles life cycle are extremely beneficial. There are effects on the environment in the material gathering process, the production of the automobile, distribution, use, repairs, and finally recycling. These effects on the environment can be limited with improvements in material selection, waste during production, recycling parts, emissions waste, and fuel economy. Automotive companies have made cars that are more environmentally friendly over the last several decades and the cars of today continue to improve with respect to their effect on the environment.

Automotive companies focus on material selection because it can be extremely important in producing cars that have less of a negative effect on the environment. Important factors in material selection are weight, formability, design and styling requirements, safety considerations, warranty costs, and field experience. The material you choose is extremely important. Some materials are harmful to the environment when being mined. If the material can be recycled easily it can be very profitable to the company. If the parts of the car can be re-used the car becomes even more environmentally friendly.

During the production process of the car there is a lot of waste generated. There is excess material created during the assembly of the vehicle. Also there is factory waste, which can be extremely harmful to the environment in a number of different ways. Good examples of ways to prevent production waste include recycling, reuse and new technologies that limit the runoff from factory waste and lessen the impact of the emission on the atmosphere. These can all be cost effective ways to protect the environment.

Fuel economy is an important aspect of automobiles and continues to become more important with the gas prices continually rising. Consumers have become more interested in this as well because people are obviously interested in trying to save money. Fuel economy is also important to the environment, if a car burns less fuel it becomes less harmful to the environment.

Emissions of automobiles can be very harmful to the environment. There are new emissions test that cars must pass to be on the road. It is extremely important to control emissions for obvious reasons such as the number of cars that are on the roads emitting gases that can be extremely harmful to the environment. Improvements in this field are important to consumers and also society as a whole.

Recycling parts is an extremely important aspect of green engineering. If the car parts can be re-used or recycled it will save money and it will keep the parts from just being thrown away in a junk yard. Companies have really begun to focus on this and today about 75 percent of the scrap waste from an automobile can be recycled. Certain companies have made great strides with respect to part recycling and re-use and this has turned economically profitable and important part to green engineering.

2 Literature Review

2.1 Pollutants

Internal combustion engines are inherently inefficient energy sources. The inefficiency of the process (33%) leads to a wide variety of exhausts. Many of these exhausts are harmful pollutants. The following pollutants are regulated in all vehicles sold in the U.S..

2.1.1 Nitrogen Oxides (NOx)

Nitrogen Oxides are a group of pollutants that are combinations of Nitrogen and Oxygen atoms. These gases are primarily formed in combustion reactions. The major sources of NOx are motor vehicles (55%), utilities (22%), and industrial commercial and residential sources (22%).

NOx forms particulates, smog, acid rain, can recombine to produce hazardous chemicals, over fertilizes water and is a greenhouse gas. Smog and particulates lead to respiratory ailments. Acid rain damages the environment and degrades building or equipment that is exposed. Hazardous chemicals, such as nitroarenes and nitrosamines, produced by NOx cause a wide variety of health problems. Over fertilizing water leads to contaminant growth, destroying our water supply and harming the environment and global warming is believed to cause environmental problems.

2.1.2 Carbon Monoxide (CO)

Inefficient combustion processes, particularly internal combustion engines, form Carbon Monoxide. CO is poisonous in high doses, and causes respiratory and nervous system problems at lower doses. CO also contributes to smog formation.

2.1.3 Particulate Matter (PM)

Particulates are any non-gaseous particles that are suspended in the air. They can be released as smoke, fine particles (dust), or as chemicals suspended in gasses. PM can also be formed when chemicals such as NOx or CO react with sunlight and water in the air.

Particulate matter comes in a wide variety and can be associated with any of a broad number of serious health problems. These problems range from aggravated asthma (dust, pollen, etc) to lung cancer (coal dust) or death (Plutonium). PM also harms the environment, and damages structures.

2.1.4 Formaldehyde

Formaldehyde is created by industrial chemical reactions, incomplete combustion reactions, and some natural resins (urea). It is used in a wide variety of commercial applications ranging from embalming fluids to mascara. Formaldehyde is a carcinogen, causes asthma attacks, and can trigger severe allergic responses. (Safreit et al., 1991)

2.1.5 Non-Methane Organic Compounds

These compounds are created by incomplete combustion reactions. They come in a vast variety, and the health effects are impossible to pinpoint. The main concern associated with these gasses is their predisposition to contribute to smog formation.

2.2 *Fuels*

Gasoline is the primary fuel used by automobiles in the United States. The EPA tests Gas and any additives used for health effects before the fuel can be sold in the US. EPA requires the addition of oxygen to gas in order to have the combustion of the fuel be more complete. The two most common additives are alcohols and ethers. The following are several of the popular alternative fuels.

2.2.1 Compressed Natural Gas (CNG)

Natural Gas is a widely available fuel source. 1.3 thousand fuel stations cater to CNG vehicles, and, with an appropriate compressor, home natural gas can be used to fuel the vehicle.

Natural gas burns more cleanly than gasoline. Emissions, aside from carbon dioxide and water vapor, from a CNG engine near the zero emission mark. This allows for fewer oil changes in a CNG vehicle. Natural gas is non-toxic and biodegradable. The only environmental risk of CNG vehicles is that leaks of natural gas could lead to global warming. However, since we are consuming methane sources rather than leaving them to their own devices, we are safe guarding against worse releases.

There is no increased risk of explosion in CNG vehicles, since natural gas evanesces rather than coalesces, and since natural gas rises rather than falls in the atmosphere. (EPA, 1999)

2.2.2 Ethanol

Ethanol, alcohol made from degrading carbohydrates, is used as an admixture in almost all gasoline. Percentage mixtures of gas and alcohol are widely available. These mixtures burn cleaner than gasoline, and are cheaper. Virtually all cars are covered by warrantee to run on E10 (10% ethanol) or lower percentage mixtures. E10 is available at almost all gas stations in corn producing states such as Iowa. E65 (85% ethanol) is available at 60 gas stations nation wide.

Ethanol blends tend to cost more than conventional gasoline, with the exception of areas where ethanol is abundant (corn producing states). Vehicles get slightly less mileage with ethanol blends. However, Ethanol blends are better for engines, and can be used instead of using harmful engine additives like starter fluid.

Ethanol blends burn far cleaner than pure gasoline due to the oxygen content of ethanol. (EPA, 2000)

2.2.3 Fuel Cells

Fuel cells are a form of electrical generation that uses hydrogen as a source of electrons. Hydrogen for fuel cells is generally generated in a power plant through electrolysis. This use of electricity to generate hydrogen means that hydrogen fuel cells act as batteries, using energy stored in hydrogen as a fuel for synthesis of electricity.

By products of hydrogen fuel cell electricity generation are pure water vapor and electricity. This means that the process of converting hydrogen to energy is perfectly clean; it does not, however, mean that the production of the hydrogen is clean. The hydrogen production is done at a power plant, so the pollution caused by the use of hydrogen fuel cells as power sources is the same as the pollution caused by electrical power generation at a power plant.

Hydrogen fuel cells are an ideal electrical storage solution for electrical automobiles due to their small size and the vast amount of energy that can be stored in a small area.

Fuel cell technology is still under development, but is expected to mature in the near future. (U.S. Dept. of Energy, 2003)

2.3 *Material Selection Problems*

When building an automobile it is crucial to choose materials that best fit that automobile based on a number of factors. According to a University of Michigan study reducing costs will continue to be the main challenge for North American automakers in choosing vehicle materials in the next decade. Retired General Motors executive Michael DiBernardo found that weight, formability, design and styling requirements, safety considerations, warranty costs and field experience also will be important factors in material selection. The choice between aluminum and steel is based on 8 factors (Proceedings of the 1996 ASME Design Engineering Technical Conferences and Computers in Engineering Conference). The factors are yield strength, shape, density, cost, manufacturability, tensile strength, Young's modulus and Poisson's ratio. Taking all these into account allows you to make the appropriate decision when choosing between steel and aluminum.

There are new developments in material selection. The weight of passenger cars and light trucks are projected to decrease by 10 percent. The weight reduction will be achieved through greater use of aluminum and plastics and less use of low-carbon steel and cast iron. The Delphi survey respondents indicate that steel will continue to be the dominant material in frame construction. Aluminum is expected to be used 15 percent more often as frame material and 20 percent more as a space frame material by 2009. In fact, aluminum is forecast to see increased application for car hoods by 22.5 percent, deck lids by 17.5 percent, truck hoods by 30 percent, and rear hatches by 17.5 percent. Further, plastics are expected to see greater use in car fenders by 15 percent, doors by 10 percent, and in truck bed applications by 20 percent.

Low Voltage Differential (LVD) approached a company in the UK about weight reduction and vehicle assembly improvements. This would require LVD to look at the material selection of Corus and see what improvements they could make. The selection of the material is important in a number of ways for the company and LVD was successful in finding some of the best materials Corus could use in certain situations. Corus has been able to save weight while still maintaining all the other appropriate qualities. LVD also has helped Corus find the most cost-effective steel solutions for a high exterior finish.

Material selection is an important aspect of automobile manufacturing. The material you choose is extremely important. If the material can be recycled then the car is much easier to dispose of after its use. If the parts can be re-used the car itself is much more environmentally friendly. In this IQP the goal is to look at environmentally friendly projects that are still profitable. In this case if the car parts can be recycled it prevents the car from having to sit in a junkyard and is profitable at the same time.

3 The Automobile Industry, Society and the Environment

3.1 Impact of Automobiles on Society

We all know the freedom that comes with getting a license. As soon as it is possible to drive ourselves, there is no longer a dependence on others for modes of transit. Indeed, with just 20 dollars of gas, it is possible to travel hundreds of miles, assuming a car is available to use.

Cars are an inherently inefficient method of transportation. Thousands of pounds of automobile need to be moved along with the passengers, compared to motorcycles or other smaller vehicles. The profile of the cab is much larger than the passengers that are generally carried, and the number of passengers is usually quite small, leading to inefficiency per cycle of movement. There are generally large amounts of accelerating and decelerating, which wastes energy. Not to mention the fact that internal combustion engines capture a small amount of the energy that is released by the burning gasoline (30% is the 2004 baseline).

Even with all of these flaws, it is very difficult to give up such freedom. Most Americans travel long distances to work each day; before automobiles this was essentially impossible. The average daily one-way commute to work in the United States takes just over 26 minutes, according to the Bureau of Transportation Statistics' *Omnibus Household Survey*.

The impact of automobiles on the lives of Americans is made apparent by the effect of interstate highways on economic development. Where interstate highways are built businesses spring up, housing is constructed, and economy booms. People buy houses near highways, in spite of the noise they generate, because of the decreased commute times.

The efficiency of cars is an important consideration to an automobile driven country such as America. A 50% increase in fuel economy will save the average American thousands of dollars per year.

3.2 Business Interests vs. Environmental Conscience

When considering the impacts of cars on the environment the interplay of the auto industry and the consumers must be observed. Consumers respond to fad and advertisement. Fads and advertisement rarely conform to any environmental ideals, as is made plain by the recent surge of SUVs which have replaced ordinary cars to service the needs of ordinary commuters. Even the low 15-20 mpg average fuel economy of most light duty trucks has not curbed the sale to a public who, by and large, has no use for a truck over a more efficient car. Environmental causes don't have the economic power many fortune 500 companies. The automobile industry has the power to move people towards more environmentally acceptable vehicles. With a small increase of automobile standards, the government could start the automobile industry on this necessary path.

The auto industry is Big Business, which means that, for all of its political and economic clout, it is, first and foremost, a business. The driving concern of any business is revenue. With such a concern in mind, it is not advisable to make an enemy of the oil industry by making fuel-efficient cars, and it is certainly not advisable to make cars that never have to be replaced or to support cars being replaced by public transit. All of these concerns are in the interest of environmental concern rather sound business practice.

It is a sound business practice to seem like an environmentally conscious business, which is the only good (in a business sense) reason that the auto industry would ever spend money to be kind to the environment. Anything that the auto industry can do to be better to the environment without spending more money than they would earn back through the good PR achieved is good business.

Since it is business sense, which ultimately drives an industry as large as the auto industry, it is necessary to create and enforce laws to protect the citizens of the country. Primarily, such laws must work to limit the exposure of the public to toxins produced by automobiles and manufacturing plants. Secondarily, laws should be put in place to protect the environment from damage that would eventually hurt everyone (such as habitat desctruction).

There are many obstacles blocking the formation of such laws. One of the largest hurdles is the influence that the auto industry has on the politics of the nation.

3.3 Political Power of the Auto Industry

Big Business has the money necessary to influence politics. The relation between campaign expenditure and election is well documented; the candidate who spends more money wins 15 times to every 1 loss (Anderson, 2000). Big Business donates a tremendous amount of money to political campaigns through organizations. The candidates backed most heavily have won the elections for the last 12 years. Through these donations companies ensure that certain issues get attention, such as the current move to change bankruptcy laws, class action liability, and drilling in the Alaskan Wildlife Preserve.

In 2000, American companies in the "top 200" list of global corporate powers made donations of 33 million dollars to US elections, outspending labor unions by 1500%. Campaign budgets are a major factor in who wins elections, perhaps the single most important factor. Companies are able to pay the way for their candidates, putting who they want into office. This allows them a significant control of US politics.

Of the top 200 global firms, 94 maintain lobbying offices in Washington D.C..

The big American auto manufacturers frequently reside within the top 5 places in the fortune 500. They have the money to influence politics, and do on a regular basis.

"What is good for General Motors is good for the country." GM CEO Charles Wilson, 1952. GM and many other large US corporations have lobbied for and received what they claimed was "good for them" over the past 50 years. Their arguments that mergers are necessary for firms to compete globally have allowed the government to take a hand-off approach to their monopolies.

General Motors, Ford Motor Co. and Daimler Chrysler were all members of the Global Climate Coalition. This coalition is an alliance of corporate powers set against the production of environmentalist air quality control standards such as the Kyoto Accord. Ford quit the coalition in Dec. 1999, followed by DaimlerChrysler the following Jan., and GM in Mar.. The reasons for the companies' withdrawals seem to be strategic. GM's CEO said, "(The withdrawal) really doesn't reflect any change in our position. We continue to oppose the Kyoto Protocol." Chrysler claimed recent evidence supported global warming when it quit, and Ford said that the coalition was getting in the way of sound environmental research.

In general, each party upon election increases corporate taxation, though there is a greater increase with democrats than with republicans (Quinn, 1991). This increased taxation shows that the clout of the companies is limited. However, there are many instances, as seen above, where the political influence of big business is quite obvious.

Companies the size of GM, Ford, and Chrysler, employing more than 1 million people, have considerable influence. These companies must be responsible with the power they wield; it is within their power to affect the laws that regulate emission standards and efficiency of automobiles.

In a Mellman Poll in 1997, 52% of Americans supported the opinion that, "The technology already exists to solve many of the problems that cause global warming, but big businesses like the oil and auto industries are preventing them from reaching consumers because it is more profitable to keep things the way they are." While just 19% supported the alternative that, "Solving the problems that cause global warming will mean developing new technologies to reduce our use of oil, coal and gasoline, which will cost billions of dollars." 19% abstained. This attitude shows a mistrust of big business, as well as a belief that the technology exists to make cars more efficient. (PIPA 2006)

In the late 1940's GM and a handful of chemical and rubber companies went to most major cities in the US, where they bought and dismantled the clean electric public transit systems so that they could be replaced by busses and cars. The companies were fined five thousand dollars; the executives were fined one dollar each (Mokhiber et al, 2000). That is as clear an example of power and influence as could be hoped for.

Another show of the political power of the auto industry occurred in the late as 1960s federal prosecutors in L.A. opened an investigation into the major automobile companies conspiring to defeat clean automobile technology. The auto industry, through Lloyd Cuttler, managed to have the grand jurors replaced with a civil consent decree asking automakers to pursue the technology (Mokhiber et al, 2000).

A current law, AB 1493, adopted by the state of California is aimed at limiting the amount of greenhouse gas emissions produced by a vehicle per mile. The law is currently being challenged by the Alliance of Automobile Manufacturers and the Association of International Automobile Manufacturers. The reason that the automobile industry claims it is opposing the law is that there would have to be limitations placed on the size of cars built in order to reach compliance with the law; it is worth noting that such claims were made by the industry when catalytic converters and unleaded gasoline were mandated.

GM, Ford and Chrysler sat down with state officials in order to decide how to approach reducing emissions into Lake Michigan. The success of the endeavor was struck down by a fluke release of mercury by a lone factory. Aside from that fluke, the gains were admirable, but the power of the companies to shape the laws by which they are governed is apparent in the approach to the pollution of the Great Lake. The power of the three companies is amplified in their home state, since they employ so many of the inhabitants and control so much of the economy. The state should not have to "sit down" with companies; the companies should be facing charges for dumping mercury into Lake Michigan.

As is apparent in the cases of legal action mentioned above, the auto industry has a powerful say in how fuel economy legislation forms and is interpreted. They have been accused time and again of holding back environmentally friendly fuel and engine alternatives, and have never invited an investigation. It could be argued that this doesn't imply that they did any such thing, but, in a non-legal sense, of course, it does. There have been wide-spread accusations that the oil industry (who unarguably pays money to the auto industry) has paid major auto manufacturers such as GM to hold back more fuel-efficient engines. Such accusations, having never been disproved, lead to a lack of public compassion toward auto-makers when it comes to enforcing higher fuel efficiency (as can be seen in the massive public support of AB 1493); why would such accusations be allowed to fester if the auto industry is innocent? These arguments are circumstantial, but the logic behind them should not be ignored. The goals the auto-industry sets for itself are quite easy to attain. There are light duty trucks that get more than thirty miles per gallon, and yet the auto industry claims that raising the required fuel-efficiency of light weight trucks to 30 miles per gallons, even with years to attain that level of product, would make the constraints on the line of vehicles overwhelming.

The Political power of the auto industry is sufficient to have a considerable impact on the laws that govern it. The auto industry is governed by business sense, which has been shown time and again to have no particular concern for the damage done in order to make profits. It is laws that keep businesses in line, the threat of punishment. If the business controls the laws, the business will not be bound by anything beyond its own ambition, competition, and illegal unions; the problems of such lawlessness were learned in the industrial revolution.

Which such political clout, it is important that the government work to counterbalance the power of such big business, either through breaking up businesses grown too large, or forcing important potential laws into public attention.

3.4 Choice

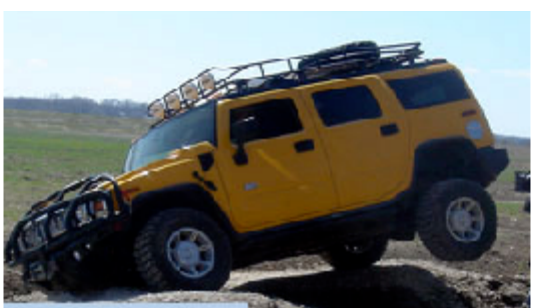
3.4.1 Background

Automobile companies have the ability to control consumers in a number of different ways. Companies control what types of cars are placed in the market. Companies can also in some ways dictate what types of cars people will buy. The automobile industry has the ability to persuade the American public by placing emphasis on certain issues. If the industry puts emphasis on environmentally conscious design then the public will also consider that important when buying an automobile. If the automobile industry would not profit from environmentally conscious design then that would not be an important issue for the companies when designing a car. If the companies ignored the environmental mental impact of automobiles then the American public would not pay as much attention to it because the industry would do its best to keep it out of the medias attention.

3.4.2 Trends

The industry has the ability to dictate the type of cars being sold on the market as well. In previous years there have been a number of luxury cars that have really hit the American public. For example the H2 Hummer and the Cadillac Escalade have been extremely popular. The automotive industry made these cars to be appealing to people of all ages. The automotive industry was able to benefit from the cars being used in music videos and in television shows. If the American public sees celebrities with these cars then they are more likely to want to purchase one of these automobiles. This is an example of the American public being controlled through commercials and the media.

Below are two pictures of the luxury Hummer and Escalade vehicles.



The automotive industry has been pushing SUV's to the American public in recent years as well. Most companies have come out with their own unique version of the SUV and most have been very successful. With the large number of SUV's available they are becoming more and more popular. People see the benefits that are advertised by the companies and follow the trend that has recently started.

The new thing being advertised in a number of different commercials is hemi power. This gives the engine more horse power but has no real need in the automobile unless you are one of the power junkies that these engines appeal to. Many people see advertisements on television about this added power and soon become interested.

Hemi power is another example of how the automobile industry can corrupt the American public through advertising. Hemi power is not a crucial aspect in a vehicle but because the companies are able to make it look so cool many people will look to purchase a car with this added power.

The efficiency of vehicles is not appreciated today. Cars have to go fast or be luxurious to be noticed by the American public. If cars are environmentally safe and have good quality ratings they are not looked at in the same way as an Escalade or Hummer which are just luxury cars with bad gas mileage and extremely harmful to the environment while the automobile is in use.

The various trends in the past year can be seen by which automobiles were the best selling and which companies were the most successful. Below is a number of companies that have been successful through November of this past market year.

Sales for Toyota are up 9.9 percent through November, and they achieved a two million unit sales a month earlier than 2004. The Prius is the best-selling hybrid in the United States, with nearly 100,000 units sold in 11 months. The Scion was was introduced to the market as a experimental small car mini-brand. The Tacoma is the best-selling small pickup in the U.S. and the Camry and Corolla were the years number one and number three best selling cars, respectively.

Honda sales are up 5.8 percent through November of 2005. The redesigned 2006 Civic won Motor Trend's Car of the Year and also the Honda Ridgeline pickup won Motor Trend's Truck of the Year. This marks the first time an automaker has taken both crowns. The Accord and Civic are the number two and number four best selling cars in the country, respectively.

Nissan cemented the company's turnaround by achieving one million unit sales in the fiscal year. Nissan will sell one million for the first time in a calendar year bringing the million selling club to six automakers. Sales are up 10.3 percent for the first 11 months of 2005. The Nissan pathfinder has been extremely successful and recently Nissan announced it is moving its U.S. headquarters from California to Tennessee trying to show its commitment to the heartland.

Hyundai **o**pened their $1.1 billion plant in Montgomery, Alabama, their first in the United States. November sales of the American-built Sonata landed the car in the top 10 best selling car list for the first time. Hyundai unveiled a couple of new vehicles including a Accent subcompact and a new sedan called the Azera. Sales of the new Tucson SUV lifted their truck sales 14.3 percent and the overall sales are up 8 percent for the year through November.

Those are just a couple of the companies and their vehicles that were successful in the past year. This trend helps to show the direction of the public towards certain vehicles and companies.

4 Roads

Roads are another strain that an automobile dependant society must face. Roads take a large amount of production energy; generally 2 - 5% of the energy used by traffic (Eurobitume.org, 2004) goes into the construction and maintenance of the road. They take up a large amount of the available land; making it unusable. Finally, roads create a wide variety of environmental pollutions. Since asphalt roadways are heavily favored in New England, this report will focus on asphalt construction.

4.1 Land Use

In the United States, roads cover roughly 155,000 km of land. This land is dedicated to transportation, and is unable to be used for any other surface-based activities. This land accounts for about 1.73% of the total land area of the country. Roads cover nearly 2% of the continental U.S..

The land used by asphalt roadways, which is roughly 37% of the total, is unable to be used for agriculture for many years after the road has been removed due to the high concentration of pollution that tends to ender the soil around such roadways.

4.2 Construction and Maintenance

Asphalt cement is composed of aggregate held together by an asphalt binder. The aggregate supplies the structural strength nessesary for the road surface, while the binder provides adhesion and water protection. The following picture shows a asphalt surface worn by use.

Figure 4-1: Asphalt surface

The aggregate is generally a combination of sand and gravel, although there has been a recent increase in the use of recycled tire as a replacement for part of the aggregate. This use of recycled tire in the concrete has been shown to reduce cracking and rutting in roadways.

The asphalt binder is a byproduct of crude oil refining. It is essentially long strings of hydrocarbon polymers. The asphalt binder in asphalt concrete never hardens the way Portland cement does; it simply cools to a higher viscosity. This difference between asphalt and cement leads to many differences in the behavior of the two concretes. One of the greatest differences between the concretes is that asphalt has a tendency to deform and "rut" over time, while cement based concrete shows far less rutting and more cracking. The malleability of asphalt concrete necessitates more frequent replacement and repairing of roads than is needed when using cement based concrete; however, since cement based concrete is more expensive, there is no significant difference between the life cycle energy/monetary cost of cement and asphalt based roadways.

Another difference between the two kinds of concrete is that asphalt based concrete expands and contracts more with temperature variation than cement based concrete. This means that steel reinforcement is less effective in asphalt-based roadways.

Asphalt roadways needed less lighting than concrete ones. The fuel economy of vehicles traveling over a road is not significantly impacted by whether the road is asphalt or concrete. The road's state of repair has a considerable impact on the fuel economy of vehicles using it; therefore, roads should be kept in a state of good repair.

4.3 Oiling Roadways

In the recent past, Americans used mineral oil to help keep dust down on the dirt roadways that dominated the country. Dust is a severe problem, and mineral oils seemed to solve it.

Unfortunately for us, dumping mineral oil into the watersheds turned out to be a mistake. The oil started showing up in drinking water, and oiling roads was outlawed.

It is this brain-dead attitude that leads to dangerous foods and drugs on the market, and which leads to unsafe technologies. We do not really understand the effects that asphalt roadways will have on the environment in the upcoming centuries. We need to study the effects in order to avoid future problems.

In a modern turn of the old road oiling strategy, contemporary dirt roads are beginning to be treated with used vegetable oils from fast food chains. The vegetable oils act as a binding agent in the dirt roads, making the roads behave similarly to asphalt. The oils are biodegratable, and can simply be plowed under and grown over. The treatment lasts 2-3 years.

4.4 Asphalt and the Environment

Asphalt is a complex polymer based on poly-carbons. There are many toxic substances suspended in asphalt, but it is commonly believed that the harmful substances are effectively bound within the asphalt.

Recent leachate testing has shown that many of the toxins held in asphalt do leach, but that they leach slowly. This means that all asphalt roadways in the United States are releasing low levels of toxic leachate into the environment. Many of the toxins leached by asphalt, especially the heavy metals, are known to bioaccumulate.

Testing has shown that chromium is released from asphalt by simple leaching. More alarmingly, testing has shown that naphthalene is released. Though naphthalene is not believed to be carcinogenic as most other Polycyclic Aromatic Hydrocarbons (PAHs) are, it is still considered a dangerous pollutant. If heavy metals and PAHs can be released from asphalt binder by leaching, do we really know enough about the health and environmental risks to say that we can accurately limit the leaching to a safe standard? That is the current approach to the danger; if asphalt raises the ground water pollutants to illegal levels, than it is a problem, if it raises them to just below the legal levels, it isn't a problem. (Kriech, 2002)

Toxins released by asphalt are poised to be a problem in the future.

5 Life Cycle

Automotive industries are expanding the life cycle of an automobile while trying to lessen the impact of an automobile throughout its entire life cycle. Waste can come during material selection, production, repairs, while the vehicle is being driven and also at the end of the automobiles life cycle. The automobiles life cycle consists of a number of different phases.

The first phase in an automobile's life cycle is material selection and production. Material production includes resource extraction and material processing. Mining materials, drilling of petroleum, refining, smelting, steel making and polymerization result in a variety of environmental burdens.

The next of an automobile's life cycle is the manufacturing stage. This stage starts with fabrication of materials into automotive parts. The next step is assembly of the parts into components.

After the manufacturing stage comes the use and service stage. This stage has the most impact on the environment. It consists of all the waste that comes while driving the car. This waste includes gasoline consumption, parts after the automobile is repaired, fluids necessary for the automobile, and the need for roads and highways for the automobiles to be driven on.

The last stage is the end of life cycle stage. In this stage automobiles are taken to be disassembled. Most automobiles have recyclable parts so that the entire car does not sit in a junkyard and take up large amounts of space. Below is a figure showing the life cycle of an automobile.

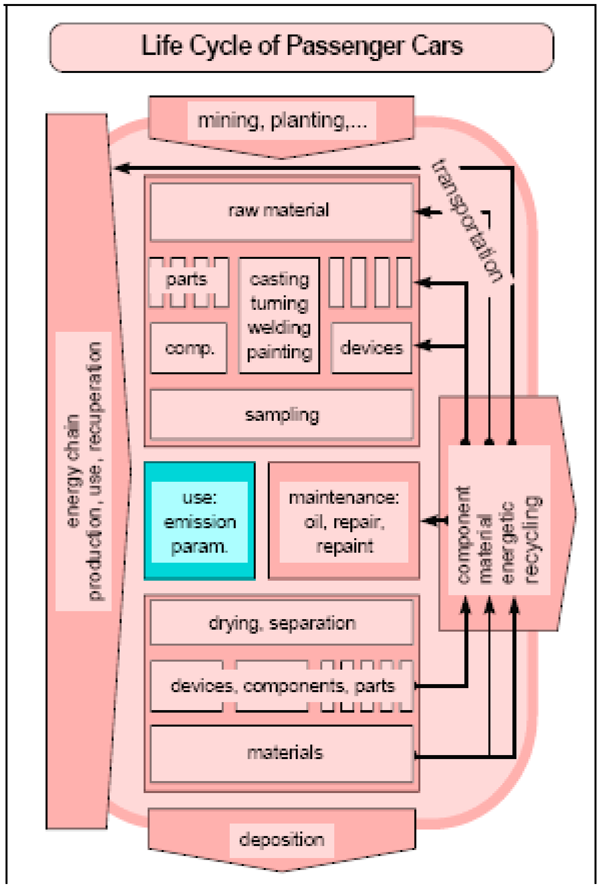
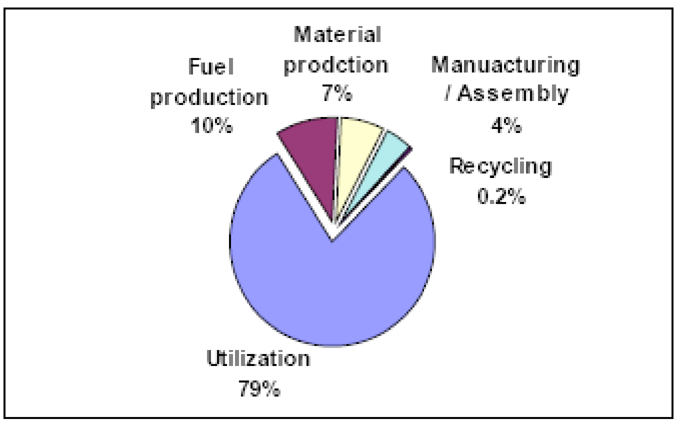


Figure 5-1: Bilitewski et al, 1998

The automobile industry as a whole has made an attempt to reduce automotive waste at every stage during the automobiles life cycle. Companies who have been acknowledged for their efforts in terms of environmentally conscious design have been able to use this in their favor. They are able to tell the public that they are making great strides in protecting our environment and some consumers will lean towards companies who have shown an effort and have been acknowledged for their effort to design with the environment in mind. Companies are not loosing money by designing cars that are environmentally friendly. They have found ways to make their efforts in things like recycling parts more and more profitable. Automobile companies have taken huge strides in protecting the environment.

In this figure the energy consumption during the life cycle is displayed. The pie graph shows the stages of the life cycle and how much energy is consumed at each of these stages.

Figure 5: Primary energy consumption during the Life Cycle of a Golf III (540 GJ) for a life time of 150,000 km and a fuel consumption of 8.1 l/100 km



Source: Schweimer, G.W., Schuckert, M. (1996): *Sachbilanz eines Golf*, Sonderdruck, Volkwagen AG, Wolfsburg, Germany

5.1 Material Selection

5.1.1 Selecting the Wrong Materials

Material selection is an important part of the design phase of an automobile. Automobile production is a complicated process. There are a number of problems that can come with selecting the wrong material. For example if a material is to rare then the price of that material is too expensive. If the company is paying lots of money for its materials than this in turn increases the price of the car. There are limited amounts of natural resources on the earth. Cars are produced at extremely high rates and there is only a certain amount of the material to go around. Materials may become difficult to obtain because the material is used in the mass production of automobiles. This is why recycling of automobiles has become so important. If materials can be recycled then there is less material that has to be obtained from the environment.

There are a number of ways that materials can be harmful to the environment and therefore material selection is extremely important when designing an automobile. Limiting this energy depends on the design of the automobile and using the most environmentally safe and cost efficient materials. Large amounts of energy are consumed in heating, cooling, and producing millions of tons of steel, aluminum, plastic, and glass. Another way that the environment can be harmed is by the large number of materials that can be damaging to the environment when they are being mined. The largest contribution to non-hazardous waste among the life-cycle stages is mining waste associated with energy generation and iron ore production. All of the processes involve a large number of materials which are incorporated in automobiles. These materials are there to achieve special engineering properties, perform critical functions, or minimize the weight of the automobile. Processing these materials involves a variety of heavy metals, toxic chemicals, chlorinated solvents, and ozone-depleting chemicals. It is important to use the materials in automobiles that are the least harmful to the environment during any stage of its life cycle if at all possible. Environmentally conscious design has been more and more important to the automotive industry because of the legislation set by the government.

In automobiles today there is a total of about 15,000 parts. An important task consists of reducing the complexity of the car by reducing the total number of parts. The number of parts should be reduced to a smaller but acceptable number of functional groups with so called “representative” materials, processes and components. Automobile manufacturers are considering a reduction in the number of different plastics used in vehicles to increase the possibility of plastic recycling. Steel, iron, plastic and non ferrousmetal dominates automobile construction. These materials account for more than 80% of material used for current vehicles. Below is a table illustrating the break down of material ratio and total weight of automobiles for a U.S. vehicle, a Japanese vehicle and two other foreign automobiles. Companies are leaning towards using light weight parts such as plastic and other non ferrousmetal parts. The plastic content in automobiles has grown drastically compared to where it was many years ago.

Table 2: Passenger Car's Material Ratio

Material	Material Ratio (% by weight)			
	Generic US vehicle[1]	Generic Japanese vehicle[2]	Generic EU compact vehicle[3]	Golf III[3]
Steel and iron	67	72.2	65	64
Plastic	8	10.1	12	16
Glass	2.8	2.8	2.5	3.1
Rubber	4.2	3.1	6	4
Fluids and Lubricants	6	3.4	2.5	5
Non ferrous metal	8	6.2	8	1.6
Electric cable				1.3
Insulation				1.1
Paint				0.9
Other materials	4	2.2	4	3
Total weight (kg)	*1438*	*1270*	*1210*	*1025*

Source: [1] Keoleian, G. A. et al. (1997): *Industrial Ecology of the Automobile - A Life-Cycle Perspective*, Society of Automotive Engineers, Inc, Warrendale, PA, USA; [2] Kobayashi, O. (1996): *Automobile LCA Study*, in: Proceedings of the Second International Conference on EcoBalance, November 1996, Tuskubla, Japan. [3] Schweimer, G.W., Schuckert, M. (1996): *Sachbilanz eines Golf*, Sonderdruck, Volkwagen AG, Wolfsburg, Germany;

In the above figure the material ratio in automobiles is broken down for several different countries based on averages in automobiles from that particular country. The data provides us with average weights and in the United States vehicles produced are significantly heavier. The U.S. in general does not use lots of plastics but that seems to be changing in present day automobiles. Limiting steel and iron is also an important task to keep the weight of an automobile down. Materials that are easily recycled are also important aspects in present day automobiles.

5.1.2 Selecting the Proper Materials

Materials can cause problems to the environment in a number of different ways. Some materials in automobiles can be difficult to work with. Materials can be difficult to put together which would then make them difficult to separate. If a material is not easily shaped or put in place it will require extra work to separate the parts of the automobile. This will obviously require more power to support the machines that are designed to take apart the automobile at the end of its life cycle. Extra use of these machines will cause more emissions which can be harmful to the environment. Certain materials will go together better than others. During the design phase it is important to the proper materials for that particular automobile. If the right materials are selected than the parts of that automobile can be designed to come apart much easier. When the parts of the automobile are designed to come apart much easier the separation of these parts is not as complicated and is much less time consuming. If automotive companies can make the recycling process quick and the materials easily separated the recycling process can be extremely profitable to the automobile industry.

Material selection influences environmental burden throughout the life cycle of an automobile. An example of a way to improve an automobile through material selection is better aerodynamic styling coupled with the use of lightweight material which will help to improve the fuel economy. Lowering the fuel economy will lower exhaust emissions in the usage phase. Fuel economy can also be improved through the development of components and systems such as lower rolling resistance tires, fuel injection and engine management.

At the end of the life cycle of an automobile the next task is to separate the parts and materials. Material separation can be completed manually or mechanically. Both techniques have their own benefits and downfalls. Manual separation requires more effort on improving the materials during the design phase so parts are easy to disassemble. The factor that limits manual separation is the time required to complete the separation. Manual separation may take time to be completed and if this occurs this technique will become too expensive and will not be used. Mechanical separation requires more effort in the design phase to have materials that can be separated based on their material properties. Materials must have specific properties, if materials do not have certain properties that the machine can recognize then it is too difficult to separate the materials by mechanical separation. Material selection therefore is critical in mechanical separation because the machine must be able to recognize certain properties and sort the material based on these properties. Manual separation does not require the materials to have similar properties but requires the parts to be easily disassembled.

5.2 *Waste During Production*

5.2.1 Background

In the manufacturing context, the focus of environmental engineering effort is after pollutants have been generated. During any type of production there is typically waste created. This is true during the production of automobiles. In the manufacturing of automobiles the focus of environmental engineering is after the pollutants have been generated. The pollutants could have serious effect on the environment if handled improperly. Traditional environmental engineering is concerned with managing the contaminants in water supplies and discharges, air emissions, and solid wastes. The air pollution from the building can be harmful to the ozone while the runoff can be harmful to steams and lakes. Waste can also come from extra material lost during the assembly of the car. Douglas Lee estimates that more than $4.2 billion per year on vehicle waste disposal. This number includes waste during the life of the car as well as production but it gives a general idea of the impact that waste on the United States as a whole.

5.2.2 Eliminating Material Waste

Many companies are focusing on cutting back on the waste created during automotive production in a cost effective manner. One way to cut back the waste of automotive companies is to recycle the waste rather than just throwing it away. If waste can be reused money can be saved because the waste will be put to use rather than just thrown in the trash. If production waste during the assembly of automobiles is all thrown away the trash will build rather quickly and cause a problem to the environment. Producers and consumers have put a greater stress on automotive design that is less harmful to the environment. If producers continue to make this an important issue consumers will follow stride and pressure companies to protect the environment.

There will always be some type of waste created during production and assembly of automobiles but limiting this waste is extremely important. One way companies have reduced this waste is by reusing and recycling raw materials. Instead of just throwing away extra materials from the assembly of a vehicle these materials are recycled and in the future reused in similar parts.

5.2.3 Factory Waste

There will always be emission of gases coming from the production and assembly processes but limiting their impact is also an important part in making automobiles more environmentally friendly. If companies can control in some way the emission coming from their plants than this will have a significant impact on the environment. Companies are trying to keep their emissions out of lakes and streams because those things can easily be affected and damaged by emissions coming from the automotive companies.

Automobile companies have extremely large factories that incorporate many processes and therefore consume a large amount of various resources and energy. It is because of this that the automobile industry is so concerned with the problems of resources and the global environment, including atmospheric and water pollution, and local environmental problems such as waste processing. Minimizing environmental impact means utilizing resources and energy with the best possible efficiency, minimizing emissions and release to the outside world, and using the optimal processing.

Rick Wagoner, chairman and chief executive officer, of General Motors recently released a message in which he discussed a number of issues surrounding GM. In this message he said that "General Motors continues to improve the environmental performance at our plants and facilities by increasing recycling and reducing waste generation, water and energy use, and emissions.

We have established a goal of reducing our global greenhouse-gas emissions from our facilities by 8 percent between 2000 and 2005, and we are making steady progress toward that target." According to information from General Motors they are nearly three-quarters of the way toward its global CO_2 emissions reduction goal at the current time. According to GM they have reduced their CO_2 emissions by more than 1.1 million metric tons, to date. To understand this number better GM uses the statement that they are on par with the annual emissions from the power consumed by 143,000 U.S. households.

Below is a figure showing the impact of a number of different emissions on air and water during the production of the Golf III.

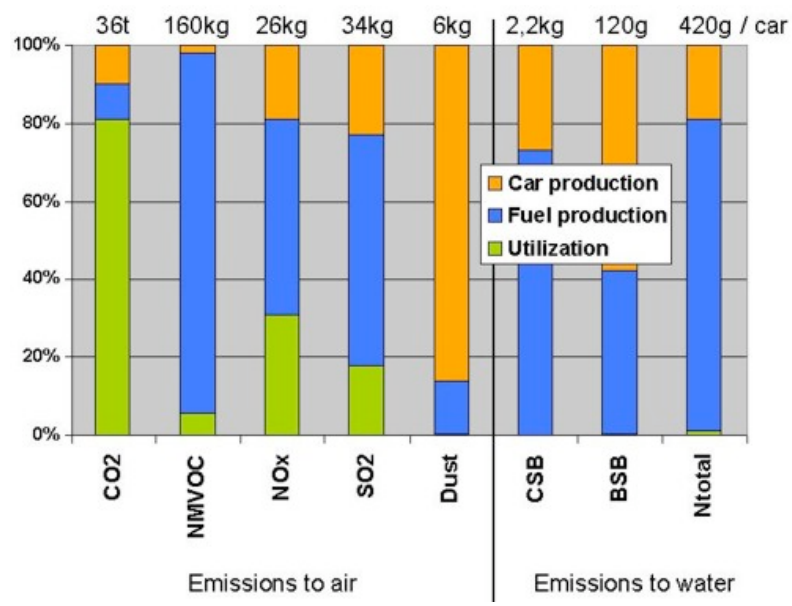


Figure 5-2: Pflieger, 2004

General Motors was inducted into the U.S. EPA WasteWise Hall of Fame in recognition of 10 years of successful waste reduction accomplishments. This induction marks the fourth consecutive year that the corporation has been recognized by the EPA for its successful waste reduction and recycling practices. Below is a figure representing where energy is consumed in the production and manufacturing of a Golf III.

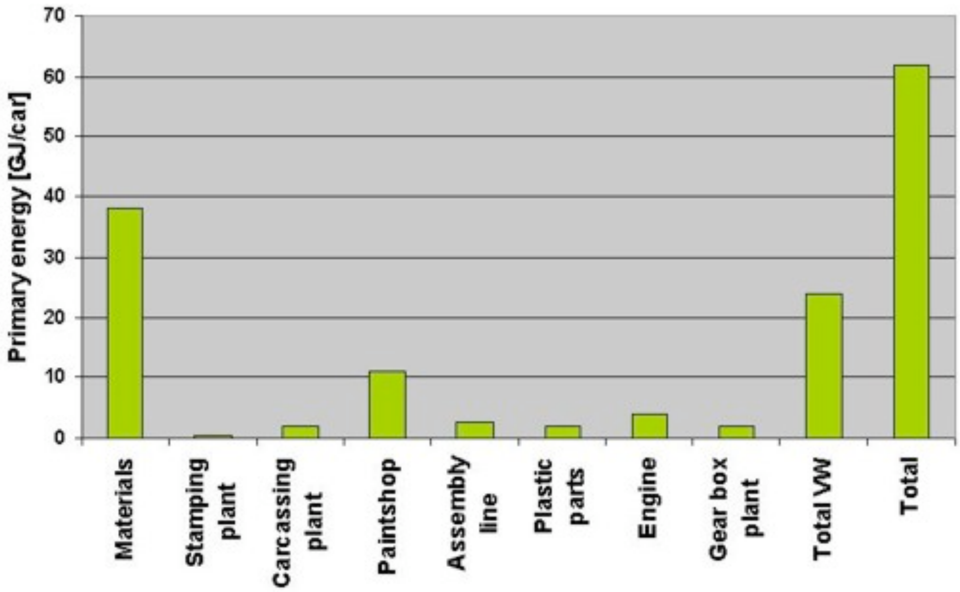


Figure 5-3: Pflieger, 2004

5.3 Vehicle Upkeep

A major problem facing the on going use of automobiles, as a primary means of transportation is the consumption of resources associated with such vehicles. The resources consumed by automobiles include gasoline, tires, engine lubricants and fluids, and the expenditure of resources associated with the production of the vehicles. The expenditure associated with production set aside, the resources spent on vehicle upkeep are a great draw on the national economy. The pollution caused by these vehicles can be shown as products of the material spent on the vehicles versus the material left at the end of the vehicles life span.

5.3.1 Gasoline

On an average, the daily consumption of gasoline in October 2005 in the United States was 199.001 million barrels. In the same month 9.374 million barrels of crude oil per day were imported, along with 14.064 million barrels of petroleum and .844 million barrels of gasoline. Domestic fields provided 4.248 million barrels of oil per day that month, and domestic refineries produced 129.971 million barrels of gasoline per day. (DoE, 2006)

Oil imports account for 67% of consumption in 2005. This percentage has been growing due to the steady drop in US production coupled with continually increasing consumption. Oil production and imports are copared in the following figure.

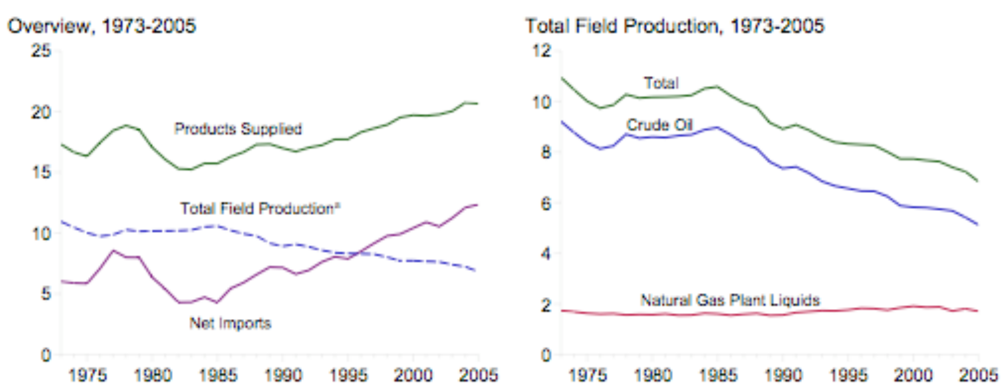


Figure 5-4: DoE, 2006

Oil imports accounted for about 30% of the total US trade deficit. Unchecked, the trends are forecasted to continue, creating a larger trade deficit; the effects of large trade deficits are inherently destabilizing to an economy. The following figure shows oil imports vs. domestic supplies and forecasts of future trends.

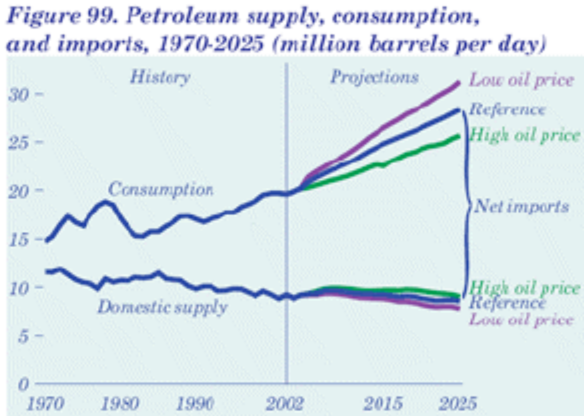


Figure 5-5: DoE, 2006

Given that only 45.8% of oil becomes gasoline and that renewal of fossil fuels occurs at an inconsequential rate, oil demand may soon exceed oil production capabilities, causing a rise in prices. According to famed geologist Marion King Hubert, global oil production will peak around 2015. After this point production will decrease while demand will continue to increase. Since U.S. transportation is dependant on gasoline, rising oil prices will have a profound impact on the economy.

In 2004, the average American bought 464 gallons of gasoline. The average cost of a gallon of gasoline was $1.81 that year, meaning that the average American spent $854.59 on gas (EIA, 2006) Since the average per capita income was $41,400 in 2004, the average person spent two percent of their income on gasoline. Coupled with insurance ($2178.62 US avg.), maintenance and vehicle depreciation, the cost of owning a car nears 10% of the average American's income. It would not take a significant increase to force many Americans to seek alternative means of transportation.

Aside from the huge economic burden of supplying gasoline, internal combustion engines are known to produce incomplete combustion. Such combustion results in harmful byproducts, which may include nitrogen dioxide, volatile organic compounds, particulate matter, and formaldehyde. Another byproduct of gasoline combustion, complete or incomplete, is carbon dioxide, which has carried much of the popular press' blame for global warming.

Due to the harmful byproducts and the large financial burden of gasoline combustion, it is imperative that vehicles be as fuel efficient as possible. Internal combustion vehicles are inherently inefficient, yet there are many steps that could be taken to make them more efficient.

The average passenger car got 22.4 miles to the gallon. There are many cars, in every size category, available to the public, which get fuel economy nearer 27-30 miles per gallon. This telling fact shows that car companies are not focusing on fuel economy. Light duty trucks showed an average fuel economy of 16.2 miles per gallon, which is actually the lowest efficiency since 1990. Again, there are many comparable vehicles on the market exhibiting higher fuel economy.

One way to force an increase in the fuel economy of vehicles is to raise the legislated standards. The standards that control fuel economy are the Corporate Average Fuel Economy (CAFÉ) Standards.

Raising CAFÉ standards by 5% annually until 2012 and then by 3% per year is a current proposal for consideration. Engineering analyses show that this level of improvement is possible without moving away from current technologies. The efficiency needed could be gathered by streamlining and optimizing engines, transmissions, tires and an effective use of higher voltage electrical systems (ACEEE, 2005).

Due to the ease with which this change in efficiency could be achieved, it might be wise to set aims for higher mileage. Perhaps continuing the 5% annual increase would be wiser than stepping down after 2012.

It is obvious that the next step in increasing fuel efficiency must be taken soon. It is equally obvious that the auto industry won't take such a step without being forced to.

5.3.2 Engine Fluids

There are four fluids that a car requires aside from gasoline: engine oil, transmission fluid, break fluid, and coolant.

Motor oil is a derivative of crude oil. It keeps the engine lubricated, cool and clean. Oil should be replaced every 3,000 miles according to popular belief. Most owner manuals will say that oil should be changed every 4,000 to 6,000 miles, depending on the car.

The average vehicle takes just under 5 quarts (1.25 gallons) of oil. The average American travels 12,000 miles per year. So the average American uses about .5 gallons (about 10 dollars worth) of motor oil a year. The US uses about 1500 million gallons of motor oil per year, with a large percent coming from industry.

The major concern with motor oil is not its price, or even the rate at which Americans consume it. The concern is the pollution caused by improperly disposed of used engine oil.

Used oil usually holds heavy metals in suspension. Such heavy metals are toxins, and may be concentrated by bioaccumulation in the environment. One gallon of motor oil can ruin a million gallons of fresh water, a year's supply of drinking water for 50 people. Used oil will move through the environment without dissolving or degrading, although toxins may leach from it and it sticks to anything. An estimated 200 million gallons of used oil is dumped down the drain, poured on the ground, or thrown in the trash each year. This oil accounts for 40% of the nation's oil pollution.

Transmission fluid is essentially the same as engine oil. It is used to pull the clutch and lubricate transmission mechanisms. There are a few minor differences between transmission fluid and engine oil, the largest is that transmission fluid is colored so that mechanics can tell the difference between it and engine oil. Transmission fluid also lacks the added detergents that are frequently found in motor oil.

As with is the case with used engine oil, transmission fluid usually holds heavy metals in suspension. Heavy metals are toxic and have the ability to severely damage nervous systems. (Purdue, 2004)

Transmission fluid should be changed every 30,000 miles, and it takes about 1.2 gallons to flush the system. The average American goes through about .48 gallons of transmission fluid every year.

Transmission fluid can be disposed of the same way engine oil is. The safest means of disposal is recycling, but it is cheaper to buy non-recycled oil, so it is difficult to run a financially viable recycling business.

Break fluid is more dangerous than either engine oil or transmission fluid. Break fluid is mostly a glycol based solvent (80-85%) and it has oil suspended in it. The fluid itself is very poisonous, causing depression of the central nervous system and kidney failure if consumed or aspirated. Break fluid suspends a higher concentration of heavy metals than oil, and can be more readily absorbed into the environment or into an organism. Break fluid is also far more flammable than oil.

Engine coolant is generally a mixture of water and antifreeze. This sort of coolant is green. There are newer long life coolants that are orange and last 5 years/100,000 miles; the two coolants should never be mixed.

The most common type of antifreeze is Ethylene Glycol. This substance is extremely toxic and sweet tasting, enticing many animals to eat it. Propylene Glycol is a newer form of antifreeze; it is acrid tasting and far less toxic than Ethylene Glycol. Both forms of antifreeze break down over time and form acids, which eat away the linings of the cooling system.

As with all other engine fluids, coolants gather heavy metals such as Benzene and lead during its use, making the used antifreeze that much more toxic. Used antifreeze is frequently deemed a hazardous waste due to its high probability of failing the Toxicity Characteristic Leaching Procedure (TCLP) test.

When improperly disposed of, antifreeze lowers dissolved oxygen levels in water, killing plants and animals, and causes a fetid odor. If antifreeze is poured into a septic system, it kills the micro organisms responsible for breaking down wastes, disabling the system.

Proper disposal of antifreeze deemed non-hazardous waste, is not very difficult. Most facilities that accept engine oil for recycling will also accept used antifreeze. Some facilities will refuse to accept antifreeze which is deemed hazardous waste, due to the higher cost of transporting it, but most facilities will transport it to a site where it is safely recycled. (CDPHE, 2003)

Coolant should be replaced every 30,000 miles. A mechanic will advise changing all engine fluids at 30,000 miles, but coolant is the only fluid where 30,000 miles or 6 months is the maximum limit set by the manufacturer. This limit is due to the ability of the coolant to generate acids over time.

Overall, engine fluids are less of a resource consumption concern than fuel or tires, but disposal of used engine fluids is a major environmental problem due to their toxicity.

5.3.3 Tires

In the United States, about one used tire is thrown away per person per year. In 2003 290 million tires were scrapped. The average tire weighs about 19.5 lbs. So, roughly 5.66 billion pounds, or 2.57 million tones, of tires are scrapped each year.

The breakdown, by weight, of materials in tires is shown in the following figure.

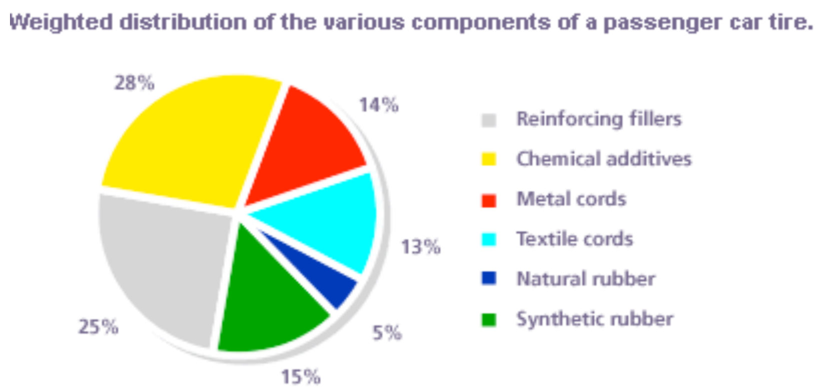


Figure 5-6: Michelin, 2006

According to the average tire weight estimated above, the US annually scraps .72 MT of chemical additives (sulfur and solvents), .64 MT of reinforcing fillers (mostly carbon black), .38 MT of metal cord (steel), .36 MT of synthetic rubber (isoprene and other oil derivatives), .33 MT of textile cord (nylon), and .13 MT of natural rubber. This is a tremendous expenditure of resources, not to mention the resources spent in procurement, manufacturing and distribution within the tire industry.

Of the 290 million tires scraped in 2003, the EPA estimates that roughly 100 million were recycled and 130 million were burned as Tire Derived Fuel (TDF). Most of the remainder becomes waste, winding up in tire piles. (EPA, 2004)

TDF shows a 25% higher BTU value than coal. The ashes left by the combustion process have a lower heavy metal count than most coals. Also, TDF produces lower levels of NOx emissions than burning coal.

The EPA supports use of TDF in industrial facilities and utility production. Of the 130 million scrap tires used for TDF the distribution is as shown in the following table. (Recycle Ohio!, 2005)

Use of TDF	Percentage
Cement Industry	41%
Paper Industry	20%
Electric Utilities	18%
Industrial Boilers	13%
Tire-to-Energy Facilities	8%

Recycling scrap tires for bulk rubber is a growing industry. The tires are shredded, the metal is removed using magnets, and the fibers are removed using shaking or blowing. The shredded rubber takes up 25% less volume than tires, making shipping more efficient. The shreds can be granulated into 3/8 inch pieces, which are then used in a variety of applications.

Figure 5-7: Tire chips (EPA, 2004)

In 2001, 31% of all granulated rubber was mixed with urethane and used in compression molding to form simple products. Such products include mats and removable speed bumps.

29% of granulated rubber is used in rubber-modified asphalt (RMA). RMA is becoming more popular due to its proven superiority to normal asphalt. Advantages include decreased rutting, reflective and thermal cracking, better de-icing properties and reduced traffic noise. Also, lower maintenance costs and significantly increased service life translate to a lower lifecycle cost for RMA than normal asphalt (Recycle Ohio, 2005).

Figure 5-8: RMA roadway (Recycle Ohio, 2005)

Figure 5-9: Standard asphalt roadway (Recycle Ohio, 2005)

The two sections of road in the figures above are sections of the same interstate near Flagstaff, Arizona. They were paved at roughly the same time. A larger degree of cracking can be seen in the standard asphalt roadway; the cracking has been tarred over and can be seen as dark lines in the picture.

Granular rubber is frequently used in athletic fields and playgrounds as a ground covering, accounting for 14% of rubber used. A combination of granulized tries and urethane is frequently used in order to create a poured pavement. The materials elastic properties help reduce injuries, and the surfaces require less maintenance than most other types. Shredded tires are even used in turf in order to improve drainage and decrease soil compaction.

The automotive tire industry reuses about 11% of granular rubber as an admixture to natural rubber. Adding the granular rubber reduces the viscosity of natural rubber, and decreases curing times.

7% of granular rubber produced is used in construction as a bulk material. The rubber makes an excellent material due to its low density, high thermal and physical insulation, and excellent drainage properties. Chips are even being used in leeching beds, due to their ease of installation and lower cost.

4% of the rubber is used in plastic rubber blends. The resulting materials retain many of the elastic properties of the rubber, providing unique materials. Such material is used in railroad ties, acoustic insulation and pallets.

The remaining 4% is used mostly in devulcanization processes. The financial viability of such processes has yet to be determined. (Recycle Ohio!, 2005)

The remaining 60 million tires produced every year, by and large, end up in tire piles. Tire piles are not only an eye sore capable of lowering property value, but house pests such as mosquitoes.

Figure 5-10: Tire stack in front of an abandoned house (Recycle Ohio!, 2005)

In the southern US *Aedes aegypti* and *Aedes albopictus*, two exotic species of mosquito, predominate in tires. These species are known vectors of Yellow Fever and Dengue. In the north *Aedes Triseriatus* and *Aedes atropalus* predominate. These species are known vectors of Encephalitis. Recently *Ae. albopictus* was introduced to the US from Japan in a shipment of used tires. Used tires are a habitat for mosquitoes, which are a known vector for disease, and are dangerous because of this.

A second hazard caused by tire piles in the likelihood of fire. Tires are very combustible, and once burning, are very hard to put out. Due to the heat and smoke produced by such fires, fire fighters have a hard time extinguishing them. Also, use of foam or water generally increases soil pollution, so the fires are frequently allowed to burn out.

Other environmental concerns associated with tires include leeching and particulate release. Although leeching can be caused by rain washing over tire piles, the main concern in leeching and particulate release is the worn off treads of automobile tires.

Assuming that the average tire is 20 cm in width, 140 cm (an aspect ratio of .5 and a diameter of 10”) in circumference and the tire is thrown away when .75 cm of tread is worn away, then the volume, per tire, worn away by use is roughly 2100 cm^3 or .0021 m^3, as described in the following equation.

$$V = 20cm * 140cm * .75cm = 2100cm^3 = .0021m^3$$

This volume per tire is then multiplied by the 290 million scrap tires produced per year, producing the total volume per year, which is 609,000 m^3. The product can be changed to a weight by multiplying by the unit weight of rubber, 1200 kg/m^3. The weight is calculated as 731 million kg, or 731,000 metric tons. (about.com, 2004)

Almost all of the 731,000 tons of rubber that is worn off of tires becomes particulate matter, while the remainder sticks to the road. Of all of the tire dust 60% is proven to be small enough to reach the deepest parts of the human lung. Research has indicated the dust to as a cause of asthma. The asthma causing characteristics of the dust are believed to be based on allergic reactions to the latex in the dust and to the pollen and mold that sticks to the dust particles. (Fisher, 2003) Apparently tires grind pollen to a finer grain, allowing it to enter the lung more deeply as well as allowing pollen a new vector (tire dust) to aggravate human lungs. (Westrup, 2001)

Alison J. Draper, an assistant professor of chemistry at Bucknell University, Lewisburg, Pa., is currently researching tire dust leachate. She has shown in controlled experiments that chemicals from tire dust leach into hard water at room temperature. This result indicates that tire dust will readily leach chemicals into water in the environment.

Draper has shown that tire dust leachate will exhibit mutagenic properties at concentrations as low as 10:1, and the mutagenic properties increase proportionally at higher concentrations. Since some of the chemicals exhibited bioaccumulation in the test organisms, a 10:1 concentration could easily be achieved by biomagnification; one trophic level in a food chain would be enough to cause such a magnification. Mutagens are feared for their ability to cause cancer (carcinogens), birth defects, and heritable defects. Once the mutagens capable of leeching from tire dust are identified, it is likely that tire manufacturing will be more strictly regulated.

5.4 Alternative Engine Designs

Approximately 79% of energy consumption in the lifecycle of an automobile, which lasts 93,206 miles and gets 19 miles per gallon of gasoline, is consumed during the use of the vehicle. Another 10% is consumed during the production of the fuel. So, nearly 89% of the total energy consumption of an automobile is accounted for by fuel consumption. This statistic makes the efficiency of the engine and the attainability of the fuel source primary concerns of an automobile using society.

Some alternative engine designs offer slightly improved efficiency. For instance, rotary engines are slightly more efficient, and the technology has not been improved upon to the degree that normal internal combustion engines have been. Generators used to power electric engines have managed to be as much as 38% more efficient than standard internal combustion designs.

Even with the many possible improvements that could be made to gasoline combustion engines, gasoline is becoming a scarcity, and internal combustion engines are inherently inefficient. Changes in the basic engine design are advisable.

There are many viable engine designs that run more efficiently or more clean running than the standard internal combustion engine. Many people own engines capable of running on fuels other than gasoline but do not make use of the fact. The main problem with almost all of the alternative designs is that they require a fuel source that gas stations do not sell.

Since gas stations will not sell a fuel that for which there is not an immediate market, alternative fuels are not readily available. Since the fuels for alternative engine designs aren't readily available, people will not buy vehicles based on those designs. This catch-22 stops the development of alternative fuel vehicles from moving forward as it should. The problem is further compounded by the fact that the oil companies oppose such a switch away from gasoline.

There are a few methods that have been employed to combat this conundrum. One of the chief methods is to design vehicles that can run off of gasoline, but can also run off of other sources. Another is to design engines that can run off of fuels that can already be bought by the public in locations other than gas stations.

5.4.1 Alternative Fuel Ready Engines

Alternative fuel ready engines are engines that can run off of gasoline, but can also run off of other fuel sources. The most common alternative fuel source for alternative fuel ready engines is ethanol. Other fuel sources include natural gas and naphthalene.

Some countries in South America, namely Brazil, are readily supporting alternative fuel ready engines. This support is due mainly to the high gasoline prices in South America.

In Brazil, the Bi-Fuel engine, capable of running on gasoline and ethanol, has been on the market for years. The system is quite successful, and ethanol is now nearly as available as, and much cheaper than, gasoline in Brazil. Ethanol based fuels are also widely available in China; the world's fastest growing automobile market.

American auto-manufacturers such as GM are embracing a bi-fuel engine called the "Flex-Fuel Engine" for sale abroad as well as in the mid-west, where E85 fuel is widely available. Flex-fuel engines are becoming more popular every year. Many common cars, such as the Taurus or Stratus, have flex fuel engines. One of the factors limiting the spread of E85 fuel in the United States is the fact that it is not significantly cheaper than gasoline. The US is unique in this phenomenon; it is caused by artificially lowered gasoline prices. However, gasoline is steadily becoming more expensive, while the price of ethanol is remaining constant. Soon E85 will be a welcome relief from the 4-dollar per gallon gas prices.

Bi-Fuel engines are not noticeably less fuel-efficient than a dedicated gasoline or ethanol engine. The engine may soon be used in hybrid electric cars as well as generators and small internal combustion engines such as lawn mowers.

A newer engine design, the Four-Fuel Engine, being introduced in Brazil, is able to run off of natural gas and naphthalene as well as ethanol and gasoline. The engine is inherently less efficient when switching between liquid and gaseous fuels, but the inefficiency has been reduced to 5-8% energy loss, which is a small number when considering that 65-70% of energy is lost to inefficiency in an internal combustion engine.

This new four-fuel engine has increased the availability of natural gas and naphthalene to the public. Such availability has lead to increased sales of CNG vehicles. Between 25,000 and 30,000 gasoline vehicles are adapted for CNG every year in Brazil.

5.4.2 Ethanol Fueled Engines

Ethanol is a fuel created from organic matter, now able to be produced from byproducts of agriculture. Many consider ethanol to be a renewable resource, although there is some concern that use of ethanol as a fuel may lead to increased leaching of nutrients from the soil.

Most gasoline in the US is mixed with ethanol because the ethanol provides oxygenation for the gasoline combustion, increasing the efficiency of the combustion process.

High percentage ethanol mixtures such as E85 are widely available in certain parts of the US. Ethanol is poised to take a large percentage of the gasoline industry's business as soon as gasoline prices increase a few dollars more.

The single most important reason for the possible success of ethanol fuels is that they can be transported using the existing gasoline transportation infrastructure.

The spread of ethanol fuels has been greatly aided by the introduction of bi-fuel engines.

5.4.3 CNG Vehicles

CNG vehicles run on compressed natural gas, which is much cheaper than gasoline. CNG is available on a very limited basis at fuel stations, but customers who have natural gas in their homes can make it in a small home compressor.

The major reason to switch to CNG is the difference in fuel prices. The Ford Crown Victoria CNG costs $1251 to fuel while the Ford Crown Victoria (standard gasoline) costs $1943 annually. The CNG model is roughly 2/3rds as expensive to fuel, and this fraction holds true for the Dodge Ram, Ford F150 and Honda Civic ($587 annually for a CNG model).

CNG also burns without creating large gaseous hydrocarbons, which lead to smog and acid rain. CNG releases carbon dioxide as a byproduct of combustion, just as gasoline does, but the fuel efficiency per mile is generally better with CNG, so less carbon dioxide is released.

CNG is also safer than gasoline, since it only burns at a very specific CNG to air ratio. CNG cannot explode due to combustion the way a gas tank can; it can, however, explode due to its high level of compression. CNG will quickly disperse in the air, making a ruptured tank a less serious concern than a ruptured gas tank. The main safety concern with CNG is the pressure in the CNG tank. A ruptured CNG tank can propel itself at an alarming rate, becoming a dangerous projectile. Most dangers inherent to a CNG tank can be designed around (good harnessing is one such design solution).

Another major benefit of CNG is that it will relieve the economic pressure caused by demand for foreign oil. The US currently has a surplus of natural gas. There are many natural gas reserves that have not yet been tapped. Perhaps most importantly, natural gas is a greenhouse gas, more effective at global warming than carbon dioxide. By burning natural gas, the world is made safer from global warming, versus burning oil, which just throws complex carbohydrates into the atmosphere.

The biggest problem that is checking the spread of CNG vehicles is the availability of CNG to the public. Alterative fuel ready engines help mitigate this problem.

5.4.4 Electric Vehicles

Electric vehicles have the potential to be much more efficient than internal combustion vehicles. An electric engine can run at roughly 90% efficiency. This is an amazing difference when compared to the 50% efficiency that is the best that could be hoped for in a internal combustion engine. Electric vehicles also have the ability to recapture energy while breaking and to spend no energy while "idling".

Most electric vehicles are based on large battery arrays, which weigh anywhere from 60 to 210 pounds and need to be replaced after a few years of use. Being plugged in overnight can recharge such vehicles. Hybrid electric technology may increase the popularity of such vehicles and eventually bring about improvement in the battery technology used.

The greatest source of inefficiency in an electric vehicle is the loss of power in a gearbox. Roughly 50% of the power generated by an engine is lost in the gearbox.

One novel approach to the problem of efficiency loss due to gearboxes is seen in "TheWheel™".

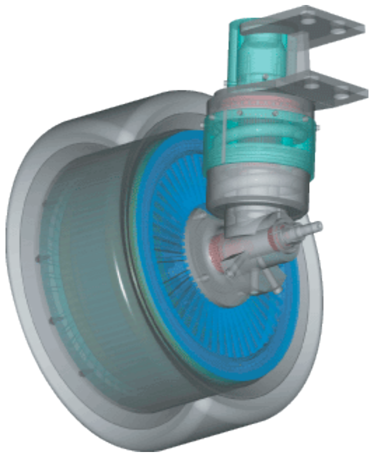


Figure 5-11: TheWheel (eTraction, 2006)

The design is based on a small electric motor mounted within the wheels of the vehicle. This design is much more efficient form a mechanical standpoint, although there is an increase in cost incurred by the necessity for at least two "motors". TheWheel™ is twice as efficient as an electric motor and nearly four times as efficient as an internal combustion engine. This design is best suited to vehicles with large wheels, such as busses. Such busses, known as "Whisper™" can be seen in the following picture.

Figure 5-12: Whisper™ busses (eTraction, 2006)

The design is poised for wide use with the increased availability of new fuel cell technologies.

5.4.4.1 Hybrid Electric Vehicles

Hybrid electric vehicles are a mixture of electric and gasoline powered vehicles. Such vehicles use an internal combustion motor to generate power for an electric engine. The energy generated by the internal combustion engine is generally stored in a small battery array.

Hybrid vehicles hold a few advantages over electric vehicles. Battery arrays in hybrid vehicles can be much smaller, which decreases the cost of replacing the array. The overall weight of a hybrid vehicle is comparable to an electric vehicle, since the larger battery array of the electric vehicle offsets the weight of the small internal combustion motor.

More importantly, a hybrid vehicle runs off of gasoline, a fact that bypasses many of the problems faced by electric vehicles. The management of the vehicle is almost the same as management of an internal combustion vehicle, allowing the vehicle owner peace of mind with his new technology. The vehicles ability to run off of gasoline means that there is no need for lengthy overnight charging of the batteries, although some newer hybrids have the ability to charge overnight, allowing them to burn slightly less gas on the next trip. The fact that they run off of gasoline also means that the oil industry has less of a problem with them than they do with alternative fuel vehicles.

The most important aspect of the increasingly popular hybrid vehicles is that they are essentially electric vehicles with a small generator. This means that the production of hybrid vehicles is paving the way for production of fully electric vehicles. The technology behind electric vehicles is being improved, as is the public understanding of electric vehicles. By the time gasoline is no longer needed to power the vehicle, people may become comfortable with the idea.

5.4.4.2 Hydrogen Fuel Cell Vehicles

Fuel cells vehicles (FCV's), the most promising of the electric vehicles, run entirely on hydrogen, usually created by power plants. The main reason that fuel cell vehicles are better than battery-powered vehicles is the range of a fuel cell vehicle. Battery operated cars generally range around 100 to 200 miles per charge, with charge times of many hours. The current fuel tanks store hydrogen at 5ksi, and give the car around 200 miles of run time. However, the technology that runs battery-powered vehicles is quite developed, while the hydrogen tanks used in fuel cell vehicles are continually improving. It is expected that the range of a fuel cell vehicle running on liquid hydrogen will be equivalent to that of a gas powered car within a decade.

FCV's can also run on hydrogen rich fuel sources, like methane, methanol or even gasoline. For the fuel cell to run on these fuel sources, the fuel must first be changed into pure hydrogen gas in a "reformer". The process of reforming does create a small amount of waste, but much less than internal combustion engines would produce for equivalent mileage.

Pure hydrogen fuel cells have zero emissions. However the power plant that generates the hydrogen to run the fuel cell does have emissions. Car companies like the idea of fuel cell electric vehicles because it removes them from the environmental debate, however the problem would simply be moved to power generation facilities rather than eliminated. However, having the power generated at one large facility will allow a much higher standard of pollution control. If nuclear power is further developed, or if renewable resources are embraced, these facilities could have a minimal impact.

The dangers of hydrogen fuel cell vehicles are not as great as the public imagines. The explosive potential of a hydrogen fuel tank is roughly the same as a gasoline tank, in that if they explode they will explode with equal force. Hydrogen fuel tanks are no more likely to explode than gasoline tanks, since they need to mix with oxygen before they can ignite. The real danger with hydrogen fuel tanks is the level of pressure difference held by the tank. The hydrogen itself is unlikely to burn or explode in an accident (only slightly more likely than a CNG storage tank), but the tank can explode quite powerfully if compromised due to its large degree of compression. Regulations would need to be set in place regarding precautions against the tank escaping and becoming a missile in the event of an accident.

5.5 Distribution

The average cost to ship a vehicle from the manufacturer to the dealership in the US is $725 (based on the Buick Lucerne). Vehicles are usually shipped via train within the continental US, and via boat for foreign manufacturing. The last leg of the vehicle's distribution is generally done by less efficient trucks.

The shipping expense associated with a Buick vehicle is roughly 3.5% of its total selling cost. That 3.5% is actually a larger amount than most dealerships can hope to make selling the vehicles at mark-ups over the manufacturer's price.

One way to diminish the cost of distribution would be to expand the railway system. Doing this would allow the dealerships to avoid shipping the cars via truck, which is the least efficient leg of the transportation. In addition, dealerships could be moved closer to railroad hubs.

Aside from the direct cost of shipping the vehicles, the dealership supply chain is inefficient due to the need to store cars at the dealerships. Such storage requires dealerships to have large parking lots, which cost a lot to construct and maintain. Storing the vehicles also causes an investment problem for the dealerships, since the vehicles are paid for, but don't create a turn over until the dealership can sell them. Vehicle depreciation can become an issue over long periods, leading to dealerships losing money or their investment. More importantly, the loss on the capital investment, which is generally estimated at about 10% per year, can quickly eat away the prospective profits of a dealership.

These dealership problems are logistic, and require logistical solutions. In Japan, most dealerships don't have a large stock of vehicles. Instead, a salesman helps the customer decide what sort of vehicle they want, and the vehicle is ordered from the manufacturer. The wait for a new vehicle is usually less than two weeks, and many of the logistical problems disappear. Volkswagen is trying to move to such a system in the UK.

5.6 Reuse

5.6.1 Background

Improper disposal of materials used in automobiles can be very harmful to the environment. Material selection has become very important to major corporations in order to prevent material waste. Using the proper material depends on finding economically profitable and environmentally friendly materials. Proper selection of materials is important when industries are trying to recycle and reuse parts of their automobiles. If a material is extremely difficult to recycle then the process is not cost efficient for that company. A company will only make the effort to recycle their parts if it will save them money in the long run. If a company knows that they will make money during the recycling process then they will put more effort into making their parts environmentally friendly. Automobiles that have lots of reusable parts will have a huge impact on the effect that automobiles have on the environment at the end of their life cycle.

Cost is a major factor when determining whether a part should be recycled or disposed of in a junkyard. Cost can be driven by a number of different factors. These factors include the cost of collecting used products. From there the products must be taken apart and identified as recyclable. The materials must then be reprocessed and then distributed to the reuse market. The result of this work must be profitable or the automotive industry will ignore the recycling process.

Companies are focusing on finding materials that will be reused or recycled into new automobiles. At this time about 75% of the weight of scrap vehicles is capable of being recovered and reused. Several reasons companies have begun to do this recycling of parts are legislation and regulation, profits and other competition with different manufacturers, and maybe even for moral reasons. Progress in the environmental performance of automobiles has been driven by legislation and not by market demand. The American public as a whole would say that they are interested in "green" automobiles but the truth is that cost is the most important factor and not the impact the automobile has on the environment. If the public demanded "green" automobiles then the automotive industry would be open to much more competition around the environmental performance of automobiles.

Automotive waste can come during the disposal of an automobile and can also come during automobile production. During the design process there is excess material from various parts. Automotive companies are making an effort to recycle this excess material if it is possible. The material can be reused in similar parts and save companies the trouble of finding more resources to come up with that material. The excess material can be recycled and this will prevent the material from being tossed in a junkyard. Recycling the waste created during assembly prevents a lot of this excess material from entering the environment.

5.6.2 Design for Reuse

General Motors, like many other automotive industries, has made strides in producing automobile parts that can be recycled. GM was the first automaker to make its vehicle recycling information easily accessible by posting the manuals to its Web site in 2001. GM now has the 2006 dismantling manuals available online. These manuals that are posted by General Motors provide automotive dismantlers with information on which parts of a particular vehicle can be recycled. An example of the manual is attached in Appendix A. This part of the manual discusses GM's environmental performance with respect to waste and recycling.

Disposal also creates a lot of automotive waste. Automobile manufacturers are trying to limit this waste created by an automobile at the end of its life cycle. Many companies are trying to choose materials that will allow certain parts to be reused once an automobile is off the road. If the material can not easily be disassembled then the ability to reuse these materials becomes difficult. If the process to separate the materials is too difficult companies will be discouraged against this process. If the proper material is chosen however the disassembly of the vehicle should not be too difficult and most of the automobile will be reused or recycled. Companies are doing a number of things to make disassembly easier. Some of the things companies are doing include, making snap on parts, trying not to combine two different polymers, and avoid certain paints where necessary. Manufacturers are rewarded for their efforts if their products meet certain standards. If this process was not economically profitable manufacturers would not put in the effort to make sure the parts can be recycled at the end of the automobiles life cycle.

Practically all of the materials in an automobile can be recycled. Companies have begun to use this recycled material more and more. Some materials are difficult to obtain when building automobiles therefore recycling parts can be profitable and extremely beneficial to the environment. Recycling parts can be difficult at points because certain automobile parts will only fit in vehicles of the same year. This obviously makes reuse difficult because there are only so many places where you can use that part. The material will more likely be recycled rather then reused in another automobile. Recycling does not cost much and is economical in most situations. This allows for parts that can't be reused to be taken out of the junkyard, remanufactured and put in another vehicle. This recycling limits the effect that automobiles have on the environment. Less environmental resources will be taken from the environment if the same materials can be used again after a cars life cycle is over. Also these materials will not be left in a junkyard where they can add to the accumulating trash that already comes from automobile.

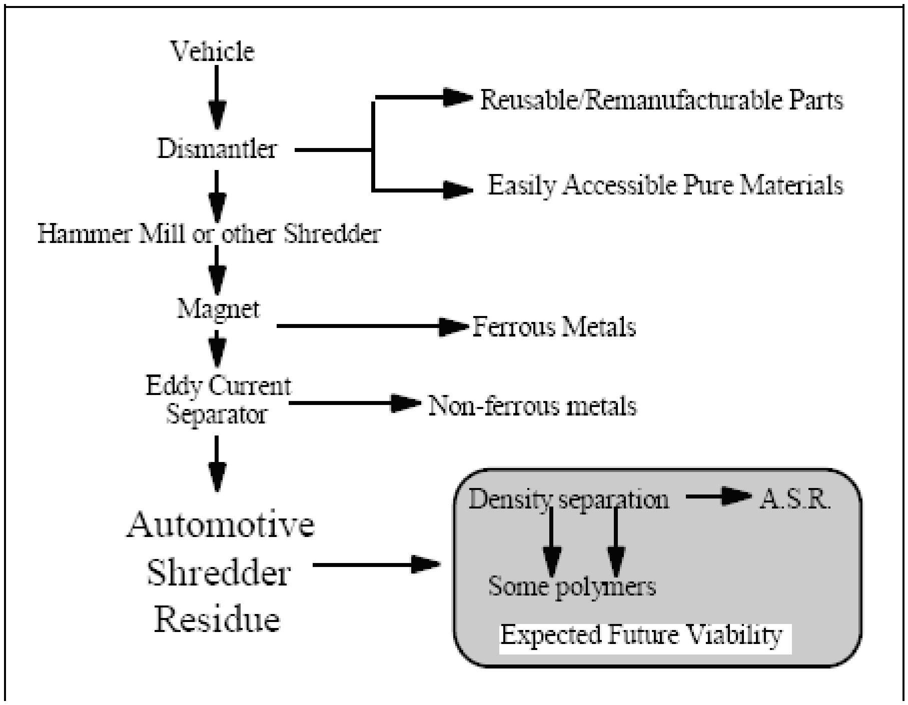


Figure 5-13: Coulter et al, 1996

Above is a figure representing the current vehicle dismantling and material separation process.

5.6.3 Materials

The reduction of plastic waste will help with solid waste management and the increasing problem of landfill usage. This type of thinking will also preserve raw materials and conserve energy. A company incorporating these ideas will not only help the environment but also save money. Recycling plastic is different than recycling glass or metal. Glass and metals are frequently reused in the same products that they were used for originally. Plastics however, must often be made into other products due to the food contact standards. Plastics cannot be re-manufactured or sterilized to meet the current standards. This makes plastics difficult to recycle but lighter cars are always presented as favorable. As mentioned most of the waste during the automobiles life cycle is during use so the best way to limit the waste may be to make the car lighter so its better on fuel rather than focusing on having heavier parts that can be recycled at the end of the products life cycle. The amount of plastics used was found in a table located on page 40. The United States as a whole uses less plastic in automobiles than most other countries and at the same time our automobiles are heavier than other countries. The trend of increasing plastics in automobiles continues to grow.

Tires create a lot of waste in junkyards. The Rubber Manufacturer's Association estimates that each year a waste tire is generated for every American. For example California alone estimates 31 million scrap tires per year. The large accumulation of whole tire waste poses a serious threat to public health. Tire accumulation in a junkyard can provide breeding grounds for mosquitoes that spread diseases. It can also be a dangerous fire threat, which could damage the environment. A fire would include air pollution and also runoff to nearby water resources. The tires can be recycled and used to manufacture new products such as asphalt pavement, playground and athletic mats, floor tile, carpet underlayment and soaker hoses.

5.7 Case Study: Buick Century

The average lifespan of a 1990 Buick Century is about 179,000 miles. Although 2000 and 2005 models have not had the time necessary to get a good understanding of their average lifetimes, they seem to break the 150,000 mark easily.

The 1990 Century had a fuel economy of 23-mpg city, 31 mpg highway, or 26 mpg average. The car had a curb weight of 2950 lbs. A 1990 Century will go through about 6,885 gallons of gasoline in its lifetime.

The more powerful 2000 model of the Century gets 20 mpg city, 30 mpg highway and 24 mpg average. The car had a curb weight of 3364 lbs. If it is assumed that the car will get an average of 175,000 miles of use in its lifetime, then the car will burn 7,292 gallons of gasoline.

The 2005 Buick Century is essentially the same car as the 2000 model. They have the same engine size, gas mileage, and storage capacities. The 2005 weighs 21 pounds less than the 2000.

The material put into the car has not changed in any way that seriously impacts the amount of energy put into material acquisition for the vehicles. The parts are still proprietary and only interchangeable with a very few other vehicles.

The over-all gas mileage has decreased by 10% from 1990 to 2005. This shows an inability of GM to take necessary action without outside influence.

6 Conclusions

The automotive industry has been able to dictate their direction for years. The industry has had the ability to direct the consumers to certain products through advertising. Luxury cars and things like hemi power are popular largely because of the advertising from the automotive industry. These examples show the type of power the industry has over the consumer. The industry also has had the ability in the past to design cars without thinking of the consequences that would occur once the car was off the road or even the impact of the car while the car was being used. The government has been successful in forcing the industry to change its ways and take the environment into consideration when designing automobiles.

Legislation has made the automotive industry take a number of strides in preventing automotive waste. The government is attempting to reward automotive industries that have succeeded to a certain extent in preventing automotive waste and punish those companies who still have not reached their standards in preventing waste. Since certain companies have been able to limit automotive waste it forces other companies to try to match their success so that consumers will not look down upon those companies who have not made an attempt at limiting the effects that their products have on the environment.

The automotive industry is attempting to design their products to be less harmful to the environment throughout the entire product life cycle. In every stage of the automobiles life cycle there is some threat to the environment. Waste can come in a number of different ways and at all different times. Most of the waste from automobiles comes during their use but limiting waste in other parts of the vehicles life cycle is also important.

Material selection is an extremely important aspect when designing an automobile. Selecting the proper material can be profitable and helpful in a number of different ways. If materials that are environmentally friendly while being collected are chosen then this will be beneficial to the environment. Some materials are easy to separate and this could be beneficial when trying to recycle parts by hand. Materials that have similar properties could be chosen to make the recycling process by machine much easier.

If waste can be limited or recycled during production there are economic and environmental rewards. Many times excess material will be lost during an automobiles production. This material is often just thrown away by automotive industries. The material will then gather up in a junk yard rather than being put to use. If this material can be reused in similar processes there are a number of benefits. One economic benefit for the company is that they will be able to reuse the excess material rather than having to gather more resources to rebuild that material. Waste comes from the factory itself during the production of automobiles. The air pollution from the building can be harmful to the ozone while the runoff can be harmful to steams and lakes. The automotive industry tries to prevent the runoff to have any effect on the surrounding companies. The factory will have some type of emissions and companies know controlling these emissions is essential. Douglas Lee estimates that more than $4.2 billion per year is spent on vehicle waste disposal. This number includes waste during the life of the car as well as production costs but it gives a general idea of the impact of that waste on the United States as a whole.

An extremely important part in environmentally conscious design is limiting the waste at the end of the vehicles life cycle. If parts of that automobile can be recycled or reused it can prevent a lot of waste in that junkyard and also be economically rewarding for the automotive industry. At this time about 75% of the weight of scrap vehicles is capable of being recovered and reused. This number has grown increasingly over recent years. Parts are being recycled and used in similar automobiles, and material is even being stripped and reused in automobiles.

Another important environmental concern is the waste produced and the resources spent fueling and maintaining automobiles. An estimated 89% of the total energy expended per automobile is spent fueling the vehicle. 10% of the energy is spent mining and processing fuel, while the remaining 79% is spent when the fuel is burned to power the car.

Internal combustion engines use roughly 30% of the energy released by the combustion of gasoline. Of the 70% of that energy which is lost, about 50% is lost in gear mechanisms and 20% (40% of energy before the gearbox loss) is lost due to inefficiency in the engine design. If the engines were more efficient, gas mileage could be increased to nearly double its current value.

Gasoline consumption, along with consumption of engine oils is the single largest contributor to the trade deficit. The average American spends nearly 10% of their annual income on vehicle upkeep (counting insurance and repair costs) over the lifetime of their automobile. The economic burden incurred by automobiles on US society is considerable.

Electric engines run at nearly 100% efficiency before the gear box (internal combustion engines average about 58%). Though they still lose 50% of that efficiency in the gearbox, the improvement is considerable. There are alternative designs, such as TheWheelTM that get more than 90% total efficiency from the engine. In a gasoline hybrid vehicle, this nearly 300% increase in efficiency could eliminate American dependence on foreign oil.

The environmental impact of automobiles is also a note worthy concern for the American public. The rise in asthma rates is associated with automobiles, as are many new environmental phenomena, such as global warming.

Improving efficiency will decrease these environmental problems proportionally. However, there are many other solutions to the environmental concerns raised by automobiles. One chief solution is the implementation of alternative vehicle fuels. CNG, battery powered electric, ethanol, and hydrogen powered electric automobiles are all possible candidates to replace the internal combustion engine. The emissions of these vehicles are far more environmentally friendly, and pose fewer health problems.

Legislation aimed at accelerating the move toward efficient new vehicle designs would be in the interest of the United States.

7 Appendix A

GMability

2004 Corporate Responsibility Report

Environmental Performance | Waste & Recycling

7.1.1.1.1 Overview (GRI EN2, EN11, EN31)

Wastes are generated by our production processes and support operations, such as facility maintenance, powerhouse services, wastewater treatment, and administrative and engineering offices. Our policies and management for hazardous and non-hazardous wastes are similar. Our goal is to reduce waste as much as possible at its source. Where this is not possible, we reuse or recycle as much as is technically and economically feasible.

7.1.1.1.2 Objectives

The goal for all GM employees is to reduce all forms of waste. As expressed in the GM Environmental Principles, we are committed to reducing waste and pollutants, conserving resources, and recycling materials from our operations.

7.1.1.1.2.1 Global Target

For all of our global manufacturing operations, we have a five-year target to reduce total waste generated by 15% from a 2000 baseline. Over the same period, we are also targeting a 15% increase in recycling rates for wastes that are currently not being recycled. Because of our expanding manufacturing presence around the world and our already high recycling rates, these are stretch targets for GM operations. GM North America, for instance, which includes the majority of our manufacturing operations, previously reduced its non-recycled waste by nearly 60% between 1997 and 2002 through waste reduction and increased recycling. As a result, further reductions in North America will be challenging but always a target for continuous improvement.

7.1.1.1.3 Actions

The most effective environmental practices focus on the sources of pollution and waste materials. It is important to reduce waste and the amount of hazardous substances, pollutants or contaminants entering any waste stream or otherwise released into the environment prior to recycling, treatment or disposal. The application and use of processes, practices, materials or products that avoid, reduce, or control pollution at its source are investigated and sought first at GM. These activities may include, for example, more efficient use of resources or material substitution.

A certain amount of waste is unavoidable with vehicle manufacturing and we have established procedures to effectively manage these wastes. Internal performance requirements are also established for a variety of waste streams that are common to automotive vehicle and component manufacturing.

We collect waste metrics data from our worldwide facilities using a combination of e-mailed surveys and a web-based reporting system. A total of 137 GM sites provided waste data in 2003, of which 111 (81%) are in North America. We continue to experience challenges with data collection across such a broad range of sites and locations, and are working to overcome global differences in waste definitions and to refine the data we report. Joint venture data is not included at this time, though it is our practice to request data from those GM facilities where we have operational/management control.

7.1.1.1.3.1 Resource Management

Our Resource Management (RM) program preserves natural resources, reduces our environmental impact and achieves cost savings. In this program, a single supplier manages all plant wastes onsite. The supplier is economically compensated to reduce waste volumes.

We have designed the program to prevent waste from being created. Resource managers receive financial incentives to find innovative ways to eliminate waste created during manufacturing. Rather than paying a waste contractor simply to dispose of materials, our approach makes the supplier a partner inside the plant. Wastes previously sent to landfill, such as cardboard boxes and wooden pallets, are now reused or recycled. The U.S. Environmental Protection Agency (EPA) has recognized the program through its WasteWise Awards. Now operating where economically feasible in all of our GM North American manufacturing facilities, our RM program has saved more than $9.4 million annually. GM is currently in the process of implementing the Resource Management program in Europe (five plants to date) and is piloting the process in one GM plant in South America.

- Waste Wise Case Study (PDF)
- GM Climate Profile (PDF)

7.1.1.1.3.2 Chemicals Management

Details on our Chemicals Management program can be found in the Managing Environmental Responsibility section of this report.

7.1.1.1.3.3 Voluntary Pollution Prevention Programs

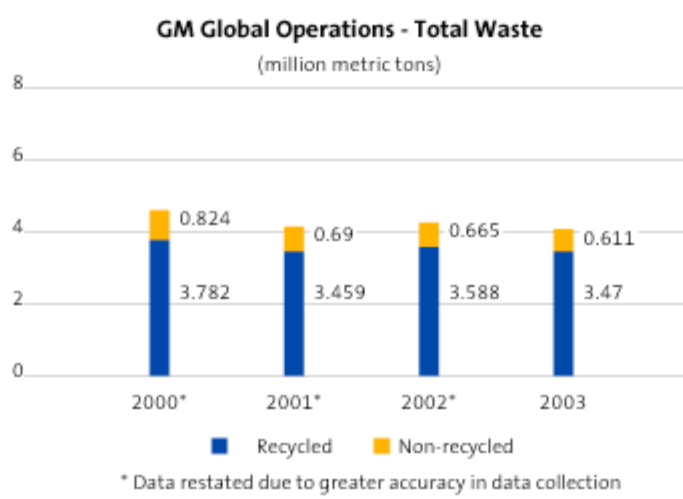
GM continues to participate in the U.S. Environmental Protection Agency (EPA) WasteWise Program, a voluntary program that helps organizations eliminate solid waste to benefit the environment. In 2003 we were awarded their "WasteWise Partner of the Year" and "Climate Change Partner of the Year" awards, the third consecutive year we have been honored with awards from WasteWise.

In 2003, our U.S. operations prevented 308,568 metric tons of waste and recycled two million metric tons of waste. Because waste also has an effect on greenhouse gas (GHG) emissions, these waste savings reduced our GHG emissions in 2003 by more than 4.9 million metric tons of carbon dioxide equivalents. According to the EPA's Waste Reduction Model (WARM), this is comparable to the annual emissions from power used by 642,579 households and the annual carbon dioxide stored by 40,532 acres of established, rapidly-growing trees

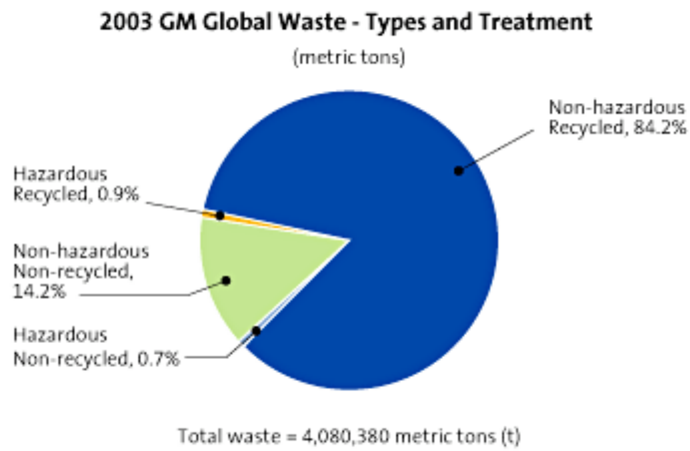
7.1.1.1.4 Performance

Our global facilities continue to make progress toward our goals to reduce waste by 15% and increase recycling by 15% by 2005. Total waste generation decreased by 4.05% in 2003, from 4.25 million metric tons* in 2002 to 4.08 million metric tons* in 2003. **Waste generation is down 11.4% since 2000** (from 4.6 million metric tons*), showing we are on target to reach our goals. Due to our progress to date, we are in the process of evaluating our 2005 targets and reserve the right to make adjustments to our targets as we approach the end of 2004. GM's 2005 report will indicate if there will have been any changes made to the target.

Non-recycled waste decreased 8.1% in 2003 falling from 0.67 million metric tons* in 2002 to 0.61 million metric tons* in 2003, and recycled waste decreased 3.3% (from 3.6 to 3.5 million metric tons*). Worldwide vehicle production was down 2% in 2003 against 2002. Production-adjusted waste amounts decreased 2.1% (2002 to 2003).



The chart below shows the methods used to manage our waste. Our facilities report that over 84% of the waste we generate worldwide is being recycled.



7.1.1.1.4.1 Recognition

In 2003 we were awarded the U.S. Environmental Protection Agency 'WasteWise Partner of the Year' award in the Very Large Business category for overall waste prevention achievements, recycling initiatives, efforts to purchase or manufacture recycled-content products, and activities to promote WasteWise. We were also awarded the 'Climate Change Partner of the Year' award for outstanding waste reduction efforts that reduced greenhouse gas (GHG) emissions and for our efforts to disseminate information about climate change. The WasteWise Awards Program recognizes the efforts and achievements of outstanding organizations each year. This was the third consecutive year that we have been honored with WasteWise awards, taking solitary top honors in the two 2003 categories.

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