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Vehicles and Emissions

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VEHICLES AND EMISSIONS

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ABSTRACT

Emissions have continued to change over the years, but how have they affected the environment and the health of individuals? To acquire more information on this topic this culminating experience project investigated the specific emission gasses that are released, the difference between emissions during the manufacturing and emissions during the lifetime of the car, and the effects that emissions create on the environment and the population. The four research questions were: 1. What are the health effects on people who are exposed to emission gases? 2. What are the environmental effects when emission gases are released? 3. What part of the automobile manufacturing process releases the most and least amount of emission gasses? 4. How will emission gasses affect the environment and people in the future? Data was collected from the Environmental Protection Agency, Center of Disease Control, Department of Energy and Case Studies that analyzed the different emission gases in the automobile industry and how they affect the environment and people's health.

The findings were: Q1. that the environment and people's health are still affected but, the automobile industry has begun to limit their emission release by recycling, treating, disposing, and recovering the energy that is used, Q2. that emissions affect the environment by hydrocarbons reacting with oxides of nitrogen which create ozone and develop into smog, greenhouse gasses and acid rain which can cause climate change and raise Earth's temperatures. Q3.

that painting an automobile releases the most amount of Carbon Dioxide emissions compared to other manufacturing portions, Q4. that current health effects are caused by exposure to emission gasses during the manufacture and operation of an automobile, but new regulations have implemented limits on the emissions that are released.

The conclusion is that emission gases have decreased over time due to the implementation of regulations on the automobile industry, but they still cause harm to the environment and people’s health. Additionally, people can turn to Electric Vehicles (EVs) or methane fuel to decrease their carbon footprint. It is recommended that further research be conducted to determine if emission gasses have continued to decrease and if additional laws and regulations have been passed to limit emission gas release during the operating and manufacturing process of automobiles.

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INTRODUCTION

"All of those cars were once just a dream in somebody's head." – Peter Gabriel (Gabriel, 2022)

The automobile population has had tremendous growth over the last few years. Anthony Downs (1979) mentioned that the automobile population has increased roughly 2.5 times numerically, however percentage-wise, it has increased about 4.9 percent. This growth has not been limited to the United States only, it is a growth that has been occurring worldwide (Downs, 1979). This raises an important question: what is happening with automobile emissions and how do they currently affect the environment and people? To better understand the research conducted, there will be a thorough exploration of emission gasses, the health effects that are caused by the emissions, and the environmental effects. With the information gathered, there will be an analysis to verify if there are any patterns in the data.

One of the components that should be taken into consideration is the automobile population. Smith (2016) explained that the current automobile population stands at 1.1 billion cars and 377 million trucks. By the year 2040, the number of cars is expected to reach 2 billion and the number of trucks will be reaching nearly 790 million (Smith, 2016). The reasoning for the automobile growth is perhaps correlated to that of the population growth. As reported by Roser, Ritchie, and Ortiz-Ospina (2019), the world population increased from 1 billion people in 1800 to 7.9 billion people today. That is a 790% increase in the population. However, the growth rate in the population declined from 2.2% to 1.0% when compared to 50 years ago (Roser, Ritchie, & Ortiz-Ospina, 2019).

Clairotte et al. (2020) created a research paper that provided information regarding the differences in emissions gasses when compared to the size of automobiles as well as the intake of fuel that is used for those automobiles. In the paper, Greenhouse Gas (GHG) emissions from on-road transport were measured from 128 vehicles and revealed that Methane (CH_4) emissions and dual-fuel Compressed Natural Gasses (CNG) appeared to be the largest emitters in automobile categories. Statistical analysis showed that lean-NOx trap (LNT) equipped diesel vehicles emitted more than Selective Catalytic Reduction (SCR) or only Diesel Oxidation Catalyst (DOC) equipped automobiles. The highest Nitrous Oxide (N_2O) emissions were also associated with automobiles (Clairotte et al., 2020).

Clairotte et al. (2020) furthermore explained that the emission trends furthermore found to increase along with the emissions standards such as Euro 5 to Euro 6 and Euro V to Euro VI. There were implementations of sophisticated after-treatment systems that are likely to be the cause of a shift. The implementation of the Euro 6d-TEMP, which became mandatory for new approval as of September 2017 for automobiles included a new driving cycle and Real Driving Emission tests that can be associated with intensive use of after-treatment systems. However, Nitrous Oxide (N2O) emissions can be expected to continue to increase. Consequently, without setting a standard on the tailpipe of Nitrous Oxide (N2O) emissions from automobiles, the regulations to reduce Greenhouse Gas (GHG) emissions from on-road transportation might remain incomplete (Clairotte et al., 2020).

In efforts to attempt to find correlations among emissions and automobiles overall, there will be steps taken to conduct this research to explore emission gasses and Electric Vehicles (EVs), the number of emission gasses released from automobiles – specifically looking into the difference among gasoline and diesel, the individual parts of automobiles along with the emission release, and the difference in emissions between trucks and cars. Additionally, more exploration of the data on the Environmental Protection Agency — P2 Opportunities (2021) will be conducted as it will be beneficial to be able to find information regarding the Toxic Release Inventory (TRI) that is measured throughout the automobile manufacturing process and how it has changed over the last few years (Environmental Protection Agency — P2 Opportunities, 2021).

In addition to reviewing the automobile industry and how it correlates to the release of emission gasses, there will be a review of how the effects of automobile emission gasses can affect the general population and how they affect the environment. The National Center for Environmental Assessment (NCEA) (2002) published that those automobiles that operate on diesel provide superior performance characteristics to the engine. However, Diesel Engine Exhaust (DE) contains harmful pollutants in either gas or particle form such as carbon dioxide, oxygen, nitrogen, water vapor, carbon monoxide, nitrogen compounds, sulfur compounds, and many more low-molecular-weight hydrocarbons. Individuals can be exposed to these pollutants through exhaust fumes on the highway as well as nonroad uses of the diesel engine (National Center for Environmental Assessment (NCEA), 2002).

The National Center for Environmental Assessment (NCEA) (2002) furthermore explained that particles present in Diesel Engine Exhaust (DE) are composed of a center core of elemental carbon and consumed organic compounds of sulfate, nitrate, metals, and other trace elements. In addition to Diesel Engine Exhaust (DE), Diesel Particulate Matter (DPM) consists of fine particles with a diameter measuring less than 2.5 µm, including a subgroup with many ultrafine particles, with a diameter measuring less than 0.1 µm. Due to the size of the particles, they are highly respirable and can reach the deep lung. Diesel Engine Exhaust (DE) emissions tend to vary based on their chemical composition and the particle sizes among different engine types, engine operating conditions (idling, accelerating, and decelerating), and fuel formulations (low or high sulfur fuel) (National Center for Environmental Assessment (NCEA), 2002).

The National Center for Environmental Assessment (NCEA) (2002) explained the different health hazardous effects caused by Diesel Engine Exhaust (DE) and Diesel Particulate Matter (DPM). The hazardous effects include acute (short-term) exposure-related symptoms, chronic (long-term) exposure-related noncancer respiratory effects, and lung cancer. Acute effects consist of irritation in the eyes, throat, and bronchial tubes; there are neurophysiological symptoms such as lightheadedness and nausea, and there are also respiratory symptoms such as a cough, or phlegm. In addition to these effects, there is evidence of immunologic effects such as worsening allergic responses and asthma-like symptoms (National Center for Environmental Assessment (NCEA), 2002).

The National Center for Environmental Assessment (NCEA) (2002) was able to determine the Chronic Long-Term Exposure of noncancer respiratory effects, animal studies were conducted that showed a spectrum of dose-dependent inflammation and histopathological changes that occurred in the lungs among several animal species, including rats, mice, hamsters, and monkeys. This study determined that exposure to Diesel Engine Exhaust (DE) could potentially pose chronic respiratory hazards to humans. As for Long-Term Chronic exposure to carcinogen effects, there is supporting evidence that demonstrates that exposure to Diesel Engine Exhaust (DE) creates an increased lung cancer risk among those who work in occupations where diesel engines are continuously used. This stems from the organics within the Diesel Engine Exhaust (DE) mixture (National Center for Environmental Assessment (NCEA), 2002).

Due to the carcinogen hazard, the National Center for Environmental Assessment (NCEA) (2002) has begun to perform a dose-response assessment of human and animal data to assist in the development of a cancer unit risk estimate. The cancer unit risk estimate can be used along with information that will help characterize the potential cancer disease impact on a population that is exposed to Diesel Engine Exhaust (DE) in areas that operate diesel engines constantly. The purpose behind having the cancer risk perspective is to demonstrate and provide a sense of the possible significance of the lung cancer hazard from environmental exposure within the workplace (National Center for Environmental Assessment (NCEA), 2002). However, Silverman (2017) conducted research that revealed that Diesel Exhaust (DE) emissions would be classified as a leading cause of carcinogens among humans. This was determined by the International Agency for Research on Cancer (IARC) in 2012 and it was based on evidence of its carcinogenicity to the lung (Silverman, 2017).

Background

To have a higher quality of understanding of what the automobile industry is, one must first know what the automotive industry entails. Rae (2022) mentioned that the automotive industry consists of automobile companies and the activities involved in the manufacturing of automobiles. The primary products that are associated with the industry are passenger automobiles and trucks. The automobile industry originated in Europe in the late 19th century. However, the United States completely dominated the automobile industry for the first half of the 20th century due to the invention of mass production techniques. Afterward, Europe and Japan began to catch up and ended up being able to compete as the top major producers and exporters of automobiles with the United States (Rae, 2022).

Unfortunately, Rae (2022) continued to explain that the mass use of automobiles was bound to have consequences such as traffic congestion, air pollution, and highway accidents. Although traffic congestion and highway accidents are unforeseen consequences, one can attempt to focus on the pollutants that are released and how to work toward reducing the emissions released. In the 1960s, the United States began to take steps that will put controls on automobiles to restrict the emission of pollutants that the automobiles release. The reason for putting these restrictions in place was that scientists believed that the emissions from automobiles and their manufacturing processes were releasing carbon dioxide into the atmosphere, which trapped additional heat and began to raise the Earth's temperature (Rae, 2022).

Rae (2022) said that due to the emission concerns that were brought to the public's attention, many automobile industries began to take additional steps to use more energy-efficient processes such as using fuel cells that convert hydrogen together with oxygen into electricity to power an electric vehicle (Rae, 2022). Furthermore, the U.S. Department of Energy (2022) considered investigating the types of fuels used for the automobile to operate. Different types of fuels are used to power an automobile such as biodiesel, electricity, ethanol, hydrogen, natural gas, and propane. Biodiesel is a fuel that can be manufactured from vegetable oils, animal fats, or recycled cooking grease and can only be used in diesel automobiles. Electricity is used to power plug-in Electric Vehicles (EVs) as well as Plug-in Hybrid Electric Vehicles (PHEVs) where the electricity will boost the overall efficiency of the automobile (U.S. Department of Energy, 2022).

The U.S. Department of Energy (2022) explained that ethanol is a renewable fuel that is produced from corn and other plant materials. Ethanol is blended with gasoline to be used by regular automobiles. Hydrogen fuel is an emissions-free alternative fuel that can be used from domestic resources such as natural gas, nuclear power, biomass, and renewable power like solar and wind. Hydrogen fuel is made for fuel cell vehicles. Natural gas is a domestic gaseous fuel that can have significant fuel cost advantages over gasoline and diesel fuel. Propane is a gaseous fuel that has been used in automobiles throughout the world for decades (U.S. Department of Energy, 2022).

However, Electric Vehicles (EVs) are not exceptional automobiles either. Forbes (2016) explained in the article titled “The Carbon Footprint of Tesla Manufacturing” that the Union of Concerned Scientists did a rigorous assessment of the carbon footprint of Electric Vehicles (EVs) and internal combustion automobiles, including hybrid automobiles. These Scientists were able to acquire information that explained that when manufacturing a full-sized Tesla Model S with rear-wheel drive in addition to an 85-Kilowatt Hour (KWH) battery, it would be equivalent to manufacturing a full-sized internal combustion automobile, nevertheless, the battery itself added 15 percent or one metric ton of Carbon

Dioxide (CO_2) emissions to the overall total of the manufacturing process (Forbes, 2016).

Moreover, the U.S. Department of Energy (2022) found it important to know that different types of automobiles that are on the road. There are diesel automobiles that run on biodiesel blends (B5 – 5% biodiesel blend and 95% biodiesel or B20 – 6% to 20% mix of biodiesel blended with petroleum). These automobiles raise the cetane number of fuel and improve fuel lubricity. The high cetane allows the engine to start easily plus reduces the ignition delay. Flexible Fuel Vehicles (FFVs) have an internal combustion engine that operates on gasoline and any blend of gasoline mixed with ethanol up to 83%. Flex Fuel (E85) is a gasoline-ethanol blend that carries between 51% and 83% ethanol, which also depends on the geographical area and the time of the season. Flexible Fuel Vehicles (FFVs) have an improved acceleration performance when they operate on higher ethanol blends, however, that also decreases their overall fuel economy (U.S. Department of Energy, 2022).

Furthermore, the U.S. Department of Energy (2022) mentioned that Fuel Cell Electric Vehicles (FCEVs) are powered by hydrogen and are known to be more efficient when compared to conventional automobiles. Fuel Cell Electric Vehicles (FCEVs) additionally produce no tailpipe emissions as they emit water vapor and warm air. Fuel Cell Electric Vehicles (FCEVs) store energy as hydrogen, which is then converted to electricity by the fuel cell and have a driving range of nearly 300 miles. Propane automobiles have been operating for decades and have given automobiles power, acceleration, and cruising speed like conventional automobiles. These automobiles are fueled by propane, also known as Liquefied Petroleum Gas (LPG), and have been broken down into two categories: dedicated which allows automobiles to operate on propane only, and bi-fuel which allows automobiles to run on either gasoline or propane (U.S. Department of Energy, 2022).

The U.S. Department of Energy (2022) continued to explain that there are different types of Electric Vehicles (EVs) as well. The different types of automobiles are Hybrid Electric Vehicles (HEVs), Plug-In Hybrid Electric Vehicles (PHEVs), and All-Electric Vehicles (EVs) which are also known as Battery Electric Vehicles (BEVs). All-Electric Vehicles (EVs) use electricity to improve the automobile's efficiency and can travel between 150 and 300 miles based on the amount of energy that is used when accelerating the automobile. Hybrid Electric Vehicles (HEVs) operate through an internal combustion engine and an electric motor that uses energy stored in a battery, nonetheless, they are also fueled with gasoline to operate the internal combustion engine. Plug-In Hybrid Electric Vehicles (PHEVs) operate by an internal combustion engine with an electric motor that uses energy stored in a battery. These automobiles can operate in an all-electric form that would require a larger battery that can be plugged into an electric power source to charge, or they can operate on a charge-depleting mode. Plug-In Hybrid Electric Vehicles (PHEVs) can only travel between 20 and

40 miles on electricity alone and would then need to rely on gasoline which is quite like a conventional hybrid automobile (U.S. Department of Energy, 2022).

According to the U.S. Department of Energy (2022), the last type of automobile would be operated by natural gas. It is important to know that there are three types of Natural Gas Vehicles (NGVs). The three types of Natural Gas Vehicles (NGVs) are dedicated, bi-fuel and dual-fuel. Dedicated automobiles are designated to run only on natural gas. Bi-fuel automobiles have two separate fueling systems which enable them to run on either natural gas or gasoline. Dual-fuel vehicles have fuel systems that run on natural gas but can also use diesel fuel for ignition assistance and are typically limited to heavy-duty vehicles. Natural Gas Vehicles (NGVs) are good for high-mileage travel and are fueled by Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG). LNG offers a greater energy density when compared to CNG which means that the fuel range is comparable to that of a conventionally fueled vehicle (U.S. Department of Energy, 2022).

In the article "Working of Electric Cars" published on Circuits Today (2010), there was information that explained that it is quite easier to fix an Electric Vehicle (EV) when compared to a conventional automobile. The reason why it is simpler to fix an Electric Vehicle (EV) has to do with the electrical components. Apart from fixing the automobile, there are additional factors that show the difference between the two. For further reference, see Figure 1 below as it reflects the difference between an Electric Vehicle (EV) and a Gasoline automobile, and it also provides a few statistics between the two (Circuits Today, 2010).

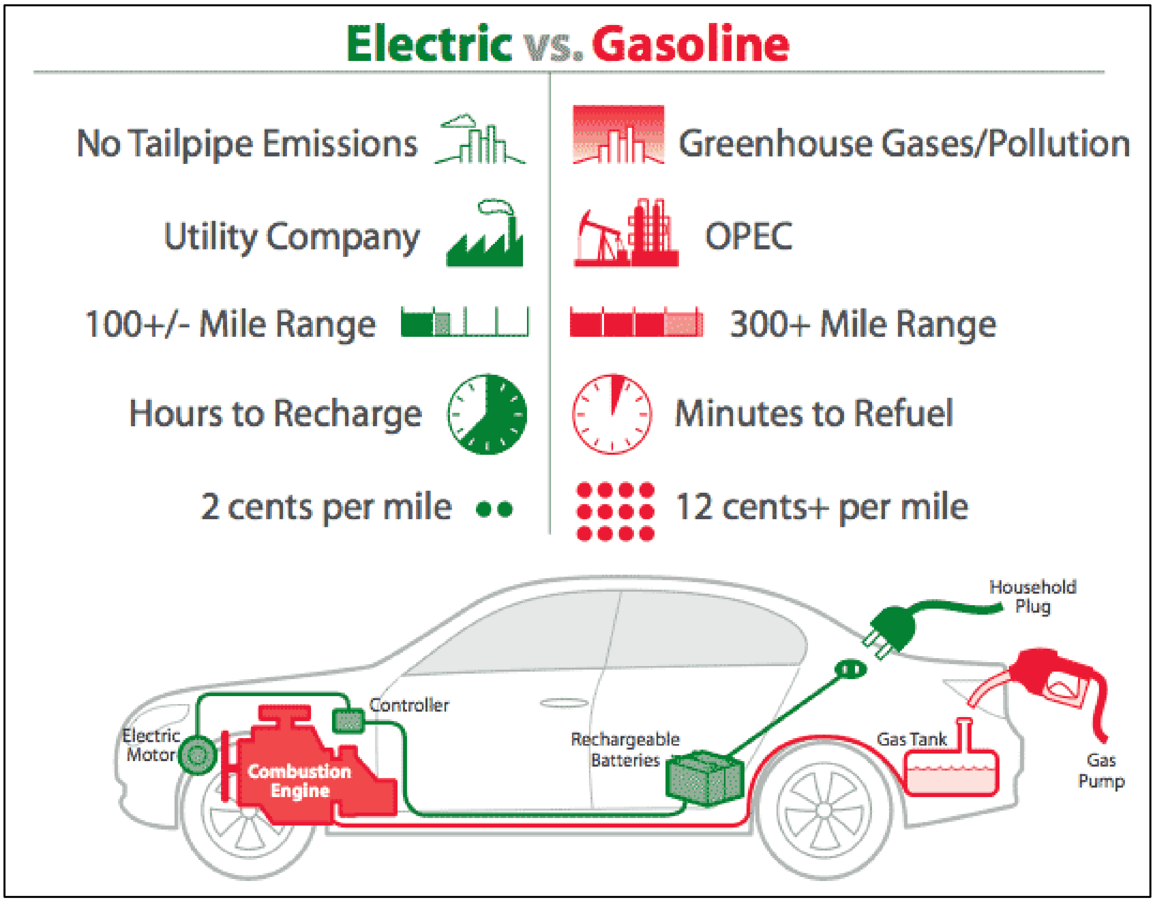

Figure 1: Gasoline and Electric Car

Comparison – Gasoline and Electric Car: Acquired image to prove the statistics between and electric Vehicle (EV) and a Gasoline automobile (Circuits Today, 2010).

The Center of Disease Control (CDC) (2019), spoke on how it is important to be aware of the chemicals that are used to produce fuel. One specific chemical used is Benzene (C_6H_6), also known as benzol, a colorless liquid with a sweet odor that can be found in air, water, and soil. Benzene (C_6H_6) is a highly flammable chemical that can evaporate in the air quite quickly and can dissolve slightly in water. An individual can pick up the scent of Benzene (C_6H_6) in the air at 60 parts of benzene per million parts of air (ppm) and recognize it as benzene at 100 parts per million (ppm). It can also be tasted in water when Benzene (C_6H_6) is between 0.5 to 4.5 parts per million (ppm) (Center of Disease Control (CDC), 2019).

The Center of Disease Control (CDC) (2019) explained that benzene (C_6H_6) was primarily discovered and isolated from coal tar during the 1800s. Today, Benzene (C_6H_6) can be found in industrial sources such as petroleum and can be used to make other chemicals, such as styrene for Styrofoam and other plastics, cumene for various resins, and cyclohexane for nylon and synthetic fibers. Benzene (C_6H_6) can be used to manufacture some types of rubbers, lubricants, dyes, detergents, drugs, and pesticides. As for natural sources, Benzene (C_6H_6) can be found in gas emissions from volcanoes and forest fires. Furthermore, the chemical cane is present in crude oil, gasoline, and cigarette smoke (Center of Disease Control (CDC), 2019).

Furthermore, the Center of Disease Control (CDC) (2019) continued to explain that Benzene (C_6H_6) is a chemical that can be found in the environment easily. Benzene (C_6H_6) levels in the air can be elevated by emissions from burning coal and oil, Benzene (C_6H_6) waste and storage operations, exhaust fumes from automobiles, and evaporation from gasoline service stations. As for indoor air, Benzene (C_6H_6) can be found in tobacco smoke and can be released into the water in soil when industrial discharge, disposal of products containing benzene, and gasoline leaks from underground storage tanks. Benzene (C_6H_6) can pass into the air from water and soil surfaces. Once in the air, Benzene (C_6H_6) reacts with other chemicals and begins to break down after a few days, but it can also be deposited on the ground through rain or snow. However, Benzene (C_6H_6) in water and soil breaks down more slowly as it is slightly soluble in water and can pass through the soil into underground water. Benzene (C_6H_6) does not build up in plants or animals (Center of Disease Control (CDC), 2019).

The Center of Disease Control (CDC) (2019) said that there are roughly 238,000 individuals in the United States who work in industries that manufacture or use Benzene (C_6H_6). Those individuals may be exposed to the highest levels of Benzene (C_6H_6). The industries that include traces of Benzene (C_6H_6) production, such as petrochemicals, petroleum refining, coke and coal chemical manufacturing, rubber tire manufacturing, and storage or transport of Benzene (C_6H_6) and petroleum products containing Benzene (C_6H_6). Other individuals who were potentially exposed to Benzene (C_6H_6) include coke oven workers within the steel industry, printers, rubber workers, shoemakers, laboratory technicians, firefighters, and gas station employees (Center of Disease Control (CDC), 2019).

The Center of Disease Control (CDC) (2019) mentioned that to reduce the risks of exposure to Benzene (C6H6), an individual can take a blood test to verify whether they were exposed to Benzene (C_6H_6) at a doctor's office. However, these tests are limited in what they tell you and must be done shortly after the exposure. It is also important to know that these tests are not helpful when attempting to detect very low levels of Benzene (C_6H_6) in the body and since Benzene (C_6H_6) tends to disappear rapidly in the blood, the measurements of the tests might only be useful in recent exposures (Center of Disease Control (CDC), 2019).

When Benzene (C_6H_6) enters the body, the Center of Disease Control (CDC) (2019) explains that it is converted into metabolites. Certain metabolites of Benzene (C_6H_6), such as phenol, muonic acid, and S-phenyl mercapturic acid can be found through urine and this measurement has been used to examine for any exposure to Benzene (C_6H_6) among those who work closely with it. A key indicator of Benzene (C_6H_6) exposure is measurements of muonic acid or S-phenyl mercapturic acid in the urine as they are more sensitive and reliable indicators. Similarly, to the blood test, the urine test is only acceptable when an individual is exposed to Benzene (C_6H_6) in the air at levels of 10 parts per million (ppm) or greater. This specific test must also be done after the individual's exposure as phenol is present in the urine from other sources such as the individual's diet or environment. One must also know that the urine test is not useful to determine how much Benzene (C_6H_6) the individual was exposed to (Center of Disease Control (CDC), 2019).

Another item mentioned by the Center of Disease Control (CDC) (2019) is that measurement of Benzene (C_6H_6) in blood or metabolites in urine cannot be used to make assumptions about whether an individual will experience harmful health effects. Blood counts of all components of the blood and examination of bone marrow can be used to determine the exposure of Benzene (C_6H_6) and its possible health effects. As for those who are exposed to high levels, complete blood analysis can be used to monitor the possible changes related to the exposure (Center of Disease Control (CDC), 2019).

Apart from the exposures and health effects that emission gasses take on a person, one can also explore how the environment is affected. Wenzel et al. (2000) explained that there were Federal test procedures created to limit the emission gasses released. The Clean Air Act Amendments (CAAA) of 1970 authorized the development of comprehensive federal and state regulations to limit emissions from both industrial sources and automobile sources. The U.S. Environmental Protection Agency (EPA) also established the Federal Test Procedure (FTP) for all automobiles to be tested under identical preparation and driving conditions. The Federal Test Procedure (FTP) was designed in the early 1970s to simulate the combined highway and city driving in urban Los Angeles. When the test was developed, it was determined that a top speed of 57 miles per hour (mph) and a top acceleration of only 3.3 miles per hour (mph) per second were set to accommodate the limitations of the dynamometers available (Wenzel et al., 2000).

Problem Statement

As the population continues to grow worldwide, emissions and carbon gasses are also increasing to meet the increasing demand for automobiles for daily operations. To better understand the automobile industry, there will be research conducted that reflects how this industry affects not only the environment but also the general population. For further knowledge, there will be data analyzed that demonstrates the emission gas release during the manufacturing process as well as the operating process of the vehicles. In addition to this, there will be supplementary information on the effects of the emission gasses and how they affect the environment and the population.

One of the major articles that heavily impacted this research by Zhang and Batterman (2014) explained that studies have been able to determine that traffic congestion has increased automobile emissions and has degraded ambient air quality. This has shown an increase in morbidity and mortality for drivers, commuters, and individuals who live near major roadways. The risk levels depend on many factors such as traffic volumes, automobile types, road types, and meteorology (Zhang and Batterman, 2014). Moreover, the research will assist in determining the future effects of emission gasses on the environment and people.

Objective

The objective of this research project is to analyze the automobile industry as well as the emission gasses that are released and how they can harm the general population and the environment. To thoroughly explore the research topic, there will be an analysis of emission gas trends that will be investigated throughout the study, such as the size of the automobile, the type of automobile, as well as the fuel intake of the automobile. Additionally, the research conducted will be focused on the manufacturing process as well as the operation process of the automobile. Moreover, the project will assist in interpreting how the emission gasses would affect the environment and the health risks due to exposure to these emission gasses.

Research Questions

For further analysis and familiarization of emission gasses and their effects. Four research questions will be explored to attempt to address the information needed for this project. Below are the questions that will be studied:

1. What are the health effects on people who are exposed to emission gasses?
2. What are the environmental effects when emission gasses are released?
3. What part of the automobile manufacturing process releases the most and least amount of emission gasses?
4. How will emission gasses affect the environment and people in the future?

The contribution that is expected to be made with this research topic is to see if there has been an overall decrease in emission gasses during the manufacturing and operation of automobiles. Plus, there will be an evaluation of the effects that emission gasses have on the environment as well as on people.

Methodology

To understand the emissions that the automobile industry releases, the project will follow a three-step research approach. First, there will be an analysis of current and potentially new investigations on the automobile industry and its emission gas releases. The investigation will analyze patterns through datasets, review case studies, and examine the toll that emission gasses take on the health effects on people and the environment. This will potentially help provide data that will determine additional patterns. Those patterns would show the increasing or decreasing emission gas numbers among different automobile factors such as the annual mileage, fuel type, as well as the emissions that are released when the automobile is being manufactured and when it is being driven.

Second, case studies will be reviewed that will provide additional information relating to the research topic. The case studies will review a Health Assessment that documents the Diesel Engine Exhaust and the health concerns to the emission exposure, they will go over the Energy-Consumption and Carbon-Emission Analysis of Vehicle and Component Manufacturing and how the measure of each varies among automobile parts, and, lastly, there will be an analysis of the Comparative Study on Life Cycle Carbon Dioxide (CO_2)

Emissions from the Production of Electric and Conventional Vehicles in China and will explain significant differences among the types of automobiles.

Finally, the research conducted will be analyzed thoroughly in pursuance of providing a conclusion along with a recommendation to the automobile industries who manufacture automobiles and the steps that can be taken to decrease the emission gas release from the manufacturing process and when the automobile is driven.

Organization of the Study

The delivery of this project has been organized as follows:

- Chapter 1 will analyze the background of the study, the problem statement, as well as the research questions involving how emission gasses as well as the manufacture and operation of automobiles have impacted the environment and the health of people.
- Chapter 2 will focus on the specific case studies that will assist in determining how the different components of automobiles release emission gasses and how they affect the health of people and the environment
- Chapter 3 will be based on the research methodology and creation based on existing data. This chapter will shine light on the different emission gasses that are released as well as how they have impacted the environment and people.

- Chapter 4 will provide an additional overview of data collection and will help in the development of the conclusion and recommendation.
- Chapter 5 will consist of the summary, recommendations, and conclusion of the automobile industry and the release of emission gasses and how they have affected the environment and people.

CHAPTER TWO:

LITERATURE REVIEW

According to Clairotte et al. (2020), there is incomplete standards on the tailpipe of Nitrous Oxide (N_2O) emissions from automobiles a regulation to reduce Greenhouse Gas (GHG) emissions from on-road transportation (Clairotte et al., 2020). This information will be useful to measure the emission gas release within the manufacturing process and the operating process of automobiles. The literature regarding this project will manage research on the following fields: emission gas release by automobile size, emission gas release by fuel type, emission gas release during the manufacturing process of the automobile, plus additional information that pertains to the number of emissions that are released. In addition to this, there will be an exploration of rules and regulations that limit the emission of gas released during an automobile's operating and manufacturing process. This data will identify the development built to limit the emission gas exposure into the environment and address any health concerns caused by the release of emission gasses.

According to the Environmental Protection Agency - Greenhouse Gas (2021), it was mentioned in their article titled “Green Vehicle Guide from a Typical Passenger Vehicle,” that there is information available which aids in describing that apart from Carbon Dioxide (CO_2) emissions, automobiles also produce methane (CH_4) and nitrous oxide (N_2O) gasses. These emissions that were discussed are formed in the tailpipe in addition to hydrofluorocarbon emissions that are formed from leaking air conditioners. The emissions of these gasses are small when they are compared to Carbon Dioxide (CO_2). However, these emissions have a higher global warming potential when compared to others (Environmental Protection Agency - Greenhouse Gas, 2021).

The Environmental Protection Agency - Greenhouse Gas (2021), also mentioned that it is imperative to differentiate the tailpipe emissions among different types of automobiles. An Electric Vehicle (EV) will not emit any tailpipe emissions. A fuel cell automobile operating on hydrogen will emit only water vapor. A Plug-In Hybrid Electric Vehicle (PHEV) that is operating on gasoline only creates tailpipe emissions based on the automobile's gasoline fuel economy (Environmental Protection Agency - Greenhouse Gas, 2021). This information helped acknowledge the greenhouse gas emissions released from automobiles and recognize how Electric Vehicles (EVs) differ from regular automobiles when comparing their operating systems and battery life.

In addition to the information gathered from the Environmental Protection Agency - Greenhouse Gas (2021), more data was provided regarding how much tailpipe carbon dioxide (CO_2) is created from burning one gallon of fuel. Carbon Dioxide (CO_2) Emissions from one gallon of gasoline release about 8,887 grams of Carbon Dioxide (CO_2) per gallon while one gallon of diesel releases roughly 10,180 grams of Carbon Dioxide (CO_2) per gallon. Based on the information on the rough grams of Carbon Dioxide (CO_2) provided, the tailpipe Carbon Dioxide (CO_2) that is emitted from driving one-mile averages to be about 404 grams of

Carbon Dioxide (CO_2) per mile for the average passenger automobile. Now, to calculate the average annual Carbon Dioxide (CO_2) emissions for a typical passenger automobile, one would take the average gasoline automobile's fuel economy, which is estimated to be about 22 miles per gallon. The average automobile drives around 11,500 miles per year. Therefore, an automobile emits about 4.6 metric tons of carbon dioxide per year (Environmental Protection Agency - Greenhouse Gas, 2021). The calculations below rule that an automobile that operates on gasoline is more efficient compared to an automobile that takes on diesel:

Gasoline

8,887 grams of Carbon Dioxide (CO_2) per gallon x 11,500 miles per year =

102,200,500

102,200,500 / 22 miles per gallon =

4,645,477.27 grams of Carbon Dioxide (CO_2) per gallon annually

Diesel

10,180 grams of Carbon Dioxide (CO_2) per gallon x 11,500 miles per year =

117,070,000

117,070,000 / 22 miles per gallon =

5,321,363.64 grams of Carbon Dioxide (CO_2) per gallon annually

Emily Folk's (2020) article "How high is the carbon footprint of automobile manufacturing" showed that in contemplation to explore automobiles' manufacturing process, one must extract the raw materials from the automobile itself. The raw materials would consist of steel, aluminum, plastic, and rubber. The process of extracting the substances is very energy-intensive, which can make it difficult to quantify the carbon footprint that is released. Greenhouse gas emissions from the automobile manufacturing industry exceed the energy footprint placed by the European Union. Surprisingly, electric vehicle manufacturing releases a larger carbon footprint when compared to the manufacturing of a regular automobile (Folk, 2020).

Folk (2020) furthermore mentioned that since 2008, the automobile manufacturing industry has worked to follow more renewable energy sources to ensure that they can accomplish more energy-efficient standards. To meet those standards, large manufacturers have begun working to reduce their carbon footprint by recycling parts and using renewable energy. As for Electric Vehicles (EVs), the carbon footprint of the manufacturing impact was the same as that of a standard automobile. However, the battery of Electric Vehicles (EVs) does increase the carbon emissions during the manufacturing process by an average of 15%. However, Tesla, in specific, recycles their batteries which aids in the recovery of the automobile's carbon footprint by nearly 70 percent (Folk, 2020).

The following case studies will provide information on the different emission gasses that are released during the operating and manufacturing processes of an automobile. Furthermore, they will address the health risks of short-term and long-term exposure to a variety of emission gasses.

Case Study One

To begin with, it is important to know the difference between an Electric Vehicle (EV) and a Conventional Vehicle. New York State - Electric Cars. (2022) explained that an Electric Vehicle (EV) is an automobile that is powered by energy stored in batteries. A conventional vehicle is an automobile with combustion engineered by gasoline or diesel (New York State - Electric Cars, 2022). In the case study titled “Comparative Study on Life Cycle CO_2 Emissions from the Production of Electric and Conventional Vehicles in China” which was written by Qiao et al. (2017), there has been an increase in Electric Vehicles (EVs) in China that correlates with an increase in Carbon Dioxide (CO_2) emissions as well. The reason for their increase would have to do with the production, manufacturing assembly, operation, disposal, in addition to many more automobile-related operations (Qiao et al., 2017).

Qiao et al. (2017) furthermore mentioned that multiple studies demonstrated that emissions from the usage of automobiles accounted for a large portion of the emission gas release. However, their focal point was predominantly on Electric Vehicles (EVs). The Internal Combustion Engine Vehicle (ICEV) contributed to 10 percent of the life of Carbon Dioxide (CO_2) emissions from automobile manufacturing. Another detail that was shared was that automobile manufacturing varies across many regions and carries numerous manufacturing techniques which will moreover cause a discrepancy in Carbon Dioxide (CO_2) emissions when they are calculated (Qiao et al., 2017).

Qiao et al. (2017) case study also mentioned that Li-ion batteries have been applied more frequently to Electric Vehicles (EVs) over recent years. Li-ion batteries are defined as a type of rechargeable battery composed of cells where lithium ions move from the negative electrode through an electrolyte to the positive electrode during a discharge and back when charging. Li-ion batteries are also known as lithium-ion batteries. The application of Li-ion batteries onto Electric Vehicles (EVs) has created a limit in the number of studies that have been made as they have focused on Carbon Dioxide (CO_2) emissions from battery production which can cause uncertainty as shown in Figure 2. However, the Carbon Dioxide (CO_2) emissions from active material production were the influential variables within Lithium Iron Phosphate (LFP) batteries and Nickel Cobalt Manganese (NCM) batteries, which are also known as Lithium Manganese Cobalt Oxide batteries. (NCM) batteries (Qiao et al., 2017).

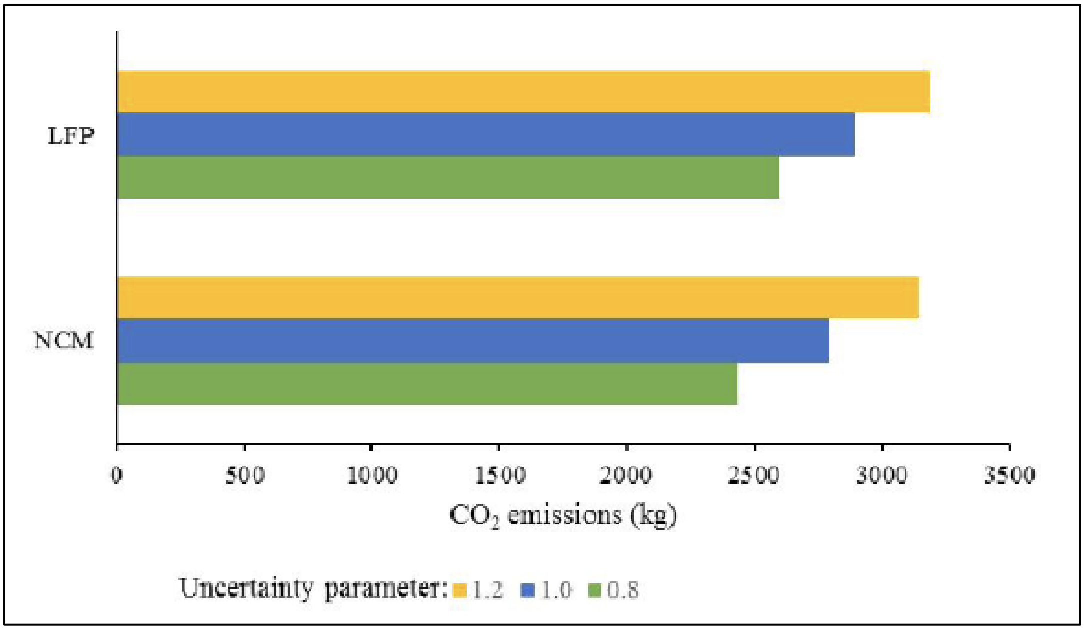

Figure 2: CO_2 Emissions

Uncertainty of CO_2 emissions from battery production: Acquired image to provide the Carbon Dioxide (CO_2) emissions within Lithium Ion Phosphate (LFP) batteries and Nickle Cobalt Manganese (NCM) batteries (Qiao et al., 2017).

Based on the information gathered from Qiao et al. (2017), there was more information provided for Li-ion batteries explaining that the manufacturing techniques for those specific batteries are still in the primary stage in China. Due to cleaner productions of active materials, to manufacture one li-ion battery such as a Lithium Iron Phosphate (LFP) battery or a Nickel Cobalt Manganese (NCM) battery, the United States produced around 1.1 tonnes of Carbon Dioxide (CO_2) emissions which are one-third of the levels of China. Additionally, an Electric Vehicle (EV) uses more steel and aluminum when it is being manufactured compared to an Internal Combustion Engine Vehicle (ICEV) which, again, causes more Carbon Dioxide (CO_2) emissions (Qiao et al., 2017).

This case study helped determine that the use of Electric Vehicles (EVs) emit a lot of Carbon Dioxide emissions during the production, manufacturing assembly, operation, disposal, and many more automobile-related operations. The highest emissions would be released among Lithium Iron Phosphate (LFP) batteries and Nickel Cobalt Manganese (NCM) batteries.

Case Study Two

As discussed in a case study by Sullivan et al. (2010), there was data provided that presented the Average Energy Consumption and Average Carbon Dioxide (CO_2) Emissions that are released throughout the automobile manufacturing process. According to the compilations, painting releases the most amount of Carbon Dioxide (CO_2) emissions and uses up the highest average Energy Consumption. Stamping an automobile releases the least amount of Carbon Dioxide (CO_2) emissions and uses the lowest average Energy Consumption. See Table 1 for additional information on the Material Transformation and Vehicle Assembly Process Data (Sullivan et al., 2010).

Table 1: Material Transformation and Vehicle Assembly Process Data

Replicated the Material transformation and Vehicle Assembly Process Data Table (Sullivan et al., 2010)

Material Transformation and Vehicle Assembly Process Data	Av. Energy Consumption (MJ/kg) – Lowest Heat Value	Av. CO_2 Emissions (kg/kg) – based on natural gas and grid electricity
Stamping	5.1	0.31
Aluminum Shape Casting	55.3	3.08
Iron Shape Casting	32	1.69
Copper Wire Production	7.1	0.43
Brass from Scrap	7.4	0.42
Secondary Lead Production	8.5	0.49
Machining	2.02	0.12
Forging	45.1	2.61
Glass Pane Forming	16	0.93
Welding	920	62
Painting	4167	268
HVAC and lighting (EV)	3335	225

Material Handling (EV)	690	39.5
Heating	3110	195
Compressed Air	1380	93
Rubber Moldings	12.9	0.74
Thermosets Moldings	4.79	0.27
PP Injection Mold	26.4	1.53
PVC Injection Mold	24.3	1.56
HDPE Blow Mold	19.7	1.13
PVC Sheet Calendaring	6.25	0.36
HDPE Pipe Extrusion	7.03	0.42

Sullivan et al. (2010) created a table that assisted in determining that the higher the energy consumption was, the higher the Carbon Dioxide (CO_2) emissions were released. The focus is on the manufacturing and vehicle assembly (VMA) stage of the life cycle, where most of the available processing data is maintained for the Case Study. Because there is no specific transformation energy and emissions data for all the materials gathered, there were surrogate representations used where deemed necessary. For example, in the case of the injection moldings of polymers, there was only data for polyvinyl chloride (PVC) and polypropylene (PP) parts (Sullivan et al., 2010).

Sullivan et al. (2010) furthermore explained that other injection molded polymers resorted to using a representative and comparable process, in this case, it was the injection molding of polypropylene that it is believed that this approach provided reasonable approximations for the specific material or transformations where data was not available. Another representation that was applied was for metal stamping. Their focus was on steel stamping, but it was also applied to aluminum and brass stamping (Sullivan et al., 2010).

To conclude, Sullivan et al. (2010), mentioned that there was an exploration of the dependence of the manufacturing and vehicle assembly (VMA) cumulative energy as well as the burdens of Carbon Dioxide (CO_2) emissions within material substitution and weight reduction. In both cases, the contribution of manufacturing and vehicle assembly (VMA) terms to that of the total vehicle life cycle is relatively small. This conforms with the assumptions made regarding the impact of the manufacturing stage burdens and changes in the Life-Cycle Burdens (LCBs) that relate to the changes in vehicle materials. Nonetheless, for advanced automobile technologies with lower operational burdens and composed of more energy-intensive materials, the manufacturing and vehicle assembly (VMA) stage burdens are expected to be larger (Sullivan et al., 2010). This case study helped determine that throughout the many parts of the manufacturing process of an automobile, painting would release the most amount of Carbon Dioxide emissions CO_2).

Case Study Three

In the case study titled "Health Assessment Document for Diesel Engine Exhaust" by the National Center for Environmental Assessment (NCEA) (2002) the health assessment was developed to provide information regarding the possible health hazards due to the exposure of Diesel Engine Exhaust (DE) emissions. Diesel Engine Exhaust (DE) is a mixture of multiple constituents in either gas or particle form. Gaseous components to Diesel Engine Exhaust (DE) are composed of carbon dioxide, oxygen, nitrogen, water vapor, carbon monoxide, nitrogen compounds, sulfur compounds, as well as multiple low-molecular-weight hydrocarbons. There are also hydrocarbon components of the Diesel Engine Exhaust (DE) that are known to be of toxicologic relevance. Those components are the aldehydes, benzene, 1-butadiene, 3-butadiene, and Polycyclic Aromatic Hydrocarbons (PAHs) and Nitro-Polycyclic Aromatic

Hydrocarbons (Nitro-PAHs). Some aldehydes are formaldehyde, acetaldehyde, and acrolein (National Center for Environmental Assessment (NCEA), 2002).

Diesel Engine Exhaust (DE) emissions vary in chemical composition and particle sizes between different engine types, engine operating conditions, and fuel formulations. The types of engines that are to be considered are heavy-duty engines and light-duty engines. The operating conditions that are weighed in are idling, accelerating, and decelerating. As for fuel formulations, that would consist of determining whether the fuel is high sulfur fuel or low sulfur fuel. There are also emission differences among on-road and nonroad engines due to nonroad engines having generally older technology (National Center for Environmental Assessment (NCEA), 2002).

Diesel Engine Exhaust (DE) emissions are emitted from “on-road” diesel engines or “nonroad” diesel engines and are measured by Diesel Particulate Matter (DPM) which is made up of 6 percent of the total particles with an aerodynamic diameter of 2.5 micrometers or less and about 23 percent of the inventory if natural and miscellaneous sources of particles with aerodynamic diameter are excluded. Estimates of Diesel Particulate Matter (DPM) percentage of the total inventory in urban centers are quite high. There is also additional available data that indicates that over the years there are significant reductions in Diesel Particulate Matter (DPM) emissions from the exhaust of on-road diesel engines, considering that limited data suggest that exhaust emissions from nonroad engines have increased (National Center for Environmental Assessment (NCEA), 2002).

Moreover, two studies were conducted among the adult population in the United States that found markedly increased relative risk of lung cancer mortality associated with smoking. After controlling smoking and other risk factors, both studies evaluated the relationships between long-term exposure to fine Particulate Matter (PM) from the least to the most polluted of the cities and lung cancer mortality. There was also no statistical between among lung cancer mortality risks between males and females. Additionally, there was an increased risk of cancerous malignancies of the lung, bladder, and lymphatic tissue. This has been reported in populations that were potentially exposed to higher levels of Diesel Engine Exhaust (DE) than those typically seen in the environment. Additional malignancies were reported such as testicular cancer, gastrointestinal cancer, and prostate cancer (National Center for Environmental Assessment (NCEA), 2002).

The potential of Diesel Engine Exhaust (DE) exposure in the work setting generally includes miners, railroad workers, truckers, bus and taxi drivers, heavy equipment operators, farm tractor drivers, and those involved with heavy-duty marine engines. Regarding the mining industry, some assert that excess lung cancer should be observed among miners if they are exposed to Diesel Engine Exhaust (DE). Diesel Engine Exhaust (DE) is also associated with lung cancer since it is present in the mines. During the early to mid-1960s, the United States introduced diesel engines into metal mines. Currently, there are roughly 265 underground metal and nonmetal mines in the United States and these mines practically use diesel-powered equipment for various tasks, such as haulage, roof bolting, etc. (National Center for Environmental Assessment (NCEA), 2002).

This case study helped determine that exposure to Diesel Engine Exhaust (DE) emissions has acute to severe health concerns. These emissions are emitted from “on-road” diesel engines or “nonroad” diesel engines and are measured by Diesel Particulate Matter (DPM).

CHAPTER THREE:

ANALYSIS

There was an article that assisted in locating the information that was able to better understand the specific automobiles that release emission gasses. One can use the Toxic Release Inventory (TRI) which measures the number of emissions that are released during the automobile manufacturing process. This furthermore provides the major sources of chemical releases and the quantities released as well as how these sources and release quantities have changed over time. The Environmental Protection Agency — P2 Opportunities (20210) also demonstrates the type of practices that are used to reduce pollution (Environmental Protection Agency — P2 Opportunities, 2021).

The Toxic Release Inventory (TRI) from the Environmental Protection Agency — P2 Opportunities (2021) reports the quantity of “waste managed” which includes the chemical waste that is handled throughout the recycling process, the burning of energy recovery, the treatment process, as well as the disposal or release of emission gasses that are set free into the environment. See Figure 3 for visual calculations of the Toxic Release Inventory (TRI) that has been managed. Between 2008 and 2020, one can identify that the quantity of waste managed improved steadily as the production index increased. It is important to know that there were additional steps taken to manage the Toxic Release Inventory (TRI). Some of the steps that were taken were recycling parts, using energy recovery, treating the toxic waste, and simply disposing of the waste in a more efficient manner (Environmental Protection Agency — P2 Opportunities, 2021).

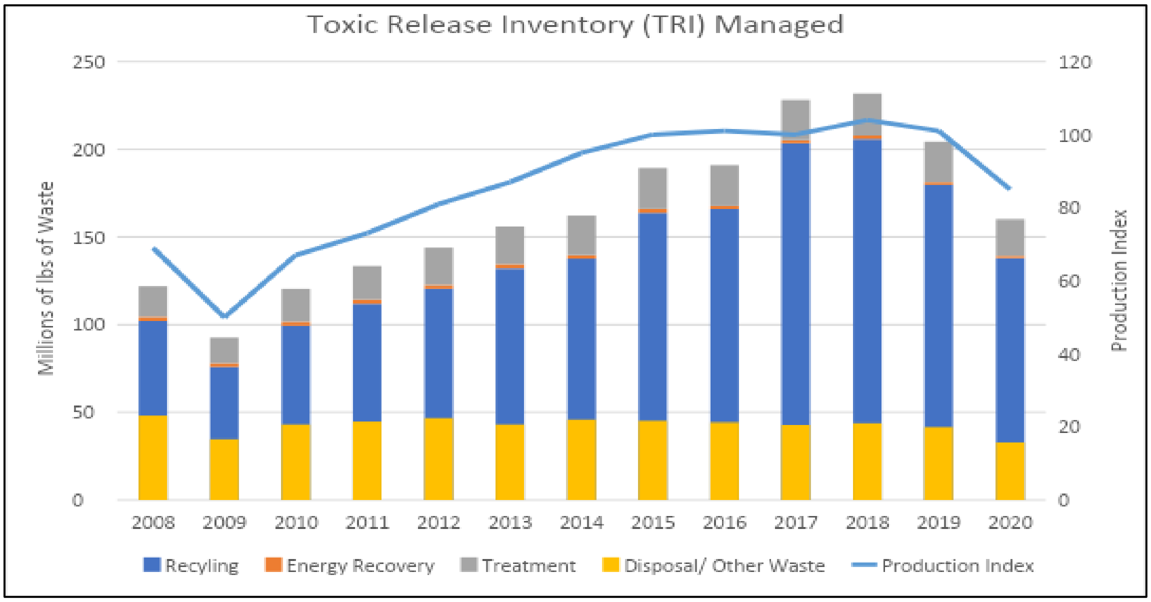

Figure 3: TRI Waste Managed

TRI Waste Managed, 2005-2020: Replicated graph from Toxic Release Inventory (TRI) Managed (Environmental protection Agency – P2 Opportunities, 2021).

The automobile manufacturers have initiated implement source reduction activities to ensure that there are initiatives taken into consideration to achieve environmental improvements. To improve the overall environmental performance of the automobile manufacturing industry, the companies will have to make reductions in the materials that they use, begin to transition to environmentally friendly coating/ painting options, and then apply bio-based materials and recycling throughout the life cycle of the automobile manufacturing process.

However, the Environmental Protection Agency — P2 Opportunities (2021) has a Toxic Release Inventory (TRI) that was released consisted of on-site air releases, on-site water discharge, on-site land disposal, off-site disposal, and other releasing methods. Figure 4 will demonstrate how the Toxic Release Inventory (TRI) that has been released has changed over time. It is important to note that based on the Toxic Release Inventory (TRI) Released there has been a slight decrease in how the toxins are released into the environment when compared to the production index (Environmental Protection Agency — P2 Opportunities, 2021).

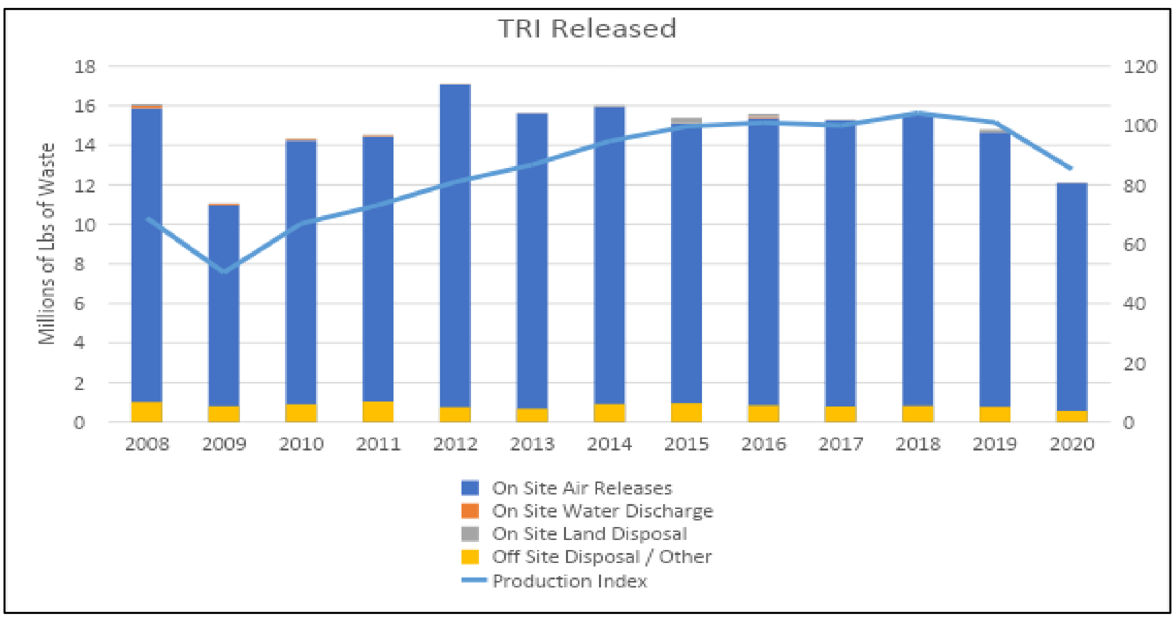

Figure 4: TRI Releases

TRI Releases, 2005-2020: Replicated graph from Toxic Release Inventory (TRI) Released (Environmental Protection Agency – P2 Opportunities, 2021).

The Environmental Protection Agency – Automotive Trends (2021) created a report where they were able to explore the automotive trends data. In the dataset they measure the Real-World Mileage per Gallon (MPG), the Real-World Carbon Dioxide (CO_2), Production Share, Horsepower, Weight, and the Carbon Footprint that automobiles release. Within the dataset, they focused on different automobile sizes; however, it was narrowed down to trucks and cars to have an average among the different sizes of automobiles. Overall, the data revealed that trucks tend to produce more Mileage per Gallons (MPGs), Carbon Dioxide (CO_2) emissions, and they have a larger Carbon Footprint when compared to a car. See below the different tables comparing Mileage per Gallons (MPGs), Carbon Dioxide (CO_2) emissions, and the Carbon Footprint among cars and trucks (Environmental Protection Agency – Automotive Trends, 2021).

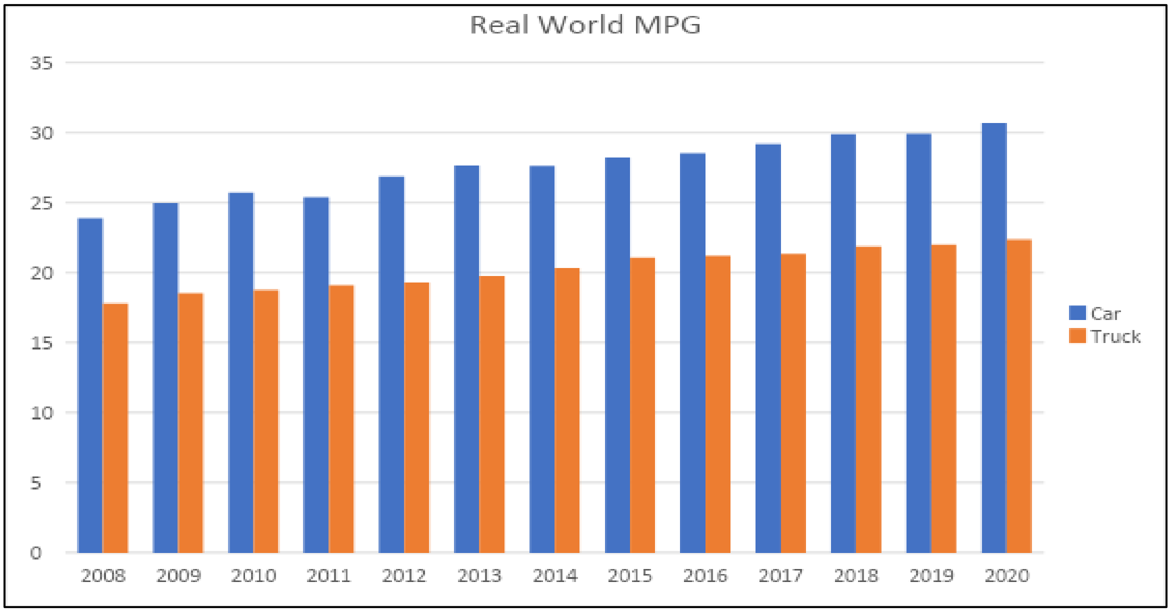

Figure 5: Real World MPG

Estimated Real World Fuel Economy, CO_2 Emissions, and Vehicle Attributes (data set): Created graph based on the data set based on the average Real World Mileage per Gallon (MPG) among Cars and Trucks (Environmental Protection Agency – Automotive Trends, 2021)

The data on the Environmental Protection Agency – Automotive Trends (2021) helped in the creation Figure 5 was able to help show that Cars have a higher Mileage per Gallon (MPG) when they are compared to Trucks. The reason for this would have to be the size alone as a Car tends to be more economically efficient when it is being operated on the road. However, the overall Mileage per Gallon (MPG) among both automobiles has begun to increase steadily. Between

2008 and 2020, there has been an increase of roughly 5 Miles per Gallon (MPG) among both Cars and Trucks (Environmental Protection Agency – Automotive Trends, 2021).

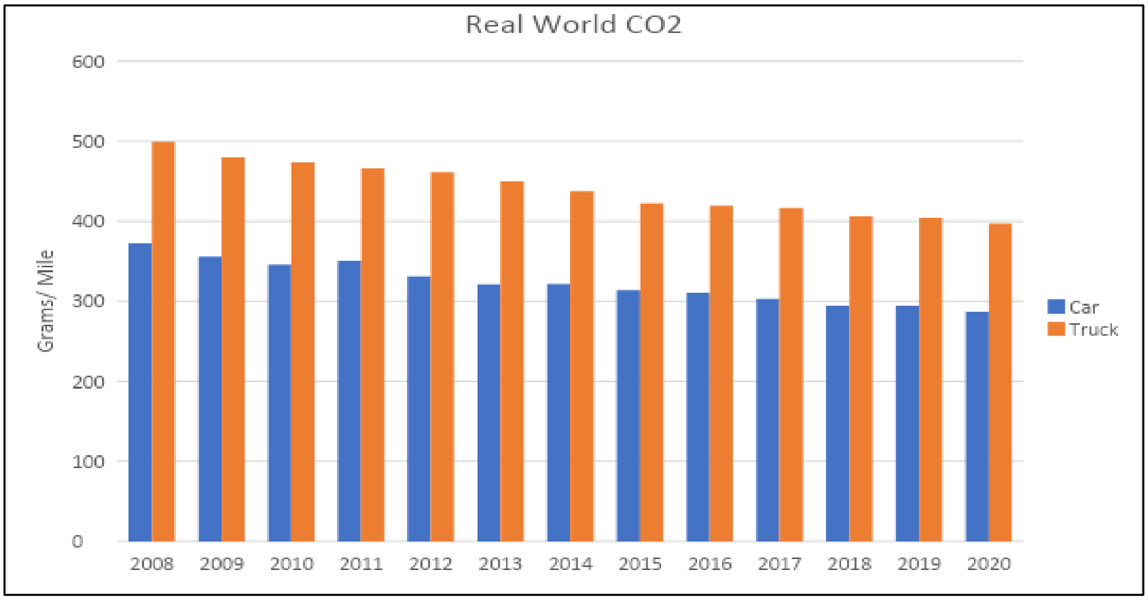

Figure 6: Real World CO_2

Estimated Real World Fuel Economy, CO_2 Emissions, and Vehicle Attributes (data set): Created graph based on the data set based on the Real World grams per mile of Carbon Dioxide (CO_2) released among Cars and Trucks (environment Protection Agency – Automotive Trends, 2021).

Figure 6, also created because of the data on the Environmental Protection Agency – Automotive Trends (2021), demonstrated that Trucks release more grams per mile of Carbon Dioxide (CO_2) compared to a Car. Overall, there has been a steady decrease in the grams per mile of Carbon

Dioxide (CO_2) between 2008 and 2020. During those years, there has been a drop of roughly 100 grams per mile of Carbon Dioxide (CO_2), which shows that automobiles are producing and releasing fewer emissions overall (Environmental Protection Agency – Automotive Trends, 2021).

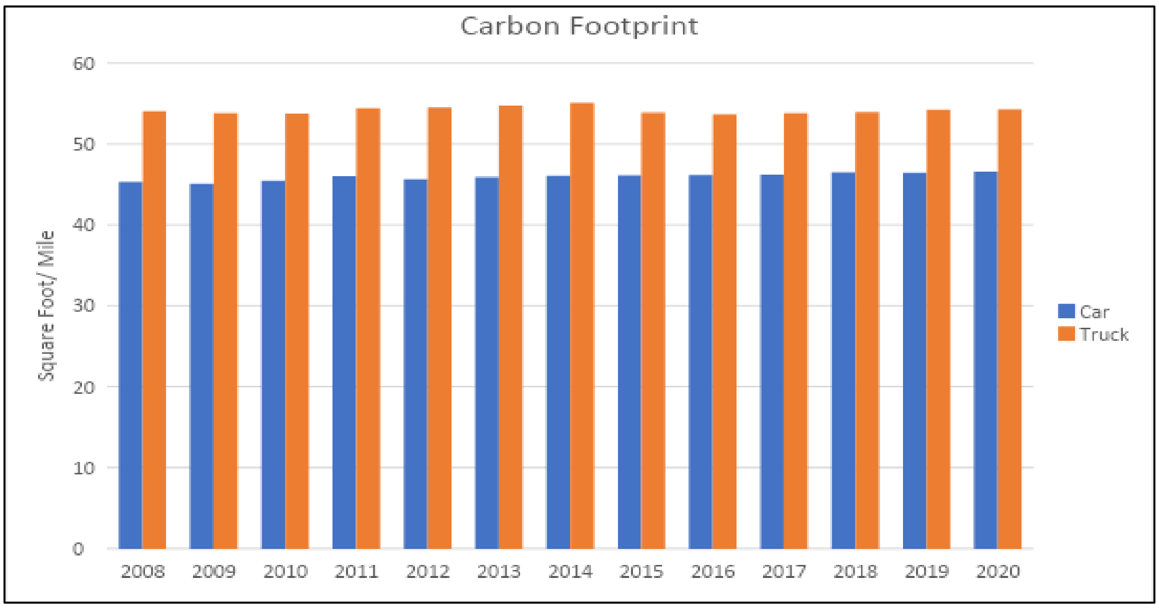

Figure 7: Carbon Footprint

Estimated Real-World Fuel Economy, CO_2 Emissions, and Vehicles Attributes (data set): Created graph based on the data set based on Square Foot per Mile of Carbon Footprint released by Cars and Trucks (Environmental Protection Agency – Automotive Trends, 2021)

The data within the Environmental Protection Agency – Automotive Trends (2021) assisted in creating Figure 7 determined that Trucks release fewer square feet per mile of Carbon Footprint compared to Cars. However, the overall

Carbon Footprint has remained nearly the same between 2008 and 2020. The only difference in the Carbon Footprint was in 2014 when it reached nearly 55 square feet per mile of Carbon Footprint (Environmental Protection Agency – Automotive Trends, 2021).

In efforts to limit the emissions released into the environment, the Center of Disease Control (CDC) (2019) has begun to set recommendations and regulations updated regularly as more emission gas information becomes available. As previously mentioned, Benzene (C_6H_6) was a specific chemical that has begun to cause harmful health effects when an individual is exposed to it. Benzene (C_6H_6) targets some of the health effects: the nervous system and the blood-forming organs. The severity of the harmful health effects depends on the amount of exposure to Benzene (C_6H_6) and the length of time that an individual is exposed (Center of Disease Control (CDC), 2019).

The Center of Disease Control (CDC) (2019) explained that brief exposure, roughly 5 to 10 minutes, to high levels of Benzene (C_6H_6) in the air, measuring between 10,000 to 20,000 parts per million (ppm), can lead to the succumbing of an individual. Exposure to lower levels of Benzene (C_6H_6) in the air, measuring between 700 to 3,000 parts per million (ppm), can cause an individual to feel drowsy, dizzy, and have a rapid heart rate, can cause headaches, tremors, confusion, and unconsciousness. In most cases, an individual will stop feeling these effects when they are no longer exposed and can breathe fresh air. The consumption of food or liquids containing low Benzene levels (C_6H_6) are unknown. However, when an individual consumes food or liquids that contain high levels, they can cause vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid heart rate, coma, and, in severe cases, death. Long-term exposure can also cause cancer of the blood-forming organs, in other words, it can be associated with the development of acute myeloid leukemia (Center of Disease Control (CDC), 2019).

As for the environment, Isaev et al. (2022) explained that air pollution is one of the key environmental problems in heavily populated areas. In Bishkek, specifically, atmospheric pollution has become one of the most significant environmental threats even though they do not have large-scale industrial pollution. Isaev et al. mentioned that Nitrogen Oxides (NO_X), such as Nitrogen Dioxide (NO_2) and Nitrogen Oxide (NO), may lead to oxygen deficiency and directly affect the central nervous system which can result in a decrease in immunity. Nitrogen Oxides (NO_X) are high-temperature combustion of fossil fuels like natural gas, coal, gasoline, and fuel oil. These fossil fuels arise from automobiles, thermal power plants, and industrial plants. Isaev et al. explained that Carbon Monoxide (CO) and Sulfur Dioxide (SO_2) are highly toxic and that they enter the atmosphere when individuals burn solid waste, exhaust gases are released from automobiles, emission release from industrial manufacturers as well as Fossil fuel power stations (Isaev et al., 2022).

CHAPTER FOUR:

EMISSIONS AND VEHICLES

Sullivan et al. (2010) wrote a case study "Energy-Consumption and Carbon-Emission Analysis of Automobiles and Component Manufacturing," which explained that there are two types of generic automobiles. The generic automobiles are summed up to be cars and trucks. Cars and Trucks are an essential part of the economy as they satisfy a broad range of consumer mobility needs and provide value to their owners. Furthermore, the case study mentioned that the objective of the Life-Cycle Assessment (LCA) was to develop an environmental system that also spoke of Life-Cycle Burdens (LCBs) such as energy, Carbon Dioxide (CO_2) emissions, and the products that are used within the automobile's life cycle. For further detail, an automobile's considerable resources (known as the materials and energy) are consumed, and emissions (environmental burdens) are generated during the production process. For Electric Vehicles (EVs), the energy required to make their materials and assembly may offset a major portion of the benefit (Sullivan et al., 2010).

Sullivan et al. (2010) explained that the life cycle of automobiles would consist of the raw material extraction and production, the product manufacture and assembly, the product use, the maintenance, the repair, as well as the automobile's end of life. The Life-Cycle Burdens (LCBs) of automobiles would be part of the manufacturing and vehicle assembly (VMA) stage as it is the largest stage. During the manufacturing and vehicle assembly (VMA) stage, materials are delivered to the factories where numerous parts are assembled into an automobile. See Figure 8 for further reference and detail on the manufacturing and vehicle assembly (VMA) (Sullivan et al., 2010).

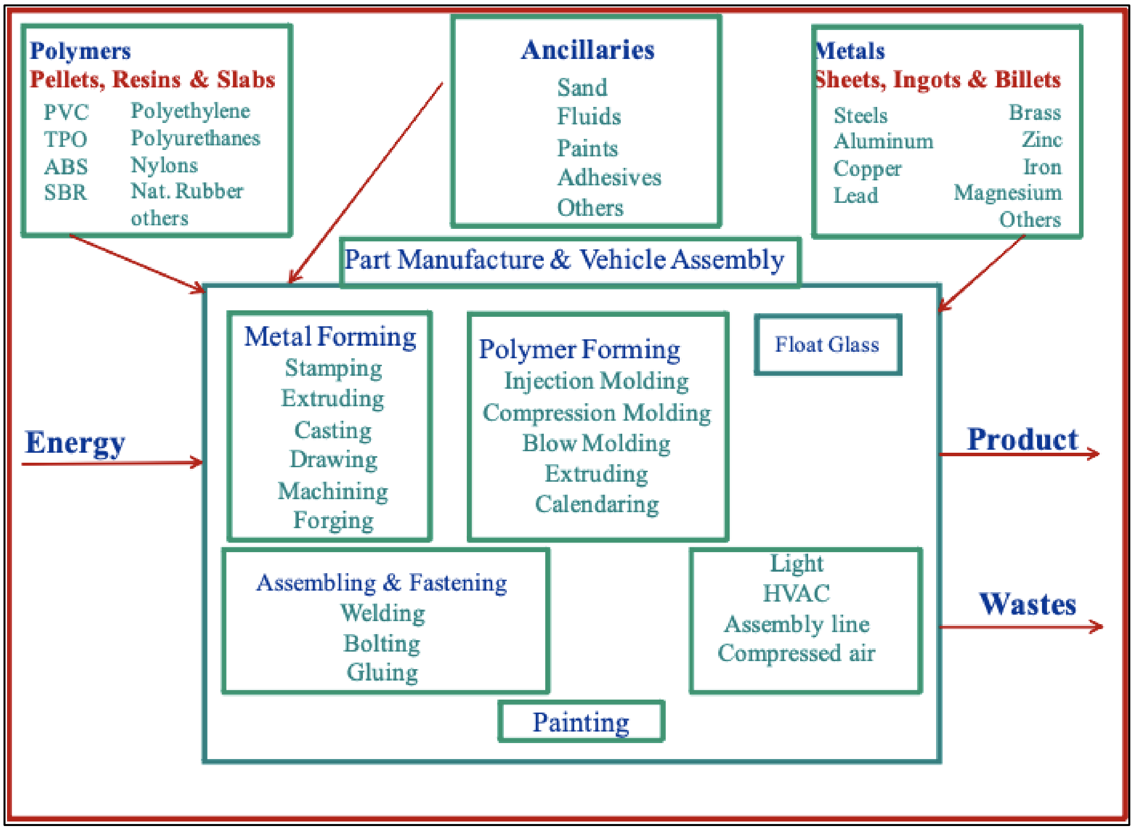

Figure 8: VMA Stage

Activities in the VMA Stage of the Life Cycle: Acquired image to provide the breakdown of the Manufacturing and automobile assembly (VMA) stage (Sullivan et al., 2010).

In addition to the manufacturing and vehicle assembly (VMA), Sullivan et al. (2010) mentioned that the Greenhouse Gasses, Regulated Emissions, and Energy use in Transportation (GREET) model examines material production in correlation with the largest burden in respect to the vehicle life cycle. The assembly burdens of Greenhouse Gasses, Regulated Emissions, and Energy use in Transportation (GREET) are based on the per-vehicle fossil energy and electricity use factors from a survey and data considering many factors such as plant utilization, capacity, and the local climate. See Figure 9 for further reference on the Greenhouse Gasses, Regulated Emissions, and Energy use in Transportation (GREET) model (Sullivan et al., 2010).

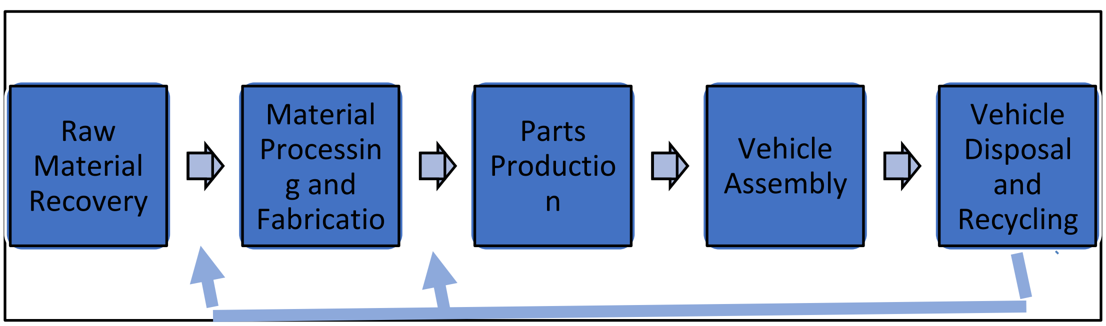

Figure 9: GREET

GREET Vehicle-Cycle Stages: Replicated the table Greenhouses Gasses, Regulated Emissions, and Energy use in Transportation (GREET) (Sullivan et al., 2010).

CHAPTER FIVE:

SUMMARY

The automobile industry as well as the emission gasses that are released from the manufacturing and operating processes of a vehicle were used to review and collect data and information throughout this research project. The emission gasses that are released among automobiles, the manufacturing process of automobiles, the type of automobiles, and the specific fuels that operate automobiles had different concerning factors when it came to determining the effects that it took on the environment as well as the health hazards that individuals are exposed to. Overall, the purpose of the exploration was to essentially answer the following questions:

1. What are the health effects to people who are exposed on emission gasses?
    a. When exposed to Diesel Engine Exhaust (DE) and Diesel Particulate Matter (DPM), there are hazardous health effects which include acute (short-term) exposure-related symptoms, and chronic (long-term) exposure-related noncancer respiratory effects, and lung cancer. Acute effects consist of irritation in the eyes, throat, and bronchial tubes; there are neurophysiological symptoms such as lightheadedness and nausea, and there are also respiratory symptoms such as a cough or phlegm. In addition to these effects, there is evidence of immunologic effects such as worsening allergic

responses and asthma-like symptoms (National Center for Environmental Assessment (NCEA), 2002). The Center of Disease Control (CDC) (2019) explained that brief exposure to high levels of Benzene (C_6H_6) in the air, can lead to the succumbing of an individual. Exposure to lower levels of Benzene (C_6H_6) in the air can cause an individual to feel drowsy, dizzy, have a rapid heart rate, and can cause headaches, tremors, confusion, and unconsciousness. In most cases, an individual will stop feeling these effects when they are no longer exposed and can breathe fresh air. However, the consumption of food or liquids containing low Benzene levels (C_6H_6) is unknown, but consuming high levels can cause vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid heart rate, coma, and, in severe cases, death. Long-term exposure can also cause cancer of the blood-forming organs, more specifically, it can be associated with the development of acute myeloid leukemia (Center of Disease Control (CDC), 2019).

2. What are the environmental effects when emission gasses are released?
   a. Rae (2022) explained that the reason for putting restrictions on the automobile industry was because scientists believed that the emissions from automobiles and their manufacturing processes were releasing Carbon Dioxide (CO_2) into the atmosphere, which

has been trapping additional heat and began to raise the Earth's temperature (Rae, 2022). According to the New York State Department of Environmental Conservation (2022), Automobile pollution contributes to greenhouse gasses and acid rain which can cause climate change. Diesel engines and fuel have airborne hydrocarbons that can form large particles in the atmosphere when they contact airborne dust and other particles. Furthermore, when it is warm and sunny, the hydrocarbons react with oxides of nitrogen which creates a secondary pollutant, ozone. In urban areas, automobiles are the largest contributor to ground-level ozone which is one of the components of smog (New York State Department of Environmental Conservation, 2022).

3. What part of the automobile manufacturing process releases the most and least amount of emission gasses?
    a. Sullivan et al. (2010) demonstrated a chart that captured emission data for different processes of manufacturing processes. The painting process is the highest emission gas pollutant (Sullivan et al., 2010).
4. How will emission gasses affect the environment and people in the future?
    a. Although emissions have had a steady decrease, it is important to know that there are restrictions within the automobile industry because the emissions from automobiles and their manufacturing

processes were releasing carbon dioxide into the atmosphere, which trapped additional heat and began to raise the Earth's temperature (Rae, 2022). Furthermore, Wenzel et al. (2000) mentioned that The Clean Air Act Amendments (CAAA) of 1970 authorized the development of comprehensive federal and state regulations to limit emissions from both industrial sources and automobile sources (Wenzel et al., 2000).

b. As for the health effects, the National Center for Environmental Assessment (NCEA) (2002) and the Center of Disease Control (CDC) (2019) were able to provide the current health effects that are caused by being exposed to emission gasses. It is recommended to limit the amount of time that a person spends around emission gasses and, if available, attempt to get tested when exposed to these emissions. Again, in some cases, the exposure will cause acute symptoms, but in others, the symptoms can be fatal (Center of Disease Control (CDC), 2019).

Recommendation

Based on the research conducted, one can argue that an Electric Vehicle (EV) releases fewer emission gasses when compared to a regular combustion automobile, however, Electric Vehicles (EVs) produce the same amount of emission gasses when the automobile is manufactured. The only difference between the two is that when an Electric Vehicle (EV) battery is manufactured, there are 30 percent more emission gasses released into the environment. Therefore, it would be recommended that it is more economically efficient to purchase an Electric Vehicle (EV) as it would produce less emissions long term. But, if there was a preference in a combustion vehicle, it would be recommended to ensure it took ethanol fuel as it is produced from corn and other plant materials.

It is also important to know the health effects that are caused by automobiles, specifically those that operate on diesel. Diesel automobiles cause individuals hazardous health effects, including acute (short-term) exposure-related symptoms, chronic (long-term) exposure-related noncancer respiratory effects, and cancer. To limit the emission gasses that an individual is exposed to, it is recommended that an individual reduce the amount of time that they spend around those emissions and attempts to get tested when exposed to potentially prepare for any health concerns that may arise. It is also recommended that people limit the amount of time that they use their vehicle as that is one of the many pollutants to the environment.

Conclusion

Based on the information gathered, the data was able to determine that even though there was an increase in trying to manage toxic waste and gasses throughout the automobile manufacturing process and automobiles continue to release the same amount of carbon footprint into the environment. But, overall, the emission gasses released while automobiles are being driven have decreased over time, even when individuals have been driving for longer time frames. To conclude the research, one can determine that the manufacturing process of automobiles will continue to release the same number of emissions but, once the automobile is physically built and, on the road, one can expect that emissions will decrease as there are more precautions along with regulations that are being taken into consideration to ensure that automobiles and automobile manufacturers are limited on the number of emission gasses that they are allowed to release. Due to the decreasing emissions, one can assume that health and environmental concerns will begin to decrease slowly.

REFERENCES

Center of Disease Control (CDC). (2019, January 3). Benzene. Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/sites/toxzine/benzene_toxzine.html

Circuits Today. (2010, January 13). Working of Electric Cars. Electronic Circuits and Diagrams-Electronic Projects and Design. https://www.circuitstoday.com/working-of-electric-cars

Clairotte, M., Suarez-Bertoa, R., Zardini, A. A., Gieschaskiel, B., Pavlovic, J., Valverde, V., Ciuffo, B., & Astorga, C. (2020). Exhaust Emission Factors of Greenhouse Gasses (GHGs) from European Road Vehicles. Environmental Sciences Europe. https://enveurope.springeropen.com/track/pdf/10.1186/s12302-020-00407-5.pdf

Downs, A. (1979). The Automotive Population Explosion. Traffic Quarterly, 33(3), 347-362. https://babel.hathitrust.org/cgi/pt?id=mdp.39015021808749&view=1up&seq=371

Environmental Protection Agency - Automotive Trends. (2021, November 19). Explore the Automotive Trends Data. U.S. Environmental Protection Agency. https://www.epa.gov/automotive-trends/explore-automotive-trends-data#DetailedData

Environmental Protection Agency - Greenhouse Gas. (2021, January 27). Greenhouse gas emissions from a typical passenger vehicle. U.S. Environmental Protection Agency. https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

Environmental Protection Agency — P2 Opportunities. (2021, December 15). Automotive Manufacturing Sector — P2 Opportunities. U.S. Environmental Protection Agency. https://www.epa.gov/toxics-release-inventory-tri-program/automotive-manufacturing-sector-p2-opportunities

Folk, E. (2020, June 3). How High is the Carbon Footprint of Auto Manufacturing? Red, Green, and Blue. https://www.redgreenandblue.org/2020/06/03/high-carbon-footprint-auto-manufacturing/

Forbes. (2016, April 22). The Carbon Footprint Of Tesla Manufacturing. https://www.forbes.com/sites/quora/2016/04/22/the-carbon-footprint-of-tesla-manufacturing/?sh=3adec0836096

Gabriel, P. (2022). Car quotes. Notable Quotes. https://www.notable-quotes.com/c/cars_quotes.html

Isaev, E., Ajikeev, B., Shamyrkanov, U., Kalnur, K., Maisalbek, K., & Sidle, R. C. (2022, January 21). Impact of Climate Change and Air Pollution Forecasting using Machine Learning Techniques in Bishkek. Open Access

Journal - Aerosol and Air Quality Research. https://aaqr.org/articles/aaqr-21-11-covid2-0336

National Center for Environmental Assessment (NCEA). (2002, May). Health Assessment Document for Diesel Engine Exhaust. Environmental Protection Agency. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NCEA&dirEntryId=29060

New York State - Electric Cars. (2022). What Makes Electric Cars Different. New York SERDA. https://www.nyserda.ny.gov/All-Programs/Drive-Clean-Rebate/About-Electric-Cars/Types-of-Cars#:~:text=Conventional%20vehicles%20use%20an%20internal,used%20to%20move%20the%20vehicle

New York State Department of Environmental Conservation. (2022). Controlling Air Pollution from Motor Vehicles. https://www.dec.ny.gov/chemical/8394.html

Qiao, Q., Zhao, F., Liu, Z., Jiang, S., & Hao, H. (2017, June 1). Comparative Study on Life Cycle CO_2 Emissions from the Production of Electric and Conventional Vehicles in China. Science Direct. https://www.sciencedirect.com/science/article/pii/S1876610217309049

Rae, J. B. (2022). The Modern Industry. Encyclopedia Britannica. https://www.britannica.com/technology/automotive-industry/The-modern-industry

Roser, M., Ritchie, H., & Ortiz-Ospina, E. (2019, May). World Population Growth. Our World in Data. https://www.ourworldindata.org/world-population-growth

Silverman, D. T. (2017, January 9). Diesel Exhaust Causes Lung Cancer – Now What? PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5352477/

Smith, M. N. (2016, April 22). The Number of Cars Worldwide is Set to Double by 2040. World Economic Forum. https://www.weforum.org/agenda/2016/04/the-number-of-cars-worldwide-is-set-to-double-by-2040

Sullivan, J. L., Burnham, A., & Wang, M. (2010, October 12). Energy-Consumption and Carbon-Emission Analysis of Vehicle and Component Manufacturing. Information and Publishing Division. https://publications.anl.gov/anlpubs/2010/10/68288.pdf

U.S. Department of Energy. (2022). Alternative fuels data center: Alternative fuels and advanced vehicles. EERE: Alternative Fuels Data Center. https://afdc.energy.gov/fuels/

Wenzel, T. P., Singer, B. C., & Slott, R. R. (2000, September). Some Issues in the Statistical Analysis of Vehicle Emissions. Energy Technologies Area | Energy Technology Area. https://eta.lbl.gov/publications/some-issues-statistical-analysis

Zhang, Z., & Batterman, B. (2014, April 15). Air Pollution and Health Risks due to Vehicle Traffic. PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4243514/