The Dangerous Side Effects of the Internal Combustion Engine

Introduction

The primary idea of an internal combustion engine is to ignite a high-energy fuel with air in a small compressed space such that following combustion, the expanding gas can do a large amount of work. By harnessing that energy, we can power cars and trucks for our everyday conveniences. However, rarely does something good comes for free. Cars and other transportation vehicles produce 6500 million tons of carbon dioxide a year, slightly over twenty percent of the world's carbon dioxide emissions. Emissions from burning fossil fuels have a significant negative impact on our environment.

Figures 1 and 2 show that transportation accounts for a significant fraction of the world's production of CO2 (23%), and that most transportation emissions come from driving on the road. Therefore, if we find a way to reduce the CO2 footprint of our cars, we would also greatly reduce the world's production of CO2.

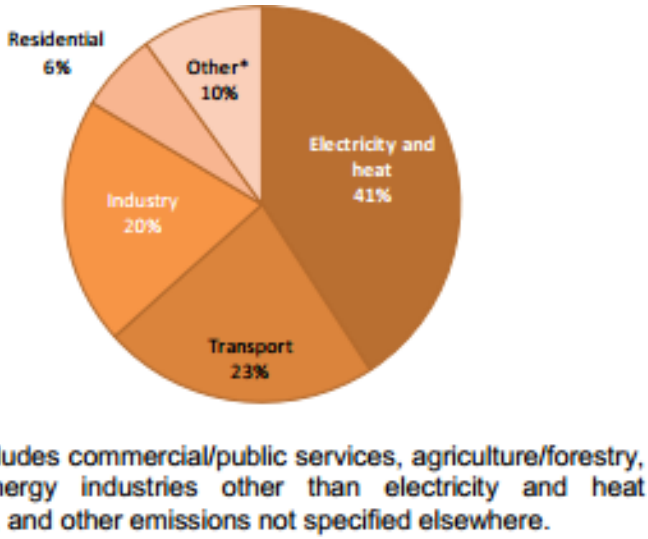

Figure 1: Sources of CO_2 emissions in 2009

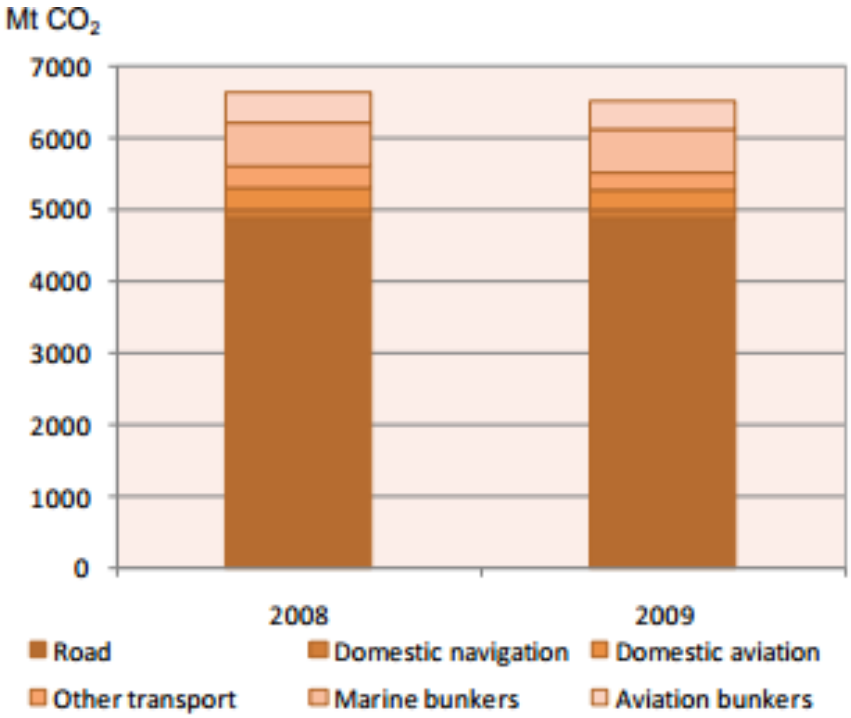

Figure 2: Transportation CO_2 emission breakdown

Key Point: CO_2 emissions from roads make up the vast majority of emissions from transport

Effect on Global Warming

Global warming is a major environmental issue. Carbon dioxide is the primary contributor to global warming because it puts the earth in a “greenhouse”. The rays of the sun enter the atmosphere at a wavelength less than four thousand nanometers (also known as ultra-violet rays). Carbon dioxide is unable to absorb light energy at this wavelength. However, when heat is radiated from the earth, it is released at wavelengths longer than four thousand meters, a wavelength where carbon dioxide is able to absorb. Most of this energy is radiated back into the atmosphere, reducing heat transfer from the earth. Many years of data have shown that the concentration of carbon dioxide in the atmosphere and the average temperature of the earth are

directly related. Although the amount of carbon dioxide added into the atmosphere may not cause severe temperature changes, an average temperature increase of two to three degrees Centigrade could cause the polar ice caps to melt. This would cause the ocean level to rise several inches, resulting in widespread floods and heat waves. This would reduce of the amount

of land people can live on, leading to widespread migration.

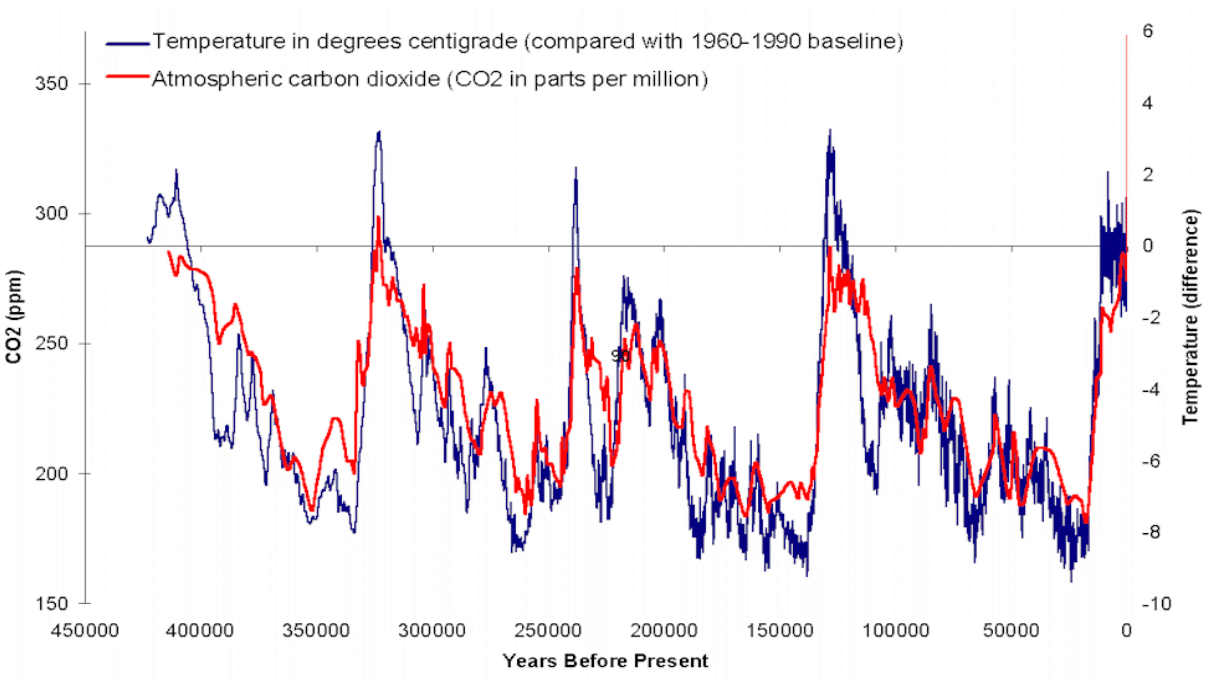

Figure 3: The correlation between CO_2 in our atmosphere and the tempterature throughout the ages

Figure 3 demonstrates the strong correlation between the amount of carbon dioxide in our atmosphere and the change in average temperature. Although the cause of these climate patterns is uncertain, adding more carbon dioxide into the atmosphere beyond the earth's natural rate may cause our environment to take a turn for the worse.

During the last hundred years, we have dumped thousands of tons of carbon dioxide into the atmosphere. However, not all of that carbon dioxide remains in the atmosphere. A large fraction of the gas dissolves into the oceans. The earth has a large carbon buffer system and goes through a carbon cycle to distribute carbon between the oceans, the earth's crust, and the

atmosphere. Carbon dioxide in the atmosphere is absorbed by the ocean through the following equilibrium reactions that acidifies the ocean:

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \qquad (1)$$

$$H_2CO_3 \Rightarrow H^+ + HCO_3^- \qquad (2)$$

$$HCO_3 \Rightarrow H^+ + CO_3^{-2} \qquad (3)$$

The slightly acidic ocean decays rocks, causing them to release ions such as calcium. These ions react with the carbonates to form solid limestone at the bottom of the ocean. The earth's tectonic plates move, causing the limestone to go through metamorphism* as temperature and pressure changes when the plates are pushed towards the earth's core, releasing carbon dioxide back into the atmosphere. Plants then absorb the carbon dioxide in the air and ground the carbon back into the rocks. This very delicate equilibrium cycle may be at risk as carbon dioxide output from man-made sources increases due to an exponential rise in population and a higher standard of living. There is a limit to the amount of carbon dioxide the ocean can absorb; when the ocean reaches that limit, we will feel the full impact of burning fossil fuels. The concentration of carbon dioxide will increase in the atmosphere, resulting in warmer temperatures and severe climate changes.

Figure 4 demonstrates how carbon dioxide in our atmosphere would create carbonic acid in the oceans to weather rocks.

* Metamorphism is the reformation of rocks due to changes in heat and pressure.

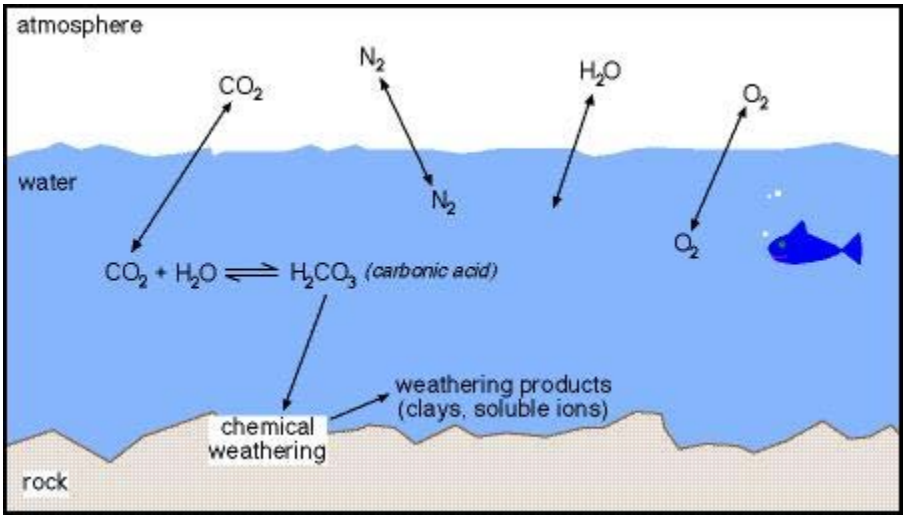

Figure 4: Carbonic acid is produced in the ocean via weathering of rocks

Figure 5 demonstrates how carbon may be cycled between the atmosphere and the ground.

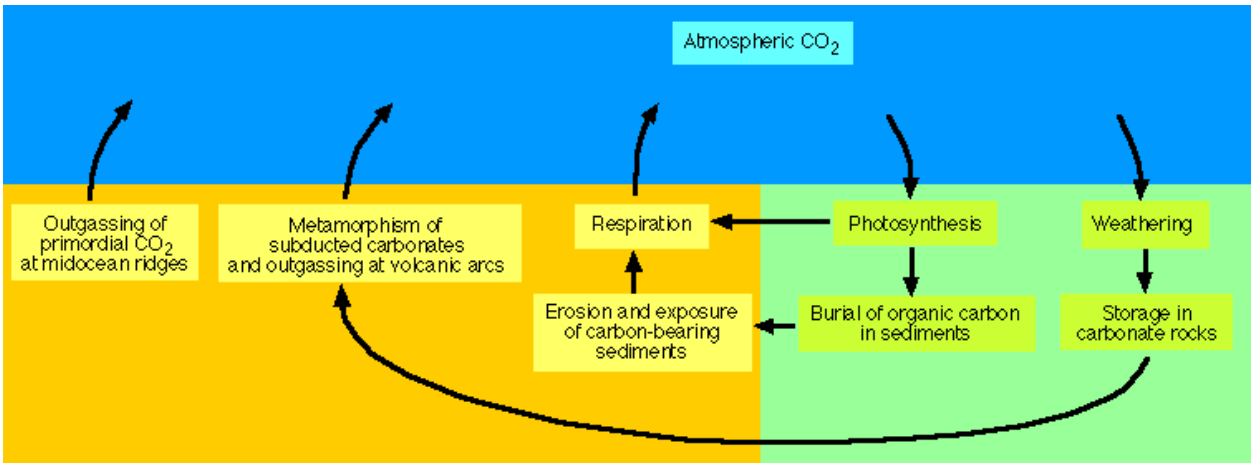

Figure 5: Summary of carbon cycle in our atmosphere

Air Pollution

When we look at aerial photographs of major urban cities such as Los Angeles or Hong Kong, we see that the city's air seems to be permeated by an unsightly haze. The internal

combustion engine contributes largely to this haze because combustion produces unwanted byproducts in addition to carbon dioxide and water. Some of these byproducts participate in chemical reactions in the atmosphere that yield chemicals hazardous to our health.

An ideal internal combustion engine burns its fuel without any side products:

$$\text{Fuel (hydrocarbon)} + O_2 + N_2 \Rightarrow H_2O + CO_2 + N_2 \qquad (4)$$

In a real (as opposed to an ideal) engine, the reaction that we see is:

$$\text{Fuel (hydrocarbon)} + O_2 + N_2 \Rightarrow H_2O + CO_2 + N_2 + CO + NO + \text{unburned fuel} \qquad (5)$$

The partially burned fuel produces a variety of partially oxidized hydrocarbons including formaldehyde, acetaldehyde, 1,3 butadine, acrolein, and benzene. Some of these unwanted side products lead to urban air pollution. Nitrous oxide (NO), a key component of smog, is responsible for much of the brown haze we see over cities such as Los Angeles.

Almost all of the hydrocarbon derivatives that are emitted from combustion are carcinogenic; some of them photochemically react in the atmosphere to produce a variety of other harmful products. Some of the hydrocarbon derivatives react with nitrous oxide in sunlight to form ozone. Inhaling ozone irritates the throat and the respiratory system. Formaldehyde is the most common aldehyde formed through incomplete combustion. Exposure to it leads to irritation of the eyes, nose, and respiratory tract; they can cause tumors and cancer in the nasal cavity. Acetaldehyde is another byproduct that similarly irritates the eyes, skin, and respiratory tract and causes tumors in nasal cavities.1,3-butadine, a human carcinogen, produced in traffic emissions, causes irritation of the skin and respiratory tract as well as blurred vision, fatigue, and headaches. It also reacts in the atmosphere to form formaldehyde and a highly toxic and corrosive substance

called acrolein. This chemical causes moderate to severe irritation of the respiratory system and could cause severe lung injury such as pulmonary edema. Chronic exposure to low levels of acrolein can cause inflammation in the lungs, liver, kidneys, and the brain. Benzene is another human carcinogen formed through the internal combustion engine that causes drowsiness and headache and could also cause blood disorders through bone-marrow depletion, reducing the number of white blood cells in the body. Carbon monoxide is potentially fatal because it limits oxygen flow in the blood stream, harming those with heart problems.

There have been advances on reducing these harmful emissions. Engineers have identified combustion conditions where formation of undesirable byproducts can be reduced. In the exhaust pipe, the three-way catalytic converter helps to burn all hydrocarbons completely to water and carbon dioxide. The first part of this converter uses a reduction catalyst with platinum and rhodium to reduce nitrogen monoxide and nitrogen dioxide emissions.

$$2NO \Rightarrow N_2 + O_2 \qquad (6)$$

$$2NO_2 \Rightarrow N_2 + 2O_2 \qquad (7)$$

The next stage of the converter reduces carbon monoxide emissions through an oxidation process using a platinum and palladium catalyst.

$$2CO + O_2 \Rightarrow 2CO_2 \qquad (8)$$

The final stage of the converter monitors the amount of oxygen in the exhaust to control the fuel-to-air ratio that enters the internal combustion engine. This allows the engine to work as efficiently as possible and ensures that there is enough oxygen for the oxidation catalyst to operate properly.

However, because every year there are more cars on the roads, we have more exhaust in the air. As of 2010, there are slightly over a billion cars in the world, a quarter of them in the U.S. The projected amount of cars in 2050 is 2.5 billion, requiring 140 barrels of oil a day. Therefore, we must continue to make advances to ensure that our air is safe to breathe.

Conclusion

Although we are slowly ruining our planet with our lifestyle, most people are unwilling to give up the comforts of modern technology to maintain the earth for healthy living. Much of the damage is due to combustion of fossil fuels in power plants and cars and trucks. Therefore, it is imperative that we look towards alternate energy sources that are friendlier to the environment. Wind, solar, and nuclear power are all viable sources for future energy. For example, a step toward reducing use of fossil fuels is provided by the U.C. Berkeley campus busses that have replaced diesel oil with hydrogen fuel cells. We also see the increasing production of hybrid cars that rely in part, on the use of electricity from a battery to power the vehicle. Although these methods increase the efficiency of our engines, they nevertheless have a carbon footprint because a fossil fuel (natural gas or coal) is used to produce hydrogen and electricity. However, science and engineering may provide the tools to solve these problems towards a better future

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