"十三五"普通高等教育本科规划教材
高等院校汽车专业"互联网+"创新规划教材

（双语教学版）

汽车新能源与排放控制

New Energy and Emission Control for Automobiles

周庆辉　编著

北京大学出版社
PEKING UNIVERSITY PRESS

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内 容 提 要

本书根据近年来多种英语公开资料编写形成，共分 8 章，从汽车排放控制的角度出发，首先分析排放污染物的生成机理，由浅入深、循序渐进地介绍汽车新能源技术，探讨汽车排放控制的问题，此外还扼要阐述国内外汽车排放标准的发展。第 1 章介绍汽车排放与环境的关系；第 2 章分析汽车排放污染物及其生成机理；第 3 章、第 4 章和第 5 章分别介绍了电动汽车、混合动力汽车和低排放燃料汽车；第 6 章和第 7 章分别详细分析了汽油机和柴油机排放控制技术；第 8 章简明扼要地分析了国内外汽车排放管理状况，包括排放标准的发展过程。

本书可作为高等院校车辆工程、能源与动力工程、汽车服务工程、环境工程等专业应用型本科学生的双语教学教材，也可以作为其他相关专业工程技术人员和管理人员的培训教材。

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前　　言

随着汽车保有量持续增长，石油燃料大量消耗，排放污染物总量持续攀升，尤其在一些大中城市汽车排放造成的环境污染问题日趋严重。发展新能源汽车，推动产业升级，有利于保护和改善环境。为了加强汽车新能源与排放控制技术的国际化交流，需要学习大量的英文技术资料。本书综合了国内外最新相关资料和相关研究成果，系统地介绍和讨论了汽车新能源与排放控制相关的新知识、新技术和新内容，并且配合双语教学，使学生掌握一定数量的专业词汇，提高英语的应用能力。

本书共分 8 章：第 1 章介绍汽车排放与环境的关系；第 2 章分析汽车排放污染物及其生成机理；第 3 章、第 4 章和第 5 章分别介绍了电动汽车、混合动力汽车和低排放燃料汽车；第 6 章和第 7 章分别详细分析了汽油机和柴油机排放控制技术；第 8 章简明扼要地分析了国内外汽车排放管理状况，包括标准的发展过程。

本书的特色和价值：

（1）内容先进。新能源汽车不断发展，汽车排放标准不断严格。新标准也带来了技术上的革新。本书从内容上结合国内外最新相关资料，介绍新能源和排放控制技术。

（2）选材新颖。选材参考了欧盟、美国、日本等国家和地区的最新排放法规和排放标准，世界著名汽车公司的相关技术资料和研究成果。

（3）语言通俗。语言简练，通俗易懂，适合于本科学生和相关专业工程技术人员。

（4）结构合理。

（5）教学适用。

本书由北京建筑大学周庆辉统筹并编写。在编写的过程中，得到了中国农业大学纪威教授，北京建筑大学杨建伟教授、孙建民教授、朱爱华副教授及陈展、陆斯媛硕士研究生等的帮助，并得到了北京大学出版社的大力支持，在此表示感谢。

由于编者水平有限，疏漏在所难免，敬请广大读者给予批评指正。

编　者

2016 年 4 月

【精彩汇总】

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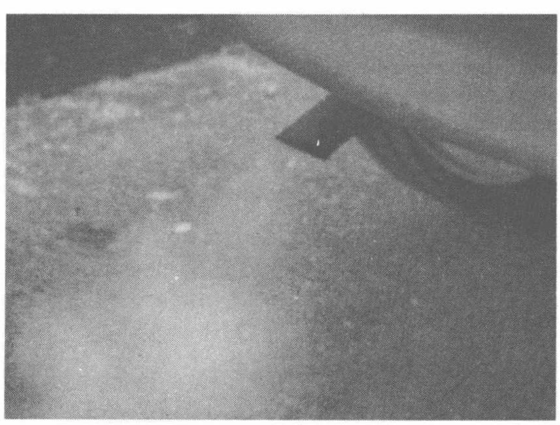
Chapter 1

Introduction

Example

You see it every time that smoke billows from your car's exhaust pipe in the Figure 1.1, so there's no denying that vehicles are major contributors to air pollution. Air pollution refers to the presence of other substances in the air that don't belong there, or excessive amounts of certain impurities that wouldn't harm us otherwise. When cars burn gasoline, certain chemicals are released into the air. Gasoline fumes escape into the air even when we pump gasoline into the fuel tanks.

Air pollution is the introduction of particulates, biological molecules, or other harmful materials into Earth's atmosphere, causing diseases, allergies, death to humans, damage to other living organisms such as animals and food crops, or the natural or built environment.



【参考视频】

Figure 1.1 Exhaust from Tailpipe

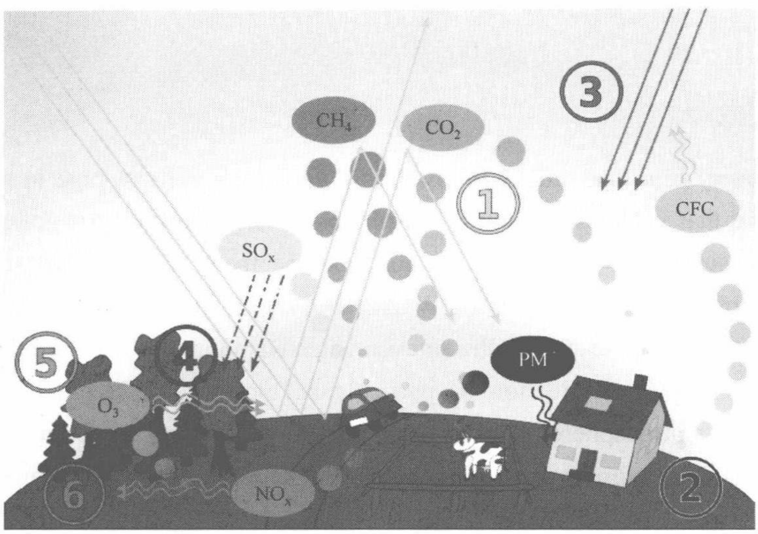
Question: How many major pollutants come from cars?

1.1 Air Pollution and Vehicles

1.1.1 Air Pollution

Air pollution is the introduction of particulates, biological molecules, or other harmful materials into Earth's atmosphere, causing diseases, death to humans, and damage to other living organisms such as animals and food crops, or the natural or built environment. Air pollution may come from anthropogenic or natural sources.

The atmosphere is a complex natural gaseous system that is essential to support life on planet Earth, as shown in Figure 1.2. Stratospheric ozone depletion due to air pollution has been recognized as a threat to human health as well as to the Earth's ecosystems.



【参考视频】

Figure 1.2 Schematic drawing, causes and effects of air pollution: (1) greenhouse effect, (2) particulate contamination, (3) increased UV radiation, (4) acid rain, (5) increased ground level ozone concentration, (6) increased levels of nitrogen oxides.

1.1.2 Sources

There are various sources that are responsible for releasing pollutants into the atmosphere, which can be classified into two major categories.

1.1.2.1 Anthropogenic sources

These sources are mostly related to the burning of multiple types of fuel.

✧ Stationary sources include smoke stacks of power plants, manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices. In some developing and poor countries, traditional biomass burning is the major source of air pollutants; traditional biomass includes wood, crop waste and dung.

- Mobile sources include motor vehicles, marine vessels, and aircraft.

1.1.2.2 Natural sources

- Dust from natural sources, usually large areas of land with little or no vegetation
- Smoke and carbon monoxide from wildfires

Emissions from cars increase the levels of carbon dioxide and other greenhouse gases in the atmosphere. At normal levels, greenhouse gases keep some of the sun's heat in the atmosphere and help warm Earth. That said, many scientists believe that burning fossil fuels such as gasoline causes greenhouse gas levels to spike, leading to global warming.

Scientists use sophisticated instruments to measure concentrations of harmful substances in the air, but it's tough to say exactly what percentage of air pollution comes from cars. This makes sense, because many other human activities contribute to air pollution as well. In fact, the production of electricity by coal-fired power plants and other sources can cause more pollution than most cars. If that wasn't enough, we pollute the air when we heat our homes and public buildings with fuels other than electricity — just as we do when we drive our cars. Even people who don't drive add to pollution when they buy goods and services that involve fuel when they're made or delivered.

In 2013, transportation contributed more than half of the carbon monoxide and nitrogen oxides, and almost a quarter of the hydrocarbons emitted into our air. Cars and trucks produce air pollution throughout their life, including pollution emitted during vehicle operation, refueling, manufacturing, and disposal. Additional emissions are associated with the refining and distribution of vehicle fuel.

Pollutants from cars contribute to various types of air pollution. When hydrocarbons and NO_x combine in sunlight, they produce ozone. High in the atmosphere, ozone protects us from the sun's ultraviolet rays. When holes in the atmosphere's ozone layer allow ozone to come closer to Earth, it contributes to smog and causes respiratory problems.

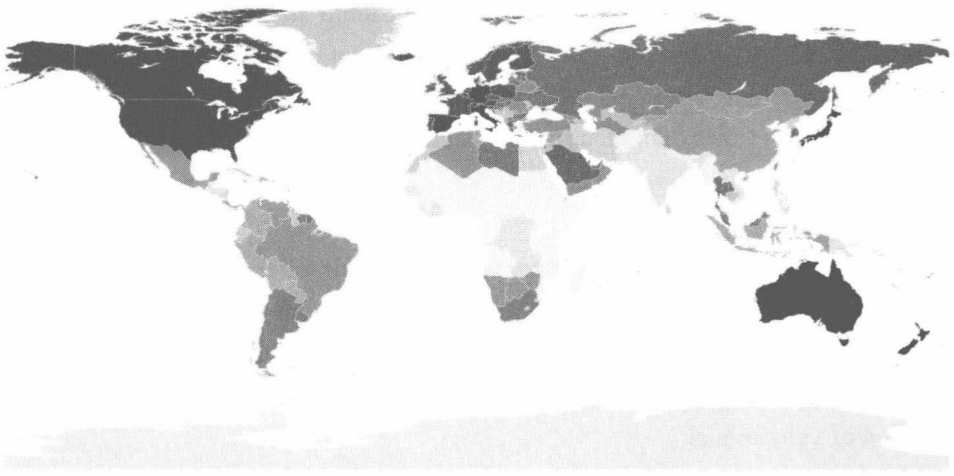
Air pollutants emitted from cars are believed to cause cancer and contribute to such problems as asthma, heart disease, birth defects and eye irritation.

1.2 Environmental Impact

While there are different types of fuel that may power cars, most rely on gasoline or diesel. The United States Environmental Protection Agency(EPA)states that the average vehicle emits 8,887 grams of carbon dioxide per gallon of gasoline. The average vehicle running on diesel fuel will emit 10,180 grams of carbon dioxide. Many governments are using fiscal policies (such as road tax or the US gas guzzler tax) to influence vehicle purchase decisions, with a low CO_2 figure often resulting in reduced taxation. Fuel taxes may act as an incentive for the production of more efficient, hence less polluting, car designs (e.g. hybrid vehicles) and the development of alternative fuels. High fuel taxes may provide a strong incentive for consumers to purchase lighter, smaller, more fuel-efficient cars, or to not drive. On average, today's automobiles are about 75 percent recyclable, and using recycled steel helps reduce energy use and pollution.

The manufacture of vehicles is resource intensive, and many manufacturers now report on the environmental performance of their factories, including energy usage, waste and water consumption.

The growth in popularity of the car allowed cities to sprawl, therefore encouraging more travel by car resulting in inactivity and obesity, which in turn can lead to increased risk of a variety of diseases.World map of passenger cars per 1,000 people as shown in Figure 1.3.



【参考图文】

Figure 1.3 Worold map of passenger cars per 1,000 people

Transportation (of all types including trucks, buses and cars) is a major contributor to air pollution in most industrialised nations. According to the American Surface Transportation Policy Project nearly half of all Americans are breathing unhealthy air. Their study showed air quality in dozens of metropolitan areas has worsened over the last decade.

Similarly, China's environmental protection ministry published a report in November 2010 which showed that about a third of 113 cities surveyed failed to meet national air standards last year. According to the World Bank, 16 of the world's 20 cities with the worst air are in China. According to Chinese government sources, about a fifth of urban Chinese breath heavily polluted air. Many places smell like high-sulfur coal and leaded gasoline. Only a third of the 340 Chinese cities that are monitored meet China's own pollution standards. It is the pollution in Beijing in 2013, as shown in the Figure 1.4.

【参考视频】

Figure 1.4 Pollution in Beijing in 2013

Animals and plants are often negatively impacted by cars via habitat destruction and pollution. Over the lifetime of the average car the "loss of habitat potential" may be over 50,000 square meters based on primary production correlations. Animals are also killed every year on roads by cars, referred to as roadkill. More recent road developments are including significant environmental mitigation in their designs such as green bridges to allow wildlife crossings, and creating wildlife corridors.

Growth in the popularity of vehicles and commuting has led to traffic congestion. Brussels was considered Europe's most congested city in 2011.

1.3 Types of Emissions

Air pollution caused by cars and trucks is split into primary and secondary pollution. Primary pollution is emitted directly into the atmosphere; secondary pollution results from chemical reactions between pollutants in the atmosphere. The following are the major pollutants released from motor vehicles:

1.3.1 Nitrogen Oxides (NO_x)

Nitrogen oxides (NO_x) refers to Nitric oxide(NO) and Nitrogen dioxide(NO_2). They are produced during combustion, especially at high temperature. These two chemicals are important trace species in Earth's atmosphere. Nitrogen oxides (NO_x) react with ammonia, moisture, and other compounds to form nitric acid vapor and related particles. Small particles can penetrate deeply into sensitive lung tissue and damage it, causing premature death in extreme cases. Inhalation of such particles may cause or worsen respiratory diseases such as emphysema and bronchitis. It may also aggravate existing heart disease. In a 2005 U.S. EPA study the largest emissions of NO_x came from on road motor vehicles, with the second largest contributor being non-road equipment which is mostly gasoline and diesel stations. The resulting nitric acid may be washed into soil, where it becomes nitrate, which is useful to growing plants. Smog in New York City as viewed from the World Trade Center in 1988 is shown in Figure 1.5.

【参考图文】

Figure 1.5　Smog in New York City as viewed from the World Trade Center in 1988

Using new, high-resolution global satellite maps of air quality indicators, NASA scientists tracked air pollution trends over the last decade in various regions and 195 cities around the globe. The United States, Europe and Japan have improved air quality thanks to emission control regulations, while China, India and the Middle East, with their fast-growing economies and expanding industry, have seen more air pollution in Figure 1.6.

【参考视频】

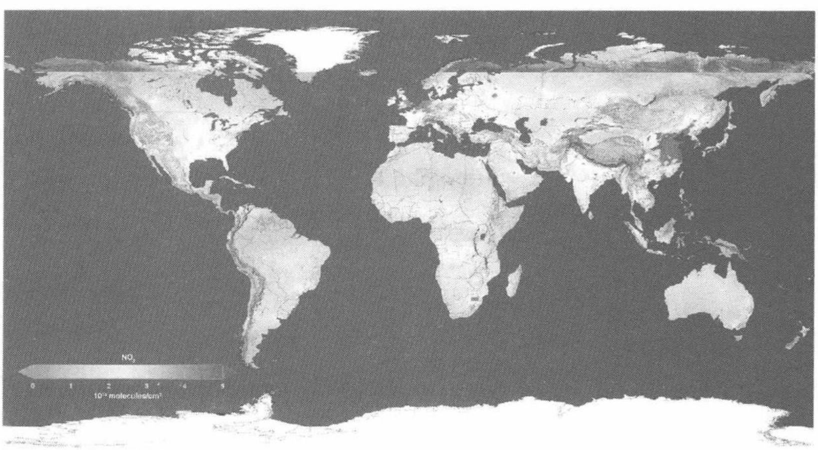


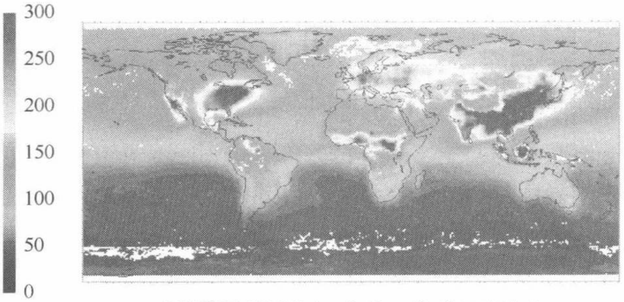
Figure 1.6　Nitrogen dioxide 2014—global air quality levels (released 14 December 2015)

1.3.2　Hydrocarbons (HC)

Hydrocarbons are a class of burned or partially burned fuel. These pollutants are a major contributor to smog, which can be a major problem in urban areas. Hydrocarbons can react with nitrogen oxides in the presence of sunlight to form ground level ozone, a primary ingredient in smog. Though beneficial in the upper atmosphere, at the ground level the gas irritates the respiratory system, causing coughing, choking, and reduced lung capacity.

1.3.3 Carbon Monoxide (CO)

Carbon monoxide poisoning is the most common type of fatal air poisoning in many countries. Carbon monoxide is colorless, odorless and tasteless, but highly toxic. It combines with hemoglobin to produce carboxyhemoglobin, which is ineffective for delivering oxygen to bodily tissues. In 2011, 52% of carbon monoxide emissions were created by mobile vehicles in the U.S. Satellite computer image of carbon monoxide March 2010 is shown in Figure 1.7.



【参考视频】

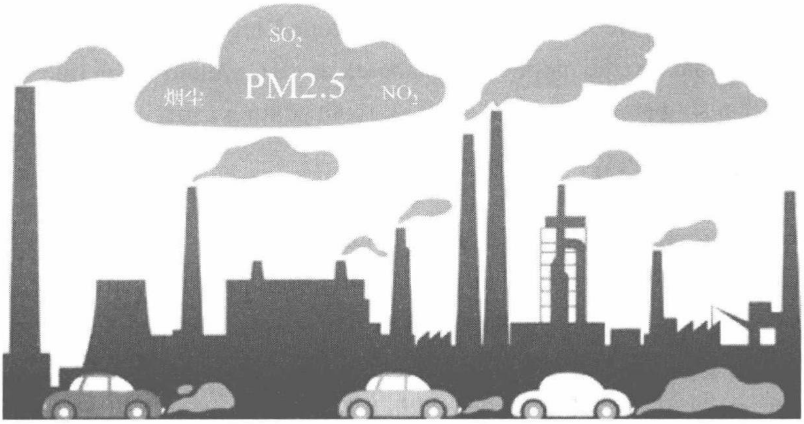
Figure 1.7 Satellite computer image of carbon monoxide March 2010

Carbon monoxide inhibits the ability of the blood to carry oxygen, and in particular dangerous to smokers and people with heart disease. It can also cause permanent damage to the nervous system.

1.3.4 Particulate Matter (PM)

The health effects of inhaling airborne particulate matter have been widely studied in humans and animals, which include asthma, lung cancer, cardiovascular issues, and premature death. Because of the size of the particles, they can penetrate the deepest part of the lungs. A 2011 UK study estimates 90 deaths per year due to passenger vehicle PM. In a 2006 publication, the U.S. Federal Highway Administration (FHWA) states that in 2002 about 1 percent of all PM10 and 2 percent of all PM2.5(as shown in Figure 1.8) emissions came from the exhaust of on-road motor vehicles (mostly from diesel engines).

Particulate matter (PM) causes lung problems including shortage of breath, cardiovascular disease, damaging lung tissue and cancer. Ultra-fine PM makes its way past the upper airway and penetrates the deepest tissue of the lungs and thence to the blood stream. At concentrations above 5 micrograms per cubic metre particulate matter presents a significant cancer risk. Many PMs are recognized as toxicants and carcinogens, as well as hazards to the reproductive and endocrine systems.



【参考视频】

Figure 1.8　PM2.5

1.3.5　Volatile Organic Compounds

Volatile organic compounds (VOCs) are organic chemicals that have a high vapor pressure at ordinary room temperature. Their high vapor pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air, a trait known as volatility. For example, formaldehyde, which evaporates from paint, has a boiling point of only –19 °C (–2 °F).

VOCs are numerous, varied, and ubiquitous. They include both human-made and naturally occurring chemical compounds. Most scents or odors are of VOCs. VOCs play an important role in communication between plants, and messages from plants to animals. Some VOCs are dangerous to human health or cause harm to the environment. Anthropogenic VOCs are regulated by law, especially indoors, where concentrations are the highest. Harmful VOCs typically are not acutely toxic, but have compounding long-term health effects. Because the concentrations are usually low and the symptoms slow to develop, research into VOCs and their effects is difficult.

When nitrogen oxides (NO_x) and volatile organic compounds (VOCs) react in the presence of sunlight, ground level ozone is formed, a primary ingredient in smog. A 2005 U.S. EPA report gives road vehicles as the second largest source of VOCs in the U.S. at 26% and 19% are from non-road equipment which is mostly gasoline and diesel stations. 27% of VOC emissions are from solvents which are used in the manufacturer of paints and paint thinners and other uses. Non-road equipment is mostly gasoline and diesel stations shown in Figure 1.9.

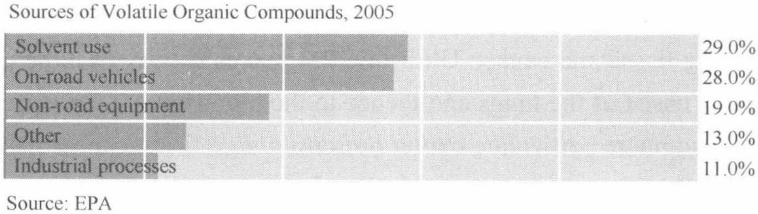
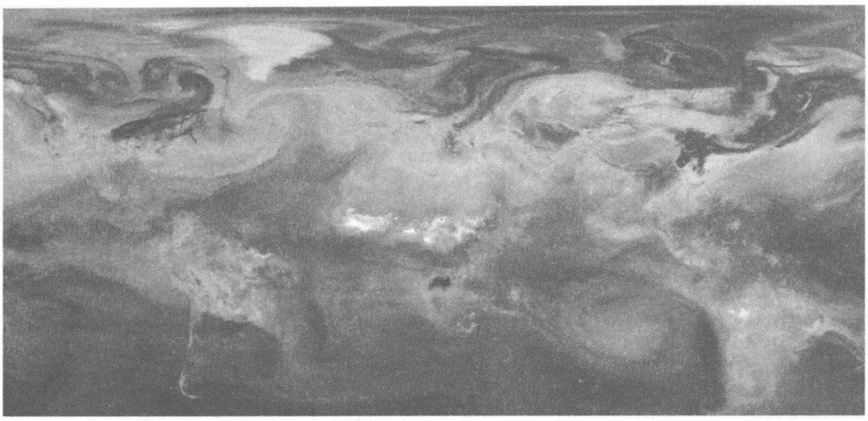


Figure 1.9　Non-road equipment is mostly gasoline and diesel station

1.3.6 Carbon Dioxide (CO_2)

NASA is advancing new tools like the supercomputer model that created this simulation of carbon dioxide in the atmosphere to better understand what will happen to Earth's climate if the land and ocean can no longer absorb nearly half of all climate-warming CO_2 emissions (See Figure 1.10). NASA scientists report that human-made carbon dioxide (CO_2) continues to increase above levels not seen in hundreds of thousands of years: currently, about half of the carbon dioxide released from the burning of fossil fuels remains in the atmosphere and is not absorbed by vegetation and the oceans.



【参考图文】

Figure 1.10 Carbon dioxide in Earth's atmosphere if *half* of global-warming emissions are *not* absorbed. (NASA simulation; 9 November 2015)

Carbon dioxide is a greenhouse gas. Motor vehicle CO_2 emissions are part of the anthropogenic contribution to the growth of CO_2 concentrations in the atmosphere which is causing climate change. Motor vehicles are calculated to generate about 20% of the European Union's man-made CO_2 emissions, with passenger cars contributing about 12%. European emission standards limit the CO_2 emissions of new passenger cars and light vehicles. The European Union average new car CO_2 emissions figure dropped by 5.4% in the year to the first quarter of 2010, down to 145.6 g/km. At present, Volkswagen offer 245 models with CO_2 emissions of less than 120 g/km. By 2020, the company will reduce the average CO_2 emissions of its European new car fleet to 95 g/km, as shown in Figure 1.11. And the company will take the powertrain technologies to minimize greenhouse gas emission, as shown in Figure 1.12.

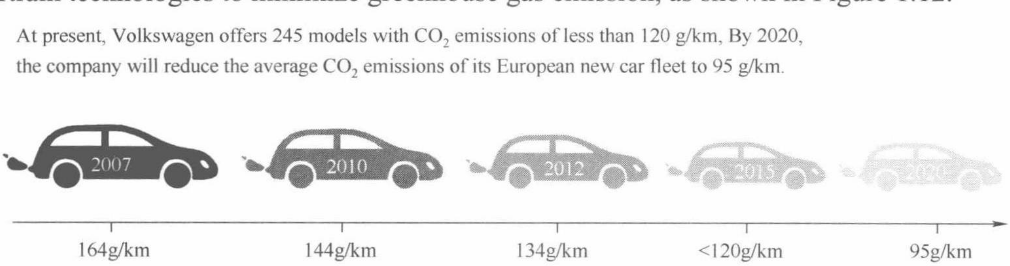


Figure 1.11 CO_2 Emissions

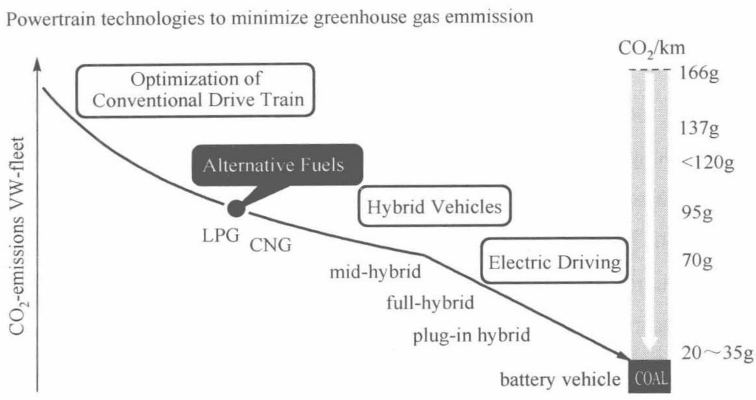


Figure 1.12 Powertrain technologies

1.4 Pollution Effects

Air pollution associated with transit fuels comes from several sources, including fuel production (e.g., petroleum refining or electric power generation), fuel transportation, evaporative emissions, and tailpipe emissions from transit vehicles. In communities where transit vehicles operate frequently, tailpipe emissions make the greatest impact on air quality. Exhaust tends to accumulate around localized hotspots such as transit bus depots and railroad stations.

Table 1.1 describes the four pollutants subject to U.S. EPA motor vehicle emissions standards—particulate matter (PM), oxides of nitrogen (NO_x), hydrocarbons (HC), and carbon monoxide (CO)—and their environmental and health effects. The table shows that PM exhaust can be toxic and that NO_x and NMHC can form ground level ozone, a principal component of smog. Because of high concentrations of soot, ozone, and smog in many urban areas, these emissions are of primary concern. Diesel vehicles are not a major source of CO.

Table 1.1 Regulated Pollutants in Diesel Exhaust and their Health and Environmental Effect

Pollutant	Source	Description	Environmental and Health Effects
Particulate Matter (PM)	Product of fuel or lubricating oil combustion	Tiny carbon particles (soot or smoke) with sometimes-toxic organic compounds attached	PM can affect respiratory health and carry toxic substances into the lungs and bloodstream. PM finer than 10 microns in diameter (PM10) is absorbed by the lungs causing lung damage. The core carbon of PM may not be the primary culprit of adverse health effects. Instead, compounds, when bonded to the tiniest carbon particulates, penetrate deep into the lungs and are suspected of triggering a cascade of effects in many body systems.

续表

Pollutant	Source	Description	Environmental and Health Effects
Oxides of Nitrogen (NO_x)	Reactions between oxygen and nitrogen in the engine's combustion chamber	Gases including NO (nitric oxide) and NO_2 (nitrogen dioxide). As emitted directly from the tailpipe, NO_x consists mainly of nitric oxide (NO) (90% NO + 10% NO_2) although vehicles equipped with certain types of aftertreatment systems can emit as much as 35% nitrogen dioxide NO_2).	NO_2 is an oxidizing gas, which in concentrations higher than 0.2 ppm, irritates and damages lung tissue. NO_2 also combines with water to form nitric acid, which is damaging to plants. NO_2 is a precursor in the formation of ground level ozone (O_3) and smog and contributes to global warming. NO is non-toxic and does not promote the formation of ozone. However, NO is rapidly converted to NO_2 in the atmosphere.
Hydrocarbons (HC) and Non-Methane Hydrocarbons (NMHC)	Unburned or partially burned fuel, fuel spills	Hydrocarbons contain both reactive species, called volatile organic compounds, and non-reactive species, such as methane.	Hydrocarbons are ozone precursors. In the presence of sunlight, reactive hydrocarbons react with NO_2 in the atmosphere to produce ozone. Methane, the principal HC constituent in CNG engine exhaust, while not photochemically reactive, is a powerful greenhouse gas.
Carbon monoxide (CO)	Incomplete combustion of carbon-containing fuels	Highly toxic gas	CO is hazardous in high concentrations because it binds with hemoglobin in the blood, impairing its ability to transport oxygen to the brain and other vital organs.

The health hazards associated with motor vehicle exhausts are particularly worrying. If you place a stationary diesel engine with the exhaust near a wall, the wall very quickly turns black with what can loosely be described as soot. Again you do not need to be a medical scientist to realize the effect that this might have on your lungs. You would need to smoke a lot of cigarettes to get the same level of deposit, and we all know the health effects of tobacco smoke. Although you do not have to stand behind diesel exhausts, you are bound to inhale a fair amount walking along a busy street and crossing the road, which often involves passing directly through vehicle exhaust.

Accepted health problems associated with car exhausts makes depressing reading and one has to wonder why society keeps quite happily emitting these substances.

New discoveries on the risks of cancer from exhaust fumes continue to emerge. Researchers in Japan have apparently isolated a compound called 3-nitrobenzanthone which is a highly potent mutagen. Clearly this is a cause for alarm. It must also be remembered that new research is constantly emerging and the overall picture may well be extremely grim. Certainly there have been large rises in asthma, many allergies and cancers that may well be linked to exhaust fumes.

The effect of carbon dioxide on the planet is another cause for alarm. The greenhouse effect of carbon dioxide is now well known. Basically, some of the short-wave radiation from the sun is absorbed by the earth and then re-emitted at a longer wavelength. This is absorbed by carbon dioxide