A First and Second Year Blog on Respiration and Pollution

for the week commencing the 24th of November 2019. (The vast bulk of this Blog is **NOT** my own work.)

- There are two biological reactions (Respiration and Photosynthesis) that you need to be aware of in Chemistry. Let us first describe some of the chemicals that are involved.

  - **Glucose (chemical formula $C_6H_{12}O_6$)** also called "blood-sugar", is a sugar contained in all animals and plants. Glucose is obtained by animals mainly by eating carbohydrates (in the form of pasta/bread/biscuits/and anything that is made from cereals such as wheat/rice/maize/etc). Glucose is also obtained from fruit and vegetables. **Glucose is an extraordinarily important part of the human diet.**

  - **Oxygen (O_2)** is the second most important constituent of air. "Atmospheric air" contains very roughly 20% Oxygen and 80% Nitrogen (N_2). Animas **inhale** Oxygen with every breath that they take and they **exhale** CO_2 with every breath that they breathe out. *Plants do exactly the opposite.* They take in CO_2 through their leaves and they release O_2.

  - **Carbon Dioxide (CO_2)** is a gas that animals exhale with every breath that they breathe out, and it is the gas that plants absorb. We need Oxygen to live, and plants need Carbon Dioxide to live.

- I know next to nothing about Biology, therefore I have relied on published sources for my information.

- The Oxygen that animals inhale into their lungs becomes bonded to the Iron in "Haemoglobin" (Hb or Hgb) in blood, and the Oxygen is thus carried around the body in the bloodstream and is thereby delivered to wherever it is needed. Many things happen during Respiration – but one of the things that happens is that Oxygen **oxidises** the Sugars in Carbohydrates, thereby forming CO_2 and Water. ***That*** is the equation you need for 'A' Level Chemistry:

$$C_6H_{12}O_6 \ + \ 6O_2 \ \longrightarrow \ 6CO_2 \ + \ 6H_2O \ ; \ \Delta H = -2{,}820 \text{ kJ mol}^{-1}$$

  *You **DO** need to know the above equation for the examination so please learn it off by heart. The stoichiometric ratio in this equation is 1 : 6 —> 6 : 6 . **Glucose + Oxygen —> CO_2 and H_2O.***

- I am told by my Biology colleagues that Respiration is the 'haemodynamic response' via ATP (adenosine triphosphate [1]) that takes place between Glucose and Oxygen to produce the energy that is produced by mitochondria during the process of Respiration[2].

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[1] Biology textbooks often state that 38 ATP molecules can be made per oxidized glucose molecule during cellular respiration (2 from glycolysis, 2 from the Krebs cycle, and about 34 from the electron transport system); but, apparently, this maximum yield is never quite reached because of losses due to leaky membranes as well as the cost of moving pyruvate and ADP (**A**denosine **dip**hosphate) into the mitochondrial matrix, and current estimates range around 29 to 30 molecules of ATP being formed per glucose molecule. *Rich, P. R. (2003). "The molecular machinery of Keilin's respiratory chain". Biochemical Society Transactions. 31 (Pt 6): 1095–1105.* doi:10.1042/BST0311095. PMID 14641005.

[2] Respiration involves three main stages: (i) Glycolytic oxidisation of Glucose (ii) the oxidisation of Pyruvate by the Krebs[2] or the Citric-Acid cycle (wherein Mitochondria in Eukaryotic cells are the organelle that produce the energy), and (iii) Oxidative Phosphorylation, which is the process in which the energy formed in the cell by Respiration is stored in ATP as a result of the transfer of electrons from either NADH (the reduced form of **N**icotinamide **A**denine **D**inucleotide where ($NAD^+ + e^- \longrightarrow NADH$) or from $FADH_2$ (**F**lavin **A**denine **D**inucleotide) to O_2 by a series of electron carriers. This process, which takes place in mitochondria, is the major source of ATP in aerobic organisms. Source: https://www.ncbi.nlm.nih.gov/books/NBK21208/.

- Respiration is one of the key ways a cell releases chemical energy to fuel cellular activity[3]. Apparently a mitochondrion is to a cell what an engine is to an automotive vehicle. An engine uses the chemical energy in petrol/diesel to provide the car with kinetic energy to put it in motion, and a mitochondrion will convert the chemical energy in Glucose *and* Oxygen to provide a cell with energy to do things (mainly 'work' as described by Physics).

- The equation for **Aerobic Respiration** is thus

  $$C_6H_{12}O_6\,(s) \;+\; 6O_2\,(g) \;\longrightarrow\; 6CO_2\,(g) \;+\; 6H_2O\,(l) \;+\; \textbf{ENERGY}$$

  Glucose Oxygen Carbon Dioxide Water

  With a stoichiometric ratio of 1 : 6 —> 6 : 6

  and for plants the equation for **Photosynthesis** is

  $$6CO_2 \;+\; 6H_2O \;+\; \textbf{SUNLIGHT} \;\longrightarrow\; C_6H_{12}O_6 \;+\; 6O_2$$

  With a stoichiometric ratio of 6 : 6 —> 1 : 6

- **Photosynthesis is to plants what Respiration is to animals, and where mitochondria convert chemical energy into energy available for work in animals, so also do chloroplasts take energy from the sun and convert it into chemical energy for plants to use in the process of growth.**

- That is probably all that you need to know about Respiration for the purposes of 'A' Level Chemistry; but, since "pollution" is becoming such an important topic, I would add that plants and animals thus work in harmony with each other. That is precisely how evolutionary Biology works. If animals and plants had killed each other (instead of helping each other to live), then life as we know it today would not exist. That is why we human beings are harming the Earth by cutting down trees (in the Amazon rain-forest, and in the Far East in places such as Java and Sumatra) and not planting a replacement tree for every tree that we have cut down[4].

- In addition, the burning of trees and undergrowth to clear the land of forests puts oxides of Carbon/ Sulphur/etc into the atmosphere, and this increases global warming by putting 'greenhouse gases' into the atmosphere. The 'particulates' that are released into the atmosphere will reflect sunlight back away from the Earth and thus counter the effect of the greenhouse gases, but the particulates stay in the atmosphere for at most two years, whereas the greenhouse gases have lives much longer than that.

- **Massive** amounts of Methane are apparently released into the atmosphere by the cattle that are farmed; and in addition, global warming could release further quantities of Methane into the atmosphere (from the lakes and seas in the currently frozen areas of the world such as Siberia) – and if that were to happen, then since Methane has a greenhouse effect almost THIRTY times more powerful than Carbon Dioxide, the effect could be catastrophic to ALL forms of life on earth. Mankind is slowly but surely poisoning the planet – with disastrous consequences to himself, but Man is also harming the innocent animals who share the planet with us. (In evolutionary terms, Man has not been a particularly successful product.)

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[3] In photosynthesis, however, a series of electron transport complexes intervene between the capture of the light and the ultimate reduction of $NAD(P)^+$. Source: https://www.sciencedirect.com/topics/medicine-and-dentistry/nicotinamide-adenine-dinucleotide.

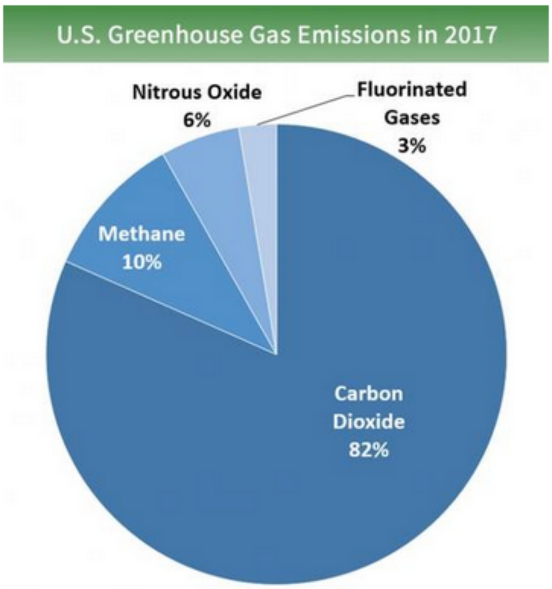
[4] We should not be quick to condemn the people who live in those countries. They are poor and they are clearing forests to try to make a living by growing things (such as palm oil) that rich people want for things such as make-up and hair shampoo! In any case the people who live in the rich countries of the world did exactly the same when they themselves were 'developing countries'. 8,000-10,000 years ago, Great Britain was covered in nothing but forests and vegetation (and hardly any human beings lived here), and now look at Britain. Nearly all of our forests have gone as we went from being a non-developed country to being a highly developed country, and how many trees are we in Britain planting every year? It would do us well to remember the old adages: "People who live in glass houses should never throw stones", and "And why beholdest thou the mote that is in thy brother's eye, but considerest not the beam that is in thine own eye?"

APPENDIX : GLOBAL WARMING

- The US Environmental Protection Agency says the following.

Greenhouse gases (GHGs) warm the Earth by absorbing energy and slowing the rate at which the energy escapes into space. GHGs act like a blanket that insulates the Earth. Different GHGs can have different effects on the Earth's warming. Two key ways in which these gases differ from each other lies in their ability to absorb energy (their “radiative efficiency”), and how long they stay in the atmosphere (also known as their “lifetime”).

The Global Warming Potential (GWP) index was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over that time period. The time period usually used for GWPs is 100 years. GWPs provide a common unit of measure, that allows analysts to add up emission estimates for different gases (e.g., to compile a national GHG inventory), and it allows policymakers to compare emission reduction opportunities across different sectors and different gases.



Total Emissions in 2017 = 6,457 Million Metric Tons of CO_2 equivalent. Percentages may not add up to 100% due to independent rounding.

- **CO_2**, by definition, has a GWP of 1 regardless of the time period used, because it is the gas that is being used as the reference index. CO_2 remains in the climate system for a very long time: CO_2 emissions cause increases in atmospheric concentrations of CO_2 that will last thousands of years.
- **Methane** (CH_4) is estimated to have a GWP of 28–36 over 100 years. CH_4 emitted today lasts about a decade on average, which is much less time than CO_2. But CH_4 also absorbs much more energy than CO_2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The CH_4 GWP also accounts for some indirect effects, such as the fact that CH_4 is a precursor to ozone, and ozone is itself a GHG.
- **Nitrous Oxide** (N_2O) has a GWP **265–298 times** that of CO_2 on a 100-year timescale.
- **Chlorofluorocarbons** (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6) are sometimes called **high-GWP gases** because, for a given amount of mass, they trap substantially more heat than CO_2. (The GWPs for these gases can be in the thousands or tens of thousands.)

Gases that trap heat in the atmosphere are called greenhouse gases. This section provides information on emissions and removals of the main greenhouse gases to and from the atmosphere. For more information on the other climate forcers, such as black carbon, please visit the Climate Change Indicators: Climate Forcing page.

- **Carbon dioxide (CO_2)**: Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
- **Methane (CH_4)**: Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.
- **Nitrous oxide (N_2O)**: Nitrous oxide is emitted during agricultural and industrial activities, combustion of fossil fuels and solid waste, as well as during treatment of wastewater.
- **Fluorinated gases**: Hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases").

Each gas' effect on climate change depends on three main factors:

How much is in the atmosphere?

Concentration, or abundance, is the amount of a particular gas in the air. Larger emissions of greenhouse gases lead to higher concentrations in the atmosphere. Greenhouse gas concentrations are measured in parts per million, parts per billion, and even parts per trillion. One part per million is equivalent to one drop of water diluted into about 13 gallons of liquid (roughly the fuel tank of a compact car).

How long do they stay in the atmosphere?

Each of these gases can remain in the atmosphere for different amounts of time, ranging from a few years to thousands of years. All of these gases remain in the atmosphere long enough to become well mixed, meaning that the amount that is measured in the atmosphere is roughly the same all over the world, regardless of the source of the emissions.

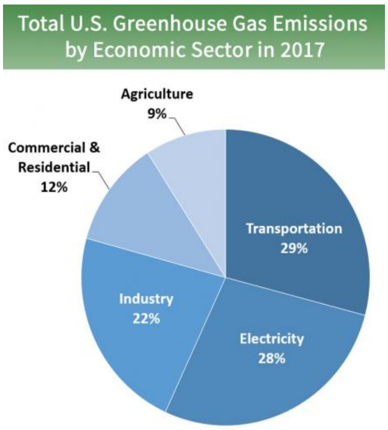
How strongly do they impact the atmosphere?

Some gases are more effective than others at making the planet warmer and "thickening the Earth's blanket".

For each greenhouse gas, a Global Warming Potential (GWP) has been calculated to reflect how long it remains in the atmosphere, on average, and how strongly it absorbs energy. Gases with a higher GWP absorb more energy, per pound, than gases with a lower GWP, and thus contribute more to warming Earth.

Note: All emission estimates are from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2017*.

Sources of Greenhouse Gas Emissions: Overview



Total Emissions in 2017 = 6,457 Million Metric Tons of CO_2 equivalent. Percentages may not add up to 100% due to independent rounding.

Land Use, Land-Use Change, and Forestry in the United States is a net sink and offsets approximately 11 percent of these greenhouse gas emissions, not included in total above. All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2017.*

Greenhouse gases trap heat and make the planet warmer. Human activities are responsible for almost all of the increase in greenhouse gases in the atmosphere over the last 150 years.[1] The largest source of greenhouse gas emissions from human activities in the United States is from burning fossil fuels for electricity, heat, and transportation.

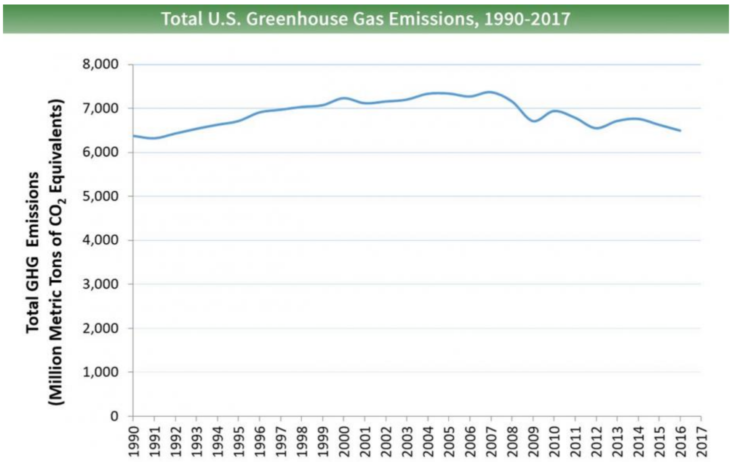
The EPA tracks total U.S. emissions by publishing the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. This annual report estimates that the total national greenhouse gas emissions and removals associated with human activities across the United States.

The primary sources of greenhouse gas emissions in the United States are:

- Transportation (28.9 percent of 2017 greenhouse gas emissions): The transportation sector generates the largest share of greenhouse gas emissions. Greenhouse gas emissions from transportation primarily come from burning fossil fuel for our cars, trucks, ships, trains, and planes. Over 90 percent of the fuel used for transportation is petroleum based, which includes primarily gasoline and diesel.[2]
- Electricity production (27.5 percent of 2017 greenhouse gas emissions): Electricity production generates the second largest share of greenhouse gas emissions. Approximately 62.9 percent of our electricity comes from burning fossil fuels, mostly coal and natural gas.[3]
- Industry (22.2 percent of 2017 greenhouse gas emissions): Greenhouse gas emissions from industry primarily come from burning fossil fuels for energy, as well as greenhouse gas emissions from certain chemical reactions necessary to produce goods from raw materials.
- Commercial and Residential (11.6 percent of 2017 greenhouse gas emissions): Greenhouse gas emissions from businesses and homes arise primarily from fossil fuels burned for heat, the use of certain products that contain greenhouse gases, and the handling of waste.
- Agriculture (9.0 percent of 2017 greenhouse gas emissions): Greenhouse gas emissions from agriculture come from livestock such as cows, agricultural soils, and rice production.
- Land Use and Forestry (offset of 11.1 percent of 2017 greenhouse gas emissions): Land areas can act as a sink (absorbing CO_2 from the atmosphere) or a source of greenhouse gas emissions. In the United States, since 1990, managed forests and other lands have absorbed more CO_2 from the atmosphere than they emit.

Emissions and Trends

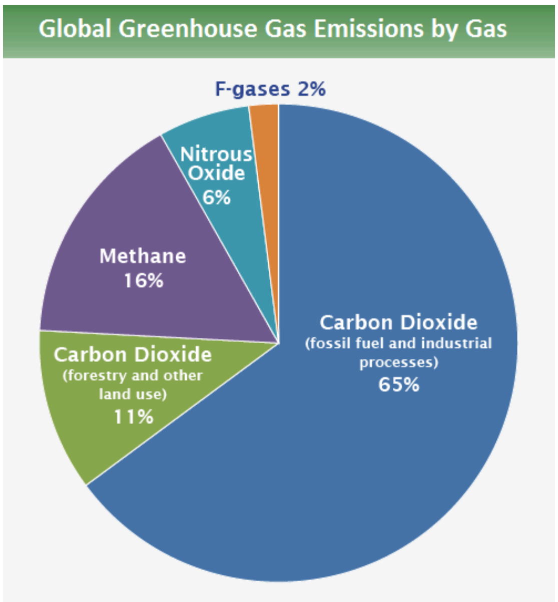
Since 1990, gross U.S. greenhouse gas emissions have increased by 1.3 percent. From year to year, emissions can rise and fall due to changes in the economy, the price of fuel, and other factors. In 2017, U.S. greenhouse gas emissions decreased compared to 2016 levels. The decrease in CO_2 emissions from fossil fuel combustion was a result of multiple factors, including a continued shift from coal to natural gas, increased use of renewables in the electric power sector, and milder weather that contributed to less overall electricity use.



All emission estimates from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2017.

Global Greenhouse Gas Emissions Data

Global Emissions by Gas



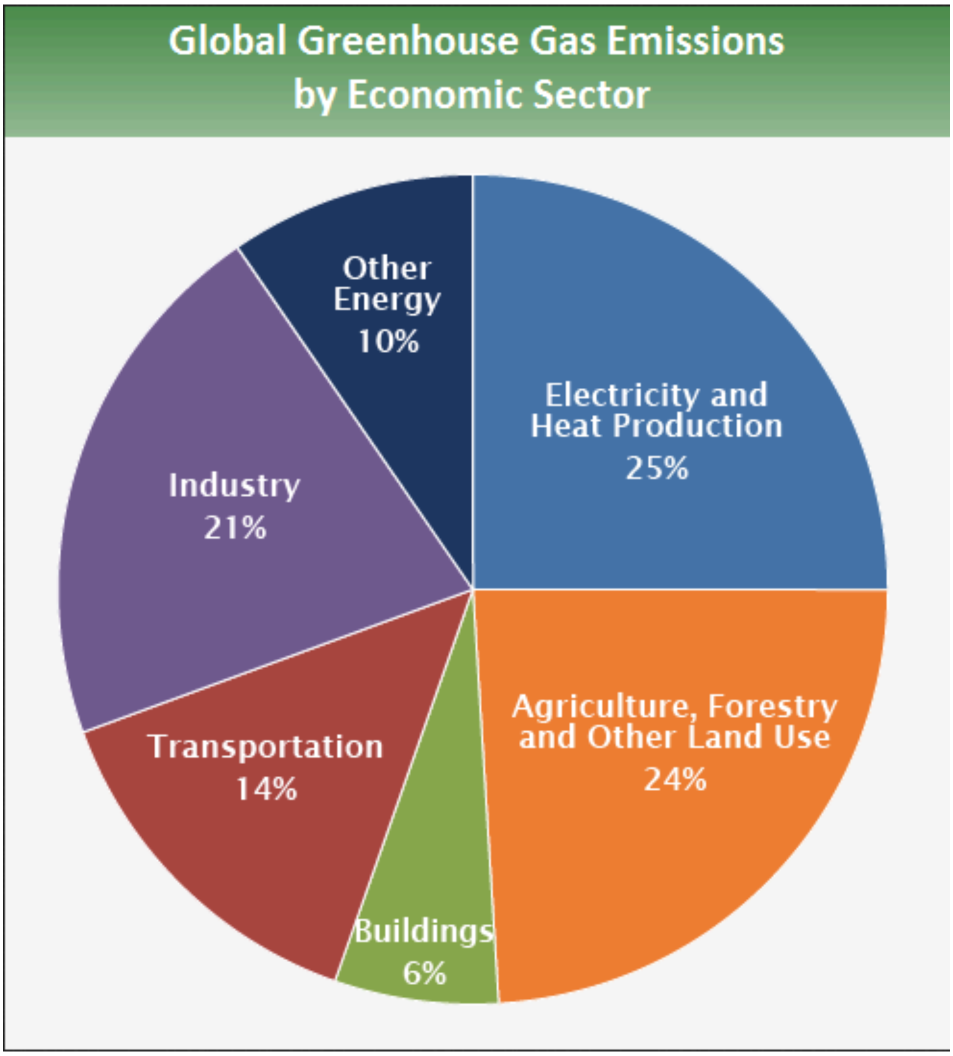
Source: IPCC (2014) Exit based on global emissions from 2010. Details about the sources included in these estimates can be found in the *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Exit

- **Carbon dioxide (CO_2)**: Fossil fuel use is the primary source of CO_2. CO_2 can also be emitted from direct human-induced impacts on forestry and other land use, such as through deforestation, land clearing for agriculture, and degradation of soils. Likewise, land can also remove CO_2 from the atmosphere through reforestation, improvement of soils, and other activities.
- **Methane (CH_4)**: Agricultural activities, waste management, energy use, and biomass burning all contribute to CH_4 emissions.
- **Nitrous oxide (N_2O)**: Agricultural activities, such as fertilizer use, are the primary source of N_2O emissions. Fossil fuel combustion also generates N_2O.
- **Fluorinated gases (F-gases)**: Industrial processes, refrigeration, and the use of a variety of consumer products contribute to emissions of F-gases, which include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6).

Black carbon is a solid particle or aerosol, not a gas, but it also contributes to warming of the atmosphere. Learn more about black carbon and climate change on our Causes of Climate Change page.

Global Emissions by Economic Sector

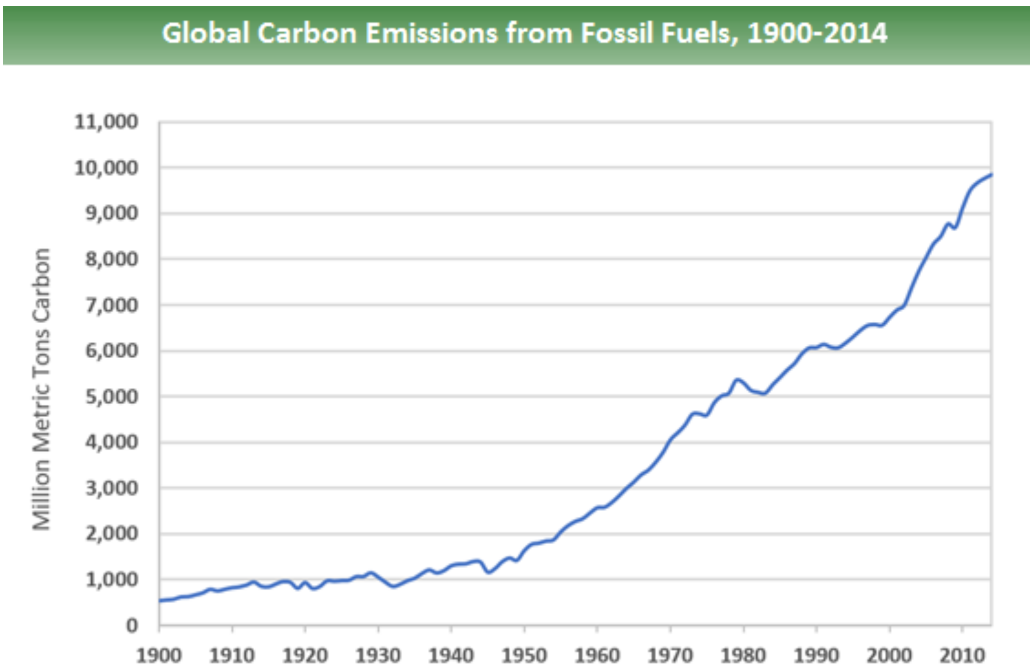
Global greenhouse gas emissions can also be broken down by the economic activities that lead to their production.[1]



Source: IPCC (2014)

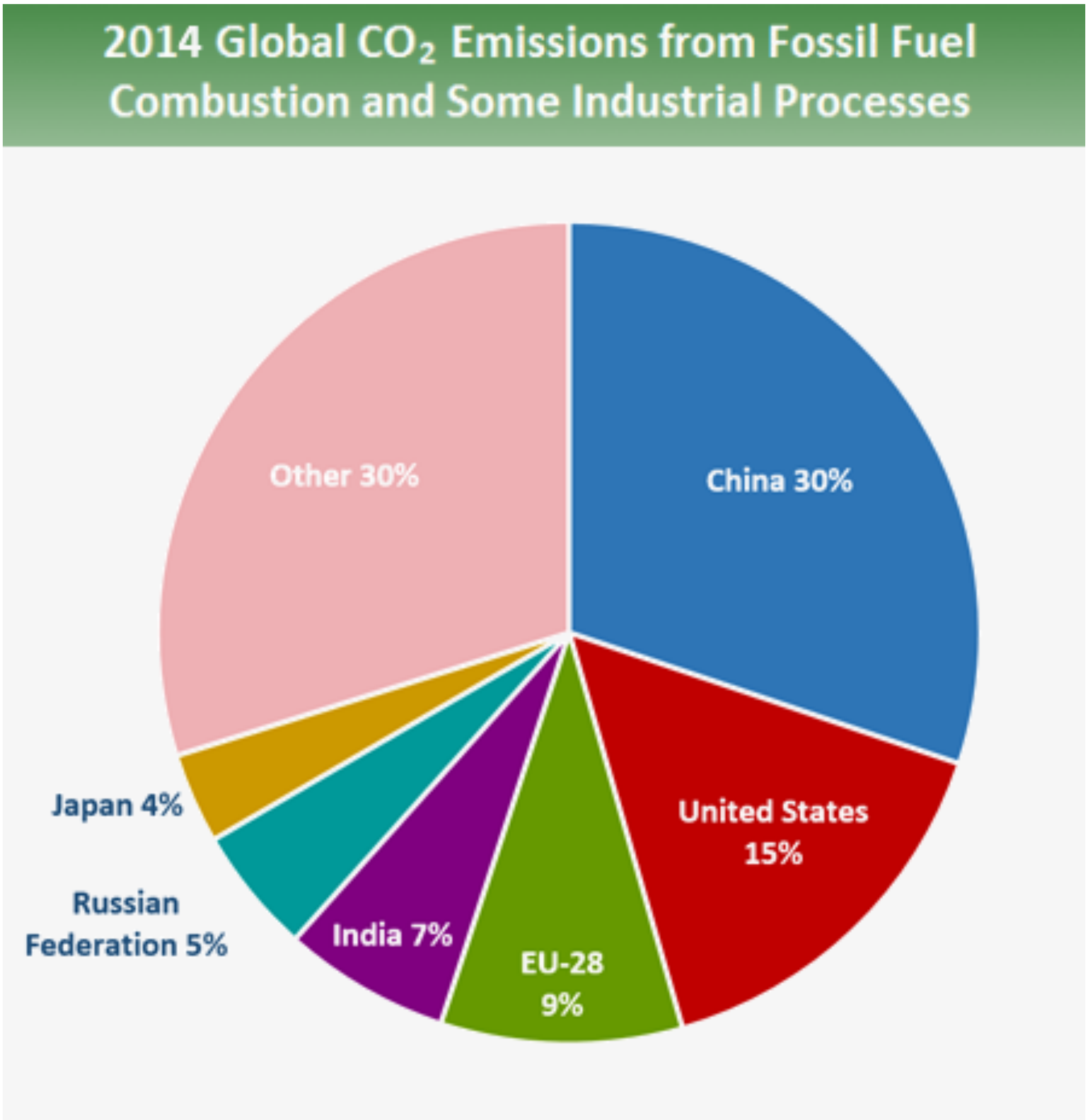
- **Electricity and Heat Production** (25% of 2010 global greenhouse gas emissions): The burning of coal, natural gas, and oil for electricity and heat is the largest single source of global greenhouse gas emissions.
- **Industry** (21% of 2010 global greenhouse gas emissions): Greenhouse gas emissions from industry primarily involve fossil fuels burned on site at facilities for energy. This sector also includes emissions from chemical, metallurgical, and mineral transformation processes not associated with energy consumption and emissions from waste management activities. (Note: Emissions from industrial electricity use are excluded and are instead covered in the Electricity and Heat Production sector.)
- **Agriculture, Forestry, and Other Land Use** (24% of 2010 global greenhouse gas emissions): Greenhouse gas emissions from this sector come mostly from agriculture (cultivation of crops and livestock) and deforestation. This estimate does not include the CO_2 that ecosystems remove from the atmosphere by sequestering carbon in biomass, dead organic matter, and soils, which offset approximately 20% of emissions from this sector.[2]
- **Transportation** (14% of 2010 global greenhouse gas emissions): Greenhouse gas emissions from this sector primarily involve fossil fuels burned for road, rail, air, and marine transportation. Almost all (95%) of the world's transportation energy comes from petroleum-based fuels, largely gasoline and diesel.
- **Buildings** (6% of 2010 global greenhouse gas emissions): Greenhouse gas emissions from this sector arise from onsite energy generation and burning fuels for heat in buildings or cooking in homes. (Note: Emissions from electricity use in buildings are excluded and are instead covered in the Electricity and Heat Production sector.)
- **Other Energy** (10% of 2010 global greenhouse gas emissions): This source of greenhouse gas emissions refers to all emissions from the Energy sector which are not directly associated with electricity or heat production, such as fuel extraction, refining, processing, and transportation.

Trends in Global Emissions



Source: Boden, T.A., Marland, G., and Andres, R.J. (2017). Global, Regional, and National Fossil-Fuel CO2Emissions.

Emissions by Country



Source: Boden, T.A., Marland, G., and Andres, R.J. (2017). National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2014, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, doi 10.3334/CDIAC/00001_V2017.In 2014, the top carbon dioxide (CO_2) emitters were China, the United States, the European Union, India, the Russian Federation, and Japan. These data include CO_2 emissions from fossil fuel combustion, as well as cement manufacturing and gas flaring. Together, these sources represent a large proportion of total global CO_2 emissions.

Emissions and sinks related to changes in land use are not included in these estimates. However, changes in land use can be important: estimates indicate that net global greenhouse gas emissions from agriculture, forestry, and other land use were over 8 billion metric tons of CO_2 equivalent,[2] or about 24% of total global greenhouse gas emissions.[3] In areas such as the United States and Europe, changes in land use associated with human activities have the net effect of absorbing CO_2, partially offsetting the emissions from deforestation in other regions.