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ENERGY, GREENHOUSE GASSES & CARBON MARKETS

“If we do not change our direction, we will end up where we are headed.”

-Anonymous

Since the industrial revolution fossil fuels (coal, oil and natural gas) have been used to produce electricity contributing to the global increase in greenhouse gases, which trap heat and make the planet warmer. In the United States the largest sources of greenhouse gasses are from burning fuel for electricity, heat and transportation.¹ *Note:* Consumption (encompassing products and services used by households) accounts for around 2/3 of global greenhouse gas emissions.²

Energy: Energy represents, in physics, the capacity for doing work. Energy may exist in potential, kinetic, thermal, electrical, chemical, nuclear, or other various forms. All forms of energy are associated with motion, and energy can be neither created nor destroyed but only changed from one form to another.³ The three major categories of energy for electricity generation are fossil fuels, nuclear energy, and renewable energy sources (solar, wind, hydro, geothermal, and biomass). Most electricity is generated with steam turbines using fossil fuels, nuclear, biomass, geothermal, and solar thermal energy.⁴

Coal: Coal is the largest domestically produced source of energy in America and is used to generate a significant amount of our nation’s electricity.⁵ Burning a pound of coal emits 2.07 pounds of CO₂.⁶ In addition, emissions from coal mining and abandoned coal mines accounted for about 8% of total U.S. methane (CH₄) emissions in 2019.⁷ While coal usage has been declining in the US since 2007, the country still burned about 500 million tons of coal in 2021 (creating over a trillion pounds of CO₂ in the atmosphere) roughly 10% of the country’s electricity needs.⁸

Oil: Petroleum is used for heating and transportation (as fuel for gas-powered vehicles). The United States keeps a Strategic Petroleum Reserve, which as of December 31, 2021 held 594.7 million barrels, equivalent to approximately 1,206 days of supply of total U.S. petroleum net imports.⁹ In 2021 the US consumed about 800 million metric tons of oil.¹⁰

Natural Gas: Methane (CH₄) is the core component of natural gas, it is the largest source of U.S. electric power generation although natural gas also contributes to about half of the CO₂ as coal.¹¹

¹ Source: EPA, “Sources of Greenhouse Gas Emissions;” <https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions>; Retrieved June 26, 2022.

² UN Emissions Gap Report, <https://www.unep.org/emissions-gap-report-2020>, Retrieved October 20, 2022.

³ Source: <https://www.britannica.com/science/energy>, Retrieved October 17, 2022

⁴ U.S. Energy Information Administration, “Electricity in the United States,” <https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php>, Retrieved October 16, 2022

⁵ <https://www.energy.gov/science-innovation/energy-sources/fossil>

⁶ <https://www.epa.gov/energy/frequent-questions-epas-greenhouse-gas-equivalencies-calculator>, Retrieved October 17, 2022.

⁷ <https://www.epa.gov/cmop/about-coal-mine-methane>, Retrieved October 20, 2022

⁸ One ton = 2,000 pounds, <https://www.statista.com/statistics/184333/coal-energy-consumption-in-the-us/>

⁹ <https://www.energy.gov/ceser/spr-quick-facts>, Retrieved October 17, 2022

¹⁰ One metric ton = 2,204 pounds, <https://www.statista.com/statistics/264825/oil-consumption-in-the-united-states/>

¹¹ <https://www.c2es.org/content/natural-gas/>

Greenhouse Gases (GHG): Greenhouse gases act like a blanket and warm the Earth by absorbing energy and slowing the rate at which the energy escapes to space. GHGs differ in terms of their ability to absorb energy (their *radiative efficiency*) and their *lifetime* or how long they stay in the atmosphere. In 1990 a team of global scientists worked to develop a measure of radiative efficiency (called Global Warming Potential or GWP) to compare the strength of different human and natural agents in causing climate change that was used in the Kyoto Protocol as a means to compare and understand various greenhouse gasses.¹² The major greenhouse gasses are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O).¹³ Additionally hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Name	Examples of Uses	Lifetime	100 year – GWP
Carbon dioxide (CO ₂)	electricity, vital to photosynthesis	*	1
Methane (CH ₄)	fuel and light	12	25
Nitrous oxide (N ₂ O)	anesthetic in operations	114	298
Hydrofluorocarbons (HFCs) (There are many HFCs, below are two examples) CH ₃ CHF ₂ CF ₃ CH ₂ CF ₃	commercial refrigeration fire suppression	1.4 240	124 9,810
Perfluorocarbons (PFCs) (There are many PFCs)	products that resist heat, oil, stains, grease, and water	1,000- 50,000	7,390- 22,800
Sulfur hexafluoride (SF ₆) (SF ₆ is categorized as a perfluorinated compound)	circuit breakers	3,200	22,800
Nitrogen trifluoride (NF ₃) (SF ₆ is categorized as a perfluorinated compound)	Semiconductor manufacturing	740	17,200

Source: Forster, P., V. Ramaswamy, P. Artaxo, T. Bernsten, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., Available at: <https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter2-1.pdf>, Retrieved October 20, 2022.

Note: Carbon is the reference GHG so its GWP will equal 1. Also “Carbon dioxide’s lifetime cannot be represented with a single value because the gas is not destroyed over time, but instead moves among different parts of the ocean–atmosphere–land system. Some of the excess carbon dioxide is absorbed quickly (for example, by the ocean surface), but some will remain in the atmosphere for thousands of years, due in part to the very slow process by which carbon is transferred to ocean sediments”

Secondary Sources: <https://www.epa.gov/climate-indicators/greenhouse-gases>

¹² Forster, P., V. Ramaswamy, P. Artaxo, T. Bernsten, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., Available at: <https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter2-1.pdf>, Retrieved October 20, 2022.

¹³ Source: United Nations, “Glossary of Climate Change Acronyms,” <https://unfccc.int/process-and-meetings/the-convention/glossary-of-climate-change-acronyms-and-terms#g>, Retrieved October 16, 2022.

Carbon dioxide (CO₂) - CO₂ is produced during the processes of decay of organic materials and the fermentation of sugars in bread, beer and wine making. It is produced by combustion of wood, peat and other organic materials and fossil fuels such as coal, petroleum and natural gas. Natural sources include volcanoes, forest fires, hot springs, geysers, etc.¹⁴ Burning fossil fuels releases carbon dioxide into the atmosphere and that carbon dioxide is the primary cause of recent global warming.

Methane (CH₄) - CH₄ occurs abundantly in nature, the production and combustion of natural gas and coal are the major human-associated sources of methane.¹⁵

Nitrous oxide (N₂O) - N₂O (or “laughing gas”) is used in surgery and dentistry as a pain reducing agent, it is also used in rocket propellant and motor racing and in synthetic fertilizer.¹⁶

Hydrofluorocarbons (HFCs) - HFCs are commonly used in a wide variety of applications, including refrigeration, air-conditioning (AC), building insulation, fire extinguishing systems, and aerosols.¹⁷ HFCs have become increasingly used as replacements for ozone-depleting substances (ODS), but because of their high GWP there is increasing concern about their impact on the environment.^{18, 19}

Perfluorocarbons (PFCs) - C_xF_y blends are used in used as solvents in tattoo removal, the electronics industry, and as refrigerants of some specialized refrigeration systems.²⁰ The CDC has notes that PCFs are now found in blood samples and are exploring possible negative health effects.²¹

Sulfur hexafluoride (SF₆) - SF₆ is the most potent greenhouse gas that has been evaluated, with a global warming potential of 23,900 times that of CO₂ when compared over a 100-year period and is extremely long-lived, with an estimated atmospheric lifetime of 800–3,200 years. It is primarily used as an electrical insulator in the power industry, in semi-conductor manufacturing, and in photovoltaic panels.²²

Nitrogen trifluoride (NF₃) - NF₃ is used in the semiconductor industry, within the manufacturing of flat-panel displays, photovoltaics, LEDs and other microelectronics.²³

¹⁴ https://en.wikipedia.org/wiki/Carbon_dioxide, Retrieved July 12, 2022.

¹⁵ https://en.wikipedia.org/wiki/Sulfur_hexafluoride, Retrieved July 11, 2022

¹⁶ <https://www.bbc.com/future/article/20210603-nitrous-oxide-the-worlds-forgotten-greenhouse-gas>, July 11, 2022

¹⁷ <https://www.epa.gov/snap/reducing-hydrofluorocarbon-hfc-use-and-emissions-federal-sector-through-snap>, Retrieved October 20, 2022.

¹⁸ <https://www.epa.gov/snap/reducing-hydrofluorocarbon-hfc-use-and-emissions-federal-sector-through-snap>, Retrieved October 20, 2022.

¹⁹ See also: <https://research.noaa.gov/article/ArtMID/587/ArticleID/593/HFC-greenhouse-gases-a-tale-of-two-or-more-futures>, Retrieved October 20, 2022.

²⁰ <https://en.wikipedia.org/wiki/Fluorocarbon>, <https://www.skirack.com/blog/fluoro-wax-ban-prep/>, July 12, 2022

²¹ https://www.cdc.gov/biomonitoring/pdf/pfcs_factsheet.pdf, Retrieved October 20, 2022

²² https://en.wikipedia.org/wiki/Sulfur_hexafluoride & <https://www.solvay.com/en/brands/sulfur-hexafluoride-sf6-electronic-grade> Retrieved July 11, 2022.

²³ https://en.wikipedia.org/wiki/Sulfur_hexafluoride, Retrieved July 11, 2022

CARBON MARKETS

Carbon markets turn CO₂ emissions into a commodity by giving it a price. Emissions fall into two categories: Carbon credits or carbon offsets, and both can be bought and sold on a carbon market. In 2021, the total value of carbon taxes paid and carbon allowances sold through auctions was approximately \$84 billion.²⁴ As of 2022, worldwide, 68 carbon pricing instruments and emissions trading systems exist representing 23% of total global greenhouse gas emissions.²⁵

Carbon taxes - the government sets a price that emitters must pay for each ton of greenhouse gas emissions they emit with the goal for businesses and consumers to take steps, such as switching fuels or adopting new technologies, to reduce their emissions to avoid paying the tax.²⁶

Cap and trade - represent government programs regarding pollution or other externalities that specifies caps (allowances) on the activity for each entity but allows each entity to trade its rights (e.g. its allotment of pollution) with other entities.²⁷ Massachusetts participates in the Regional Greenhouse Gas Initiative (RGGI), which is a cooperative effort among eleven Eastern states to reduce carbon dioxide (CO₂) emissions from power plants within each participating state.²⁸

Carbon credits - (carbon allowances) work like permission slips for emissions, when a company buys a carbon credit, they gain permission to generate one ton of CO₂ emissions (CO₂e). Companies who end up with excess credits can sell them to other companies.

Carbon offsets – are carbon revenue traded between companies, when a company removes a unit of carbon from the atmosphere, they can generate a carbon offset other companies can then purchase that carbon offset to reduce their own carbon footprint.

Both carbon taxes and cap-and-trade programs are market mechanisms with the goal to reduce pollution by making major carbon emitters pay in order to incentivize the adoption of clean sources of energy that have lower climate impacts. The difference is that a carbon tax has legislators establishing the level of taxation, while cap-and-trade's price is a function of the cap—the lower the amount of pollution allowed, the more entities covered by the policy bid up the price, leading to deeper pollution reductions. Both incentivize the cheapest pollution reductions (e.g. efficiency investments).²⁹

Carbon Capture and Storage (CSS) – (a.k.a. carbon sequestration) is the process of capturing and storing carbon dioxide before it is released into the air. This technology is currently being pursued to allow the continued use of fossil fuels.³⁰

²⁴ <https://openknowledge.worldbank.org/handle/10986/37455>

²⁵ <https://openknowledge.worldbank.org/handle/10986/37455>

²⁶ <https://www.c2es.org/content/carbon-tax-basics/>, Retrieved October 21, 2022

²⁷ Bliss, R.T., Potter, M.E. (2020), “ESG and Alternative Investments” Alternative Investments: An Allocators Approach. 4th Edition, Page: pp. 49-90. Chartered Alternative Investments Association.

²⁸ https://www.rggi.org/sites/default/files/Uploads/Fact%20Sheets/RGGI_101_Factsheet.pdf, Retrieved October 21, 2022

²⁹ <https://www.climatesolutions.org/article/2021-01/why-cap-and-invest-one-strategy-carbon-reduction>, October 21, 2022

³⁰ <https://sgp.fas.org/crs/misc/R44902.pdf>, Retrieved October 17, 2022