Climate Change Series, Introduction

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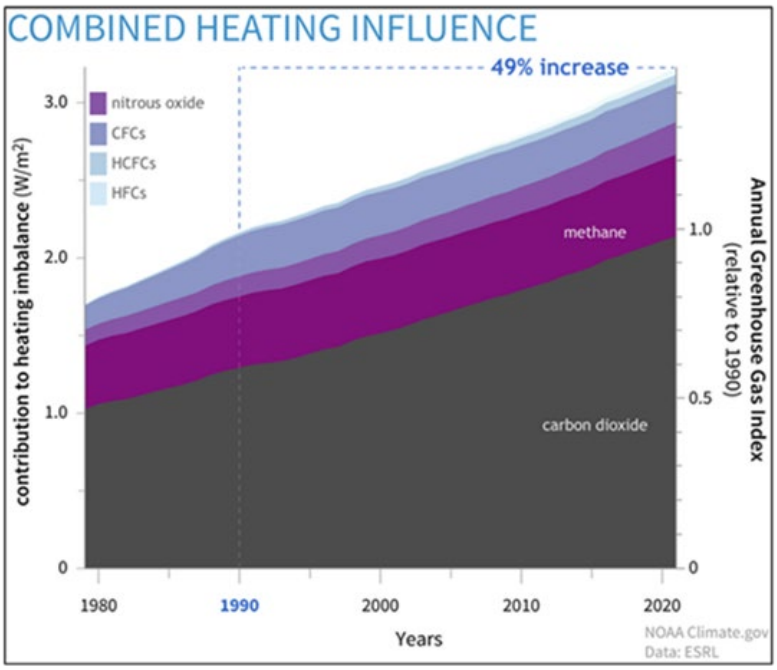
1. Primary Cause

The main cause of climate change is the human emission of greenhouse gasses (GHG).

The GHG also must be emitted by combusting (burning) hydrocarbon fuel without either:

- The same amount of GHG being absorbed during the manufacture of this fuel, plus a surplus amount being absorbed to:
  - Compensate for the energy required to manufacture and transport the fuel if generating this energy also produces GHG.
- And/or an independent process captures and sequesters GHG from a different, non-emitting source (like direct-air GHG-capture). Like the above other main bullet, a surplus amount of GHG should be absorbed and sequestered to:
  - Compensate for the energy required to capture and sequester the GHG, if generating this energy also produces GHG.

These GHGs absorb and retain the energy from solar radiation (light), thus heating up the atmosphere. Thus, the term: "global warming." The primary greenhouse gases (GHG) and their contribution to global heat imbalance over recent time can be seen in the chart below.[1]



[1] Rebecca Lindsey, Climate.gov, "Climate Change: Annual greenhouse gas index," June 17, 2022. https://www.climate.gov/news-features/understanding-climate/climate-change-annual-greenhouse-gas-index

Note that from 1990 to the present, the heating potential of these GHGs has increased almost 50%. All of the GHGs shown on the above chart are human-emitted (anthropogenic). Although our methods of generating them are somewhat different. We will cover this below, starting with the GHG with the highest impact.

2. Primary Greenhouse Gasses

2.1. Carbon Dioxide (CO_2)

A large majority of carbon dioxide is generated by burning stuff. If the "stuff" is organic, like wood, roughly the same amount of GHG is absorbed when it is growing, as is emitted when it is burning. Not that burning wood is "good," wood's combustion emits many dangerous pollutants, like:

- Organic and inorganic particulate matter
- Soot or black carbon
- Nitrogen oxide
- Carbon monoxide
- Volatile organic compounds
- Polyaromatic hydrocarbons
- Furans and dioxins
- Benzene and formaldehyde (toxic and carcinogenic).

But there is (roughly) no net emissions of CO_2. Thus, with some sophisticated pre- (like gasification) and/or after-treatment wood can be used as a "clean-fuel." The same applies to many other organic materials, but we need to make sure there is no leakage of GHG during pre- and/or after-treatment without compensation as we described in section 1.

As can be seen in the above chart, CO_2 is also responsible for a large majority of global warming. So much of the work in progress to mitigate this warming is focused on reducing CO_2 emissions. It is also very long-lived in the atmosphere, *estimates are often intentionally vague, ranging anywhere from hundreds to thousands of years.*[2] *The reason for the murky timeline is that CO_2 molecules, once they enter the air, follow different paths and can last for radically different amounts of time.*

2.2. Methane (CH_4)

Methane is the primary ingredient in "natural gas," and the production of this fuel is where most of the anthropogenic emissions come from. It is also emitted by many natural processes, but the good news is it relatively short-lived. *Methane, for instance—another important greenhouse gas—reacts with oxygen to turn into CO_2 and water within a matter of years, and that process can be observed and measured.*[2] The bad news is that it turns into CO_2, which is long-lived. Methane has a global warming potential (GWP) of 27 to 30 over 100 years. CO_2's GHP is 1.

[2] https://climate.mit.edu/ask-mit/how-do-we-know-how-long-carbon-dioxide-remains-atmosphere

2.3. Nitrous Oxide (N_2O)

The main human emission-sources of nitrous oxide are:

- Agriculture (mainly from nitrogen fertilizer)
- Fossel fuel combustion
- Industrial processes
- Biomass burning
- Sewage treatment plants

Nitrous oxide molecules remain in the atmosphere for an average of 121 years before being removed by sinks or destroyed by chemical reactions. One pound of nitrous oxide has 265 times the warming effect on the atmosphere than one pound of carbon dioxide.

2.4. Chlorofluorocarbons (CFCs), Hydrochlorofluorocarbons (HCFCs) & Hydrofluorocarbons (HFCs)

CFCs were the original refrigerant. HCFCs are the close neighbor of CFCs. The main difference between the two types of refrigerants was that HCFCs contain one additional hydrogen atom compared to CFCs.

Although these were very useful (and probably vital) gasses for humans, they were lost into the atmosphere during transportation and maintenance of refrigeration systems, and were very powerful greenhouse gasses. They also had other major environmental issues.

CFCs and HCFCs were phased out due to the Chlorine that they contained. In the 1970s it was found out that the Chlorine was damaging the ozone layer. Due to the excessive use and venting of CFCs/HCFCs into the atmosphere, a hole in the ozone had formed. In an effort to solve the issue the Montreal Protocol was formed. Numerous countries signed the treaty and all pledged to phase out CFCs/HCFCs entirely.

September 16, 2020, marked the 33-year anniversary of the original Montreal Protocol. Use of CFC refrigerants is now banned in the U.S., and new production and import of most hydrochlorofluorocarbons (HCFCs) were phased out as of 2020. Replacing these HCFCs in new equipment and for system retrofit are many new hydrofluorocarbons, or HFCs, and HFC-blend refrigerants that include R-410A and R-407C. Widely used HFCs have lifetimes after being emitted of years to decades in the atmosphere.

Note that each of the above abbreviations cover a large family of compounds, each with a different global-warming potential (GWP, CO_2 has GWP of 1). These range from well under 1 to almost 15,000. To see these go through the link immediately below. The site linked below that is additional information on this subject.

https://ghgprotocol.org/sites/default/files/2024-08/Global-Warming-Potential-Values%20(August%202024).pdf

https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

Also note that the lifetime in the atmosphere also covers a wide range for these substances, ranging from a few days to almost 250 years. The good news is they are emitted in pretty tiny amounts. Go through the link below for more information.

https://www.fluorocarbons.org/wp-content/uploads/2020/07/2020_07_27_Fluorocarbon-Molecules-environmental-properties-and-main-applications-2020-July.pdf

3. Climate Change Duration

If we stopped emitting greenhouse gasses (GHG) today, and did nothing else to solve this problem, it would be centuries before the climate returned to preindustrial conditions. The other bad news is that we humans are pretty thoroughly addicted to burning GHG-emitting fuels. If we (sensibly) work really hard to free ourselves of this addition, we might reduce the **growth** of these emissions by the end of this century, and start reducing these emissions during the following century.

Note that the first line in the above paragraph says: "…did nothing else to solve this problem," which leads to the question, what can we do. Actually, several things. The easiest is to: (1) expand the world's forests since trees absorb and sequester CO_2, (2) allow the trees to reach a reasonable level of maturity and cut them down, and (3) build long-lived structures from them, and (4) plant more tree seedlings. However, we would need to do this continually on a massive scale to sequester a significant amount of CO_2. However, not only is the above sequence relatively easy, but it has several side-benefits:

- We can start doing it very soon (like next year) because we don't need to invent anything.
- As this sequence matures, it will provide many reasonably good-paying jobs that each only require a few months of training.
- The workers in the above jobs get to live in healthy, rural environments.
- Since the above four steps happen sequentially over 20 or 30 years, the work-force could be added at a reasonable pace.
- As each worker gained experience some could be up-trained to be a supervisor and then up-trained to be a manager as the work-force expanded.
- The "long-lived structures" could serve a wide range of functions. For instance, wood has been used to build a large domed stadium[3], as well as the obvious houses, shopping centers, apartment buildings, factories, etc.
- The structures (and the wood to build them) would have value and, thus pay all of the workers' salaries (including the workers that build the structures).

Another thing we can do, which is not quite as easy is direct air capture of CO_2 and either geologic sequestration or utilization for a function that chemically changes the CO_2 to a non-GHG-compound. An example of this type of utilization would be to enrich the air inside of a greenhouse to accelerate plants therein growth rate. The plants would convert the CO_2 to oxygen and the carbon in the plant's biomass.

4. The Penalty for Non-Diligence

This will be a short section. Global warming will have many consequences in future decades, even if we do diligently repair our climate. These consequences include.

- Destruction of our ecosystems
- Increasing secondary and higher-order destruction (like increasing wildfire and sea-level rise)
- All types of destructive storms
- Many human-deaths from heat-related causes

[3] https://en.wikipedia.org/wiki/Superior_Dome

- And because of all of the above, human deaths from wars, famine and other higher-order disasters.

Understand that this is not my battle. I will be very lucky to still be alive (and hopefully, still writing) a decade or two from now. All I can do is make recommendations for future generations.