Global warming and global action beyond COP27

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In this article I want to review the causes of global warming, examine which greenhouse gases and human activities are most responsible for it, and what we must do globally to curb it, beyond COP27, the latest annual UN conference that took place in November 2022 in Egypt.

In trying to reach a broad audience, I realize that some readers may already be familiar with arguments and details presented here for the sake of completeness. My goal is to show that this existential problem still has solutions but that we must act with much greater urgency if we want to control it before it's too late.

How the greenhouse gases work

Global warming is caused by the following mechanism:

The radiation from the sun heats up our earth. This heat would normally be re-radiated into outer space by infrared radiation. However, our human activities annually emit about 50 billion tons or Gigatons of greenhouse gases of *equivalent* CO_2 (carbon dioxide). Of these, about 30-50% are absorbed by the oceans (thereby acidifying them and seriously affecting their entire ecology), and about a quarter are stored in trees and plants worldwide through the process of photosynthesis via the chlorophyll in the leaves. The remaining 17-20 Gtons accumulate each year in the atmosphere, and similarly to the glass covering a greenhouse, block the infrared radiation from escaping by reflecting it back to earth and raising its temperature. The total accumulation of these gases is about 3200 Gtons. Since the beginning of the industrial age, it has produced a temperature increase of about 1.2 degree Celsius with a total

equivalent CO_2 gas density by volume of about 450 parts per million molecules in our atmosphere. The reason the word "*equivalent"* is used is because ~70% of the effect is due to CO_2. The remaining 30% is caused by CH_4 (methane in natural gas) which has a Green House Potential (GHP) ~28 times greater than CO_2, smaller amounts of N_2O (nitrous oxide) with a GHP of 280, as well as fluorine and other greenhouse molecules.

Future temperature increases

In 2015 when the Paris Agreement on Climate Change was signed by 195 countries, it was projected that if the world wanted to avoid the worst and most disruptive effects, the total temperature increase by 2050 would have to be limited to 1.5 degree Celsius. According to the Intergovernmental Panel on Climate Change (IPCC), we are NOT on track to meeting this goal. Already at the current 1.2-degree Celsius increase, the planet is witnessing very serious storms, floods, droughts, wildfires, and sea level rises. As examples, one third of Pakistan was flooded this year, and hurricanes are devastating Florida and Puerto Rico. Unless the countries that produce the most greenhouse gases make draconian cuts in the near future, which seems unlikely, we may well be headed towards a 2-degree Celsius rise by 2050, which could well be disastrous. Under these circumstances, ~30% of the high-altitude glaciers could melt, the Northern polar ice cap could disappear entirely, and the Siberian tundra permafrost may release all its methane, two entirely irreversible phenomena.

Major responsible countries

When we look at all the countries in the world, we see that a group of six are responsible for 26.7 Gtons, more than half the annual total release of greenhouse gases, as shown in Table 1 below:

Table 1: Largest country emissions and GDP statistics

Countries in 2022	Gtons	Tons/ Capita	% of Global Emissions	GDP in $Trillions
China	14	10	28%	18.3
United States	4	12	8%	23
European Union	3	7	6%	17
India	3	2.3	6%	3.5
Russia	1.7	1.1	3.4%	2.1
Japan	1.0	0.8	2.0%	4.5

Of these, the net contributions of probably China and certainly India will continue to increase for several years, and we don't know what effect the war in Ukraine will have on the other group of countries.

What was achieved at COP27 in November 2022?

As this article is being written, the twelve-day 27th Conference of the Parties or COP27 has just ended in Sharm el Sheik, Egypt. Its major achievement has been that the wealthier industrialized countries have agreed to create a fund to pay the poorer developing nations for the losses and damages already incurred by them because of global warming. The details of the fund's size and who will benefit from it remain to be determined. Other than that, the U.S. and Japan made a

commitment to Indonesia to help it wean itself financially from using its coal. Also, according to Michael Bloomberg, the participants seemed to gain a better understanding of how domestic private sectors and banks could be incentivized to invest in worldwide greenhouse gas reductions. Unfortunately, no other new firm commitments were made.

Bill Gates' excellent book and some of its consequences

One positive contribution that was made in 2020 was the comprehensive book published by Bill Gates on "How to avoid a climate disaster." The book doesn't have all the answers, but it creates a complete inventory of all the human sources of greenhouse gas emissions and where technological innovations, and investments are needed to curtail them. Table 2 below summarizes the percentages contributed by each human activity in the world, to which I have added the percentages of emissions in the U.S. for comparison.

Table 2

Human activity	% of world emissions	% of U.S. emissions
Producing electricity	27%	27%
Making things (steel, cement, plastics, etc,)	31%	22%
Growing things (plants, animals), land management	19%	10%
Transportation (cars, trucks, ships and planes)	16%	28%
Keeping warm and cool (heating, cooling buildings)	7%	12%

With this tabulation, Gates identified what he calls the Green Premium or excess percent cost incurred by a green technology that would avoid

the release of greenhouse gases and figured out systematically what innovations are needed as early as possible to replace them by the most efficient fully green ones. Gates addresses these two challenges in lengthy detail which I cannot possibly match here, but I am summarizing some of them below, adding some ideas of my own.

Technical innovations needed

1)Electricity: Many of the activities listed in Table 2 above include the use of electricity. If we consider that we will have to charge our fully electric car fleet and the upcoming increase in world population, the need for electricity may as much as triple (currently 5000 gigawatts of power). All of this will have to be clean green electricity. It must be generated by renewable solar or wind energy (which are both intermittent), some more hydroelectricity, possibly nuclear fission reactors (if they can ever be made safe, and their radioactive waste sequestered for thousands of years), and possibly nuclear fusion reactors. The very recent breakthrough at LLNL's National Fusion Ignition Facility is good news although it only yielded 1 kw-hour out for ½ kw-hour in. Barring any surprises, a commercial electric power station based on fusion is still ~30 years away. It will not create as much radioactive waste as fission reactors, but it will still not be free of it

The intermittency problem (daily and seasonal) of solar and wind may not be solved by storage batteries alone, but the energy may be stored in the future in hydrogen generated by electrolysis of water with excess renewable electricity. Safe hydrogen storage still requires considerable R&D.

2)Manufacturing and construction: The green premium of making steel and plastics may be brought down close to 1 by replacing heat from greenhouse gases by electrical heat. On the other hand, the making of

cement from limestone calcium and sand does not yet seem to have an affordable green alternative. A revolutionary invention is urgently needed for the construction of buildings, dams on rivers for hydroelectricity, and bridges, let alone dikes to protect us from sea-level rise).

3)Agriculture: With the projected world population growth, at least 50% more food will be needed. Plant growth can be increased with fertilizers containing phosphorous, potassium and nitrogen, but nitrogen has a problem because it turns into nitrous oxide which is a potent greenhouse gas. We will need to waste less food and produce better fertilizers to promote regenerative agriculture. Since **aerobic** composting works, could we mass produce artificial "manure" without methane, from plants? [Stay away from landfills!]

Cattle and pigs by belching and farting methane produce about 5% of world greenhouse gases. A recent discovery apparently reduces the methane belched by cows by feeding them small amounts of seaweed. This would be good news if implemented on a large scale. However, growing cattle and pigs is a very inefficient method of providing us with proteins and fats. The best way would be to drastically cut down on our red meat consumption.

As far as land management is concerned, the most important step we can take is to completely stop the destruction of rain forests (already cut back by 17% in Brazil). On the other hand, planting a billion new trees in the world as some have suggested is a losing proposition. We wouldn't even find the necessary water!

4)Transportation: There are currently about one billion cars in the world, most of them propelled by gasoline. By ~2050 they will all have to be replaced by electric vehicles with inexpensive rechargeable batteries. The same is true for small trucks and buses. As to large trucks, ships and planes, batteries are too heavy for them, and we will have to

produce biofuels or electro fuels to propel them. Sugar cane and switchgrass are good sources but much more R&D is needed in this area.

5)Buildings: Buildings will have to be much better insulated, and heated and cooled entirely by electricity. The efficiency of current air conditioners can easily be doubled, but the use of gas for air conditioners and water heaters can best be replaced by heat pumps.

In all these areas, we must increase conservation and discourage wasteful consumption.

Are there any other methods available to 1) decrease greenhouse gases in the atmosphere, or 2) decrease the sunlight heating the earth? Yes, but they are long shots. The first category includes Carbon Capture and Storage (CCS) at the point of production like a cement factory, but where to store the gas securely is not obvious. Another possibility is to directly capture the gas from the atmosphere with an absorbing surface. This process works but is not very efficient. The second category includes reducing the sunlight heating the earth by releasing billions of light-reflecting sulfur micro pellets into the upper atmosphere. However, this form of geoengineering may take at least ten years to develop and a fleet of high-altitude airplanes to spread around the planet, and it may cause irreversible collateral damage. Another less invasive technique would be to make clouds brighter and more light-reflective by seeding them with salt.

Economic obstacles and incentives

We have just seen that to solve our global warming problem, we will need many innovations. If all these innovations had a green premium of less than 1, i.e., if the green technology were less costly than the current non-green one, we could count on the market economy to adopt it naturally within a short transition period. Unfortunately, this is not the case.

When George H. W. Bush became President in 1988, like many Republicans at the time, he was ideologically inclined to make the fight against global warming an important part of his agenda. After all, President Richard Nixon had already created the E.P.A. in 1970. Unfortunately, Bush's chief-of-staff John Sununu talked him out of it: "it's going to hurt the economy and your popularity." Bush acquiesced and most Republican politicians since then have followed suit. Fundamentally, it's possible that many of them are not climate deniers in principle but worry that fighting global warming affects the economy negatively and antagonizes the oil, gas and other businesses that support them. They don't fully appreciate that a green economy can result in enormous new business opportunities and jobs. Maybe, some of them will change their minds in the future for this reason and for the good of the planet.

Who pays to curb global warming?

Global warming affects the entire world but is caused predominantly by the wealthiest industrial countries. We don't know exactly what it will cost to fix it, but we know that the people who will suffer the most if it isn't curbed are the poorest. We do know also that if the money is NOT spent now by the richer countries, the cost of sustaining the planet later will be much higher for all. The current annual GDP of the world is 96 trillion dollars. As seen in Table 1, the U.S., the European Union, Japan and Russia add up to half of this. Except for Russia in the current atmosphere, you might think that these rich countries could jointly spend $200 billion per year (less than ½%) on this problem to save the entire world community. To put this number in perspective, consider that with its 2022 Inflation Reduction Act, the Biden Administration has dedicated $369 billion to deal with the problem domestically over the next seven years. That is $50 billion per year, a large sum but nothing in comparison with our defense budget of $858 billion this year!

In the last three chapters of his book, Bill Gates also makes many constructive economic suggestions on how governments at all levels, private sectors, universities, foundations (like his) and we as individuals can help this cause. Here are a few examples.

Governments can act to slow down population growth to decrease overall demand. They must greatly increase R&D to speed up the necessary innovations via their national laboratories, universities or other research institutions. Gates seems to favor raising carbon taxes, fees, or cap-and-trade systems, but Bill McKibben has given convincing arguments that it is far too late now for these measures to have a decisive effect: even a large tax of $100 per ton of carbon would do nothing. Besides, economist Paul Krugman argues convincingly that government subsidies have a better chance of overcoming political opposition. Then, once the proper innovations become available, the governments must help them make it to the market at large, "beyond the valley of death." The private sector can then feel safe investing in these innovations just as it is building solar and wind plants, because they are profitable.

State and local governments can and often do (but not always) adopt positive policies like California with its automobile fuel efficiency standards. In San Mateo County where I live, we have the Peninsula Clean Energy coalition which only delivers renewable electricity and the very climate-proactive State Senator Josh Becker. Stanford University with the Precourt Institute and the Woods Institute for the Environment is also making important R&D investments in the field.

On the other hand, the California Public Utility Commission (CPUC) took a highly regressive step on December 15th, 2022, against future solar rooftop owners in the state. As a result of fierce lobbying by the private utilities like PG&E, the CPUC changed the rules by which any **new** owners will be compensated from now on. Under previous (so-called NEM2) rules, California utilities paid for a private solar kilowatt-hour delivered to the grid about the same (30 cents) as they charged for a

conventional kilowatt-hour purchased from them after sundown. In contrast, under the new (NEM3) rules, they will pay only 25% (~8cents) for a solar-produced kilowatt-hour after April 15th, 2023. Although the 1.5 million current owners (like me) will be grandfathered under the old rules, this will discourage future potential homeowners from buying solar panels unless they are wealthy enough to pair them up with storage batteries that are still far too costly (up to $20 thousand for a 13-kWh battery). Very poor decision for sunny California!

Finally, we as individual consumers have other options. We can buy electric cars, which will be helpful as long as we recharge their batteries with clean green electricity and we can install heat pumps outside our houses to get rid of natural gas. We can switch from cow to soy or oat milk (just as good), and to paraphrase Nancy Reagan, we can "*just say no to red meat*!" The cattle ranchers and butchers will not love us for this and will fight these steps tooth and nail, but they will have to adapt. Cows and sheep may be grown just for leather and wool. Free-range poultry, fish (even farmed) and other seafood may still be used for human consumption, helping us lower our cholesterol and heart disease. Third-world countries can make important contributions in these areas.

Never underestimate what individuals can do. One example that stands out is former Professor Art Rosenfeld at UCB and LBNL who completely revolutionized energy conservation standards, first in California and then everywhere else. He developed new heat-trapping windows, new light bulbs, caused industry to double the efficiency of refrigerators, and computer-modeled the improvement of buildings for temperature control. Art ended up becoming California Energy Commissioner and working for the Clinton Administration, where he probably inspired VP Al Gore with his ideas. Art's innovations spread all over the world.

Conclusions

The famous economist John Maynard Keynes pointed out that ***demand*** is what pushes the economy into action. And fear is a strong promoter of

demand. When Covid-19 hit humanity as an existential threat, government and the private sector didn't waste much time to work together to produce vaccines, even though many people were vaccine deniers. The danger of the Maldives, Bangladesh, Madagascar, Florida and coastal cities like New York and San Francisco being under water and creating millions of refugees is just as scary as the pandemic and should trigger even greater demand.

The world spends close to 2 trillion dollars per year for defense, including horrible nuclear weapons, with very little popular objections but argues *ad nauseam* over a small fraction of this sum to fight global warming. As I have argued in my book "The Human Condition," our species "Homo" doesn't deserve to be called "Sapiens". Will we ever wake up?

Here is my final suggestion. As a scientist who worked all his life with particle physicists, I am keenly aware of the prestige and excitement created annually by the Nobel Prize. Why not ask Bill Gates and Michael Bloomberg to create a billion-dollar fund together to establish the Gates-Bloomberg Prize to save our planet?

Let us act collectively now before it is too late. Greta Thunberg and our grandchildren will be here in 2050 and they will never forgive us if we don't.