



Global Warming in Round Numbers— Toward a Zero-Carbon Economy

By Michael A. Tamor



Michael A. Tamor recently retired as the Henry Ford Technical Fellow for Energy Systems and Sustainability at Arizona State University. He is a Fellow of the American Physical Society. This East-West Wire is based on a presentation Dr. Tamor made at the East-West Center in February 2019. He can be reached at mtamor@bex.net.

“I believe we can decarbonize the economy by enacting clear and effective goals and allowing the maximum scope for innovation and personal choice.”

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Evidence of rising global temperatures is overwhelming. Likewise, the evidence is clear that people are causing most of this rise through their use of fossil fuels. Yet people are not behaving as if they feel threatened by the crisis that climate models predict. Two important arguments can cut through this confusion—first, that global warming is real and humans are causing it, mainly through carbon emissions, and second, that we can achieve a carbon-neutral economy without giving up the lifestyle we enjoy.

Global warming is real and humans are causing it

Scientists have a very good record of how much carbon dioxide (CO₂) was in the atmosphere as far back as one million years ago. This record shows that the CO₂ concentration in the earth’s atmosphere is now at the highest level since humans began to walk upright. Most of this increase has occurred in the past 100 years, and CO₂ concentration is still rising fast.

The evidence also shows that humans are causing this rise in CO₂. For one thing, concentrations of atmospheric CO₂ around the world are measurably higher downwind of industrialized areas.

Scientists know that increasing CO₂ concentration traps more heat in the atmosphere—the famous greenhouse effect. And average temperatures are going up everywhere in the world, with land and the air warming about twice as fast as the ocean surface.

The difference between warming on the land and on the ocean drives seemingly contradictory trends. Because evaporation increases exponentially with temperature—and what goes up must come down—global average precipitation must increase. With temperatures rising faster on land than on the ocean, however, the increase in rain and snowfall is less than the increase in evaporation off the land. This simple math tells us that we face a future of more rain and snowfall and more storms, but combined with widespread droughts.

We can fix it

The 2015 United Nations Framework Convention on Climate Change (UNFCCC) seeks to hold the increase in the world’s average temperatures to 1.5 degrees C above pre-industrial levels. A second goal is to achieve a balance between human-caused emissions and removal of greenhouse gases from the atmosphere.

To meet these goals, it is important to focus first on carbon emissions, simply because CO₂ is the dominant contributor to global warming and it does not break down in the atmosphere. Because it makes sense to take the easy actions first, what follows is a possible “decarbonization” strategy in order of increasing cost and difficulty.

Stop burning fossil fuels for electricity. As of 2016, electricity generation accounted for 36 percent of all CO₂ emissions in the US. Over the past two decades, the cost of renewable electricity generation has declined much more quickly than anyone anticipated, so that today in many regions electricity from solar or wind power costs the same as power from coal or other fossil fuels.

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In some regions, it actually costs less. However, cheap at the generator does not always mean cheap at the meter. The shift to 100 percent non-fossil electricity will require re-engineering the entire system for electricity transmission and distribution.

Expand the use of electricity. This will be easier in some sectors than others. It will be relatively easy to switch to electricity for heating and other energy needs in commercial and residential buildings, estimated in 2016 to account for roughly 11 percent of US CO₂ emissions. It will be feasible, but more expensive, to switch to electricity for most industrial uses, which accounted for another 16 percent of emissions. However, some processes, such as making steel and cement, must rely on combustion. These will require a substitute renewable fuel, most likely hydrogen or a renewable hydrocarbon.

The transportation sector, which accounted for 36 percent of all US CO₂ emissions in 2016, is also undergoing significant changes. Adoption of light-duty electric cars is forecast to accelerate dramatically when cost parity is reached in the early 2020s. Limited range is still a challenge, however, along with the need to install more charging infrastructure, but we are seeing rapid progress in both these areas. In the coming decades, roughly 80 percent of personal travel is likely to be electrified.

As technologies improve, electric trucks are entering the market, and electric buses are rapidly replacing diesel in many regions across the US. Biofuels and hydrogen-powered fuel cells offer other alternatives, over the longer term, particularly for rail and ocean shipping.

Aviation is a special problem because the weight of the fuel is an extreme constraint. At takeoff for a long-distance flight, up to one-half of the total weight of an airplane is fuel. Without high-density aviation fuel, currently produced from fossil sources, the fuel would weigh more than plane.

Develop non-fossil fuels. Even with massive electrification of vehicles and industrial processes, there will still be a need for large quantities of energy-dense, non-fossil hydrocarbon fuel for transportation and industry. Biofuels may be one solution. Today's biofuel technologies release nearly one-half of their hard-won carbon back into the atmosphere as they convert biomass to fuel, but research and development continue to improve these technologies, and there has been a lot of progress.

Hydrogen from renewable sources may eventually prove a good option, but it is still in the research and development stages. Currently 95 percent of hydrogen fuel in the US comes from natural gas—a fossil fuel. Two innovative approaches are now at the research stage: the use of renewable hydrogen to double the yield of fuel

from biomass and the production of fuel from carbon captured directly from the air.

What does a zero-carbon economy look like?

The mainstay of the zero-carbon economy is renewable electricity—as much as three times more than we use today. What cannot be electrified must be powered by renewable fuel sources wherever possible. Most of the technologies needed to start the transition to a zero-carbon economy are already available, such as solar and wind power, and those needed to complete the transition are not far off.

A simplified model of a growing US economy suggests that shifting entirely away from fossil sources of energy will cost roughly 1 percent of gross domestic product (GDP). This may sound onerous, but it is equivalent to the cost of one mild recession. The benefits in terms of jobs, a cleaner environment, and quieter cities—not to mention avoiding global catastrophe—certainly outweigh this cost.

Decarbonization is a 50-year enterprise, but government policy must focus first of all on stopping the emission of fossil CO₂, which today accounts for 82 percent of all greenhouse gas emissions. I believe this can be done without mandating behavior or unduly interfering in markets, but rather by enacting clear and effective goals and allowing the maximum scope for innovation and personal choice.



1601 East-West Road
Honolulu, HI 96848-1601
EastWestCenter.org

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Series editors:

Derek Ferrar, ferrard@EastWestCenter.org | Sidney B. Westley, westleys@EastWestCenter.org