ASAP Research Note:

Effect of CO_2 Emissions on Global Temperatures

November, 2019

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Global warming is occurring as predicted. A scientific consensus exists that global temperature is about 1.0 degree Celsius warmer today when compared with the 1850-1900 global temperature. Fig. 1 and Fig. 2 show the actual measured increases in global temperature and the projections to 2100. ASAP research indicates that the current trajectory of increases in average global temperature above pre-industrial levels is +1.5 degrees Celsius in 2057 and +2.0 degrees Celsius in 2093 as shown in Fig. 2.

ASAP's global temperature projection is relatively similar to the United Nations, Intergovernmental Panel on Climate Change (IPCC), Scenario B1, which assumes that humans worldwide will make more sustainable development choices by using a greater range of more efficient energy technologies such as solar and wind energy. In the IPCC Scenario B1, carbon emissions are projected to increase from today's rate of about 10 billion metric tons per year to about 12 billion metric tons per year in 2040, and then gradually decline to 5 billion metric tons per year by 2100. The downside of this carbon emissions pathway is that global temperature increases +2.0 degrees Celsius by 2100, and temperatures will continue to increase in the twenty-second century. This scenario is not acceptable if we accept an upper limit of +2.0 degrees Celsius, and steeper carbon emissions reductions need to occur.

The Paris Climate Agreement (November 2016) is about limiting the increase in average global temperature to below 2.0 degrees Celsius above pre-industrial levels, 1850-1900, and to aspire to limiting global temperature rise to 1.5 degrees Celsius. Aligning with a 1.5 degrees Celsius outcome is about preventing the worst projected climate impacts. IPCC climate scientists state that to stay below the +2.0 degrees Celsius increase in average global temperature will require the entire world to realize a zero net-carbon emissions, which entails a complete end to fossil fuel combustion by 2070. The +1.5 degrees Celsius target is likely not achievable, and the +2.0 degrees Celsius limit is a huge challenge.

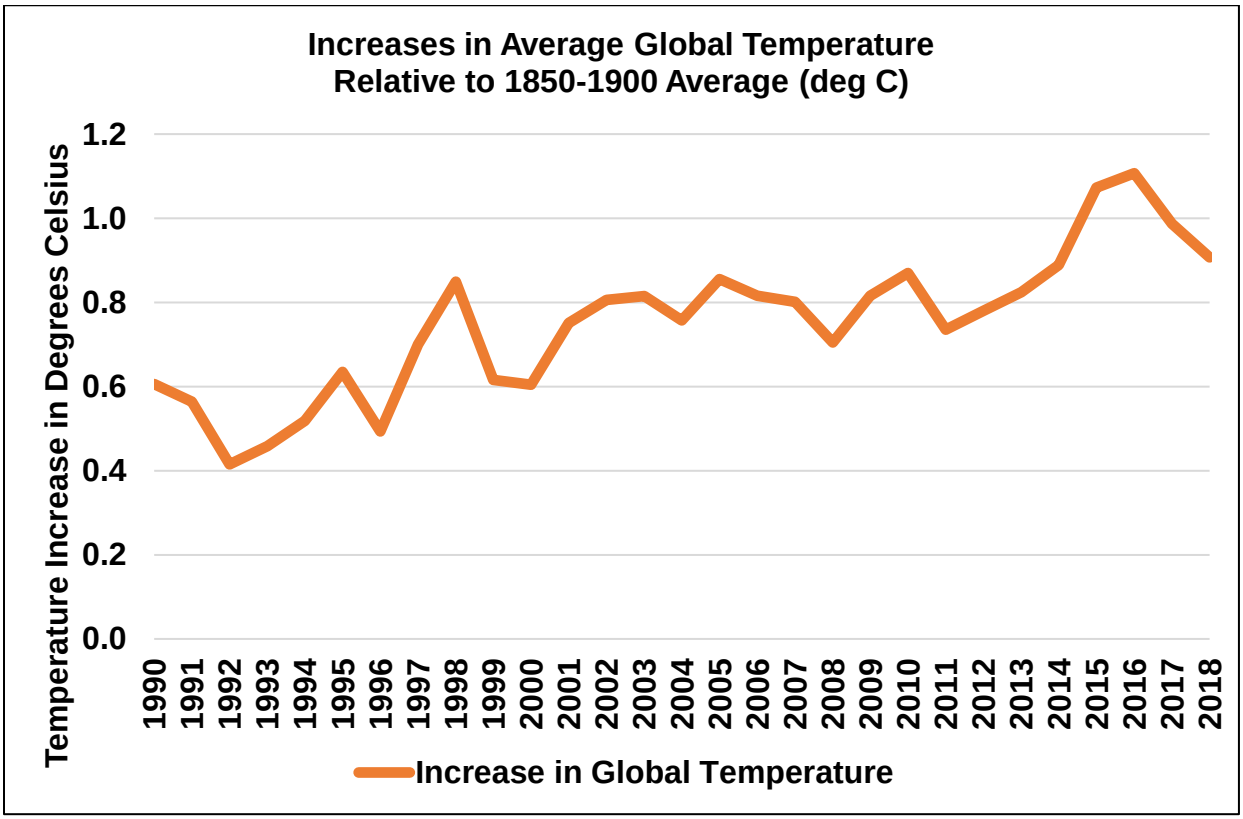

Figure 1. Increase in average global temperature.

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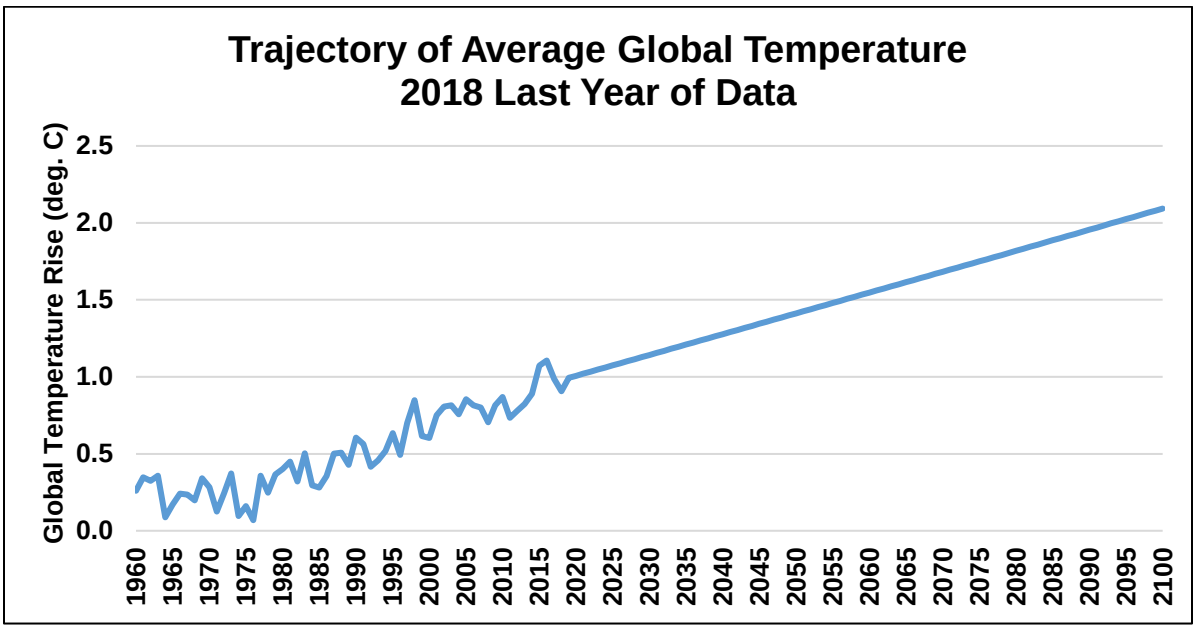

Figure 2. The Hadley Centre average global temperature estimates are anomalies to 1960-1990 averages. The 1850-1900 average global temperature is 0.31 degrees Celsius lower than the 1960-1990 average, hence, need to add 0.31 degrees C to the Hadley Centre 1960-1990 anomalies. The Boulton and Watt steam engine was designed from 1763 to 1775 and marks the beginning of the industrial era, but it took over a hundred years for industrialization to develop. Therefore, the 1850-1900 average is the benchmark global temperature for the pre-industrial era.

Carbon emissions from the human combustion of fossil fuels is the great climate change event caused by the industrial revolution. While the natural carbon cycle has many components that affect climate, they are largely in balance. What is throwing the natural carbon cycle out of balance are the carbon emissions from the human combustion of fossil fuels. The increase in human carbon emissions from 1960-2018 is shown in Fig. 3. The carbon emissions take the form of carbon dioxide, which settles in the troposphere at an altitude of 5 to 6 miles and cause an increase in the atmospheric carbon dioxide (CO_2) concentration levels. It is the atmospheric CO_2 concentration that creates global warming, i.e., the greenhouse effect, and causes climate change. Today, the atmospheric concentration of CO_2 is greater than any level recorded over the past 400,000 years and will continue to increase at an increasing rate if carbon emissions are not abated.

Therefore, the effects of global warming, which are being felt today, will only increase in intensity in the future as the world continues to warm. A sobering thought is that sea levels have been 50-80 feet higher than 2018 sea levels when atmospheric CO_2 concentration levels have reached their maximum levels during past glacial interludes, and the cause of concern is that current atmospheric CO_2 concentration levels are at a historical high point. Policymakers are confronted with responding to the risks posed by emissions of greenhouse gases in the face of significant scientific uncertainties. However, they are also faced with the fact that climate-induced environmental changes cannot be reversed quickly, if at all, owing to the lengthy time scales associated with the climate system. The relevant question is not “what is the best course for the next 100 years,” but rather “what is the best course for the near term given the expected long-term climate change and accompanying uncertainties.” ASAP believes the prudent course is for society to make the transition to an all electric economy with wind and PV electricity. The benefits are clean air, and the costs are affordable.

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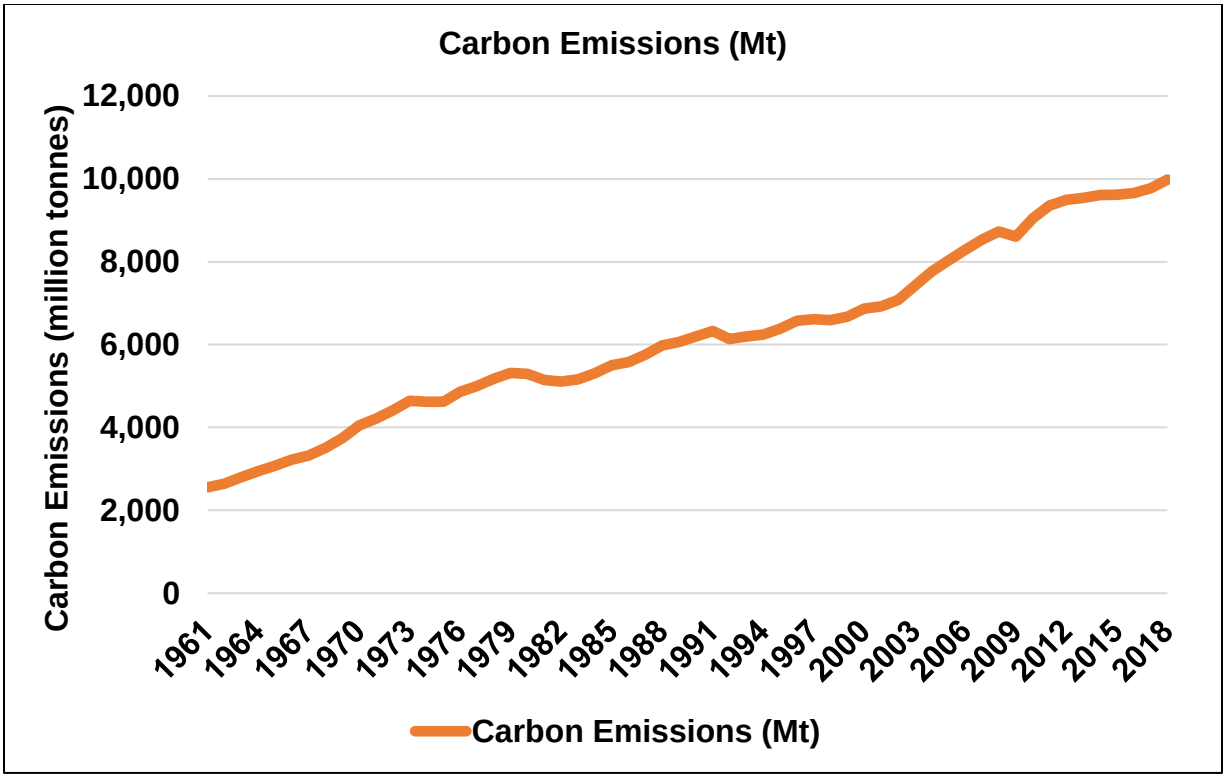

Figure 3. Human caused carbon emissions.

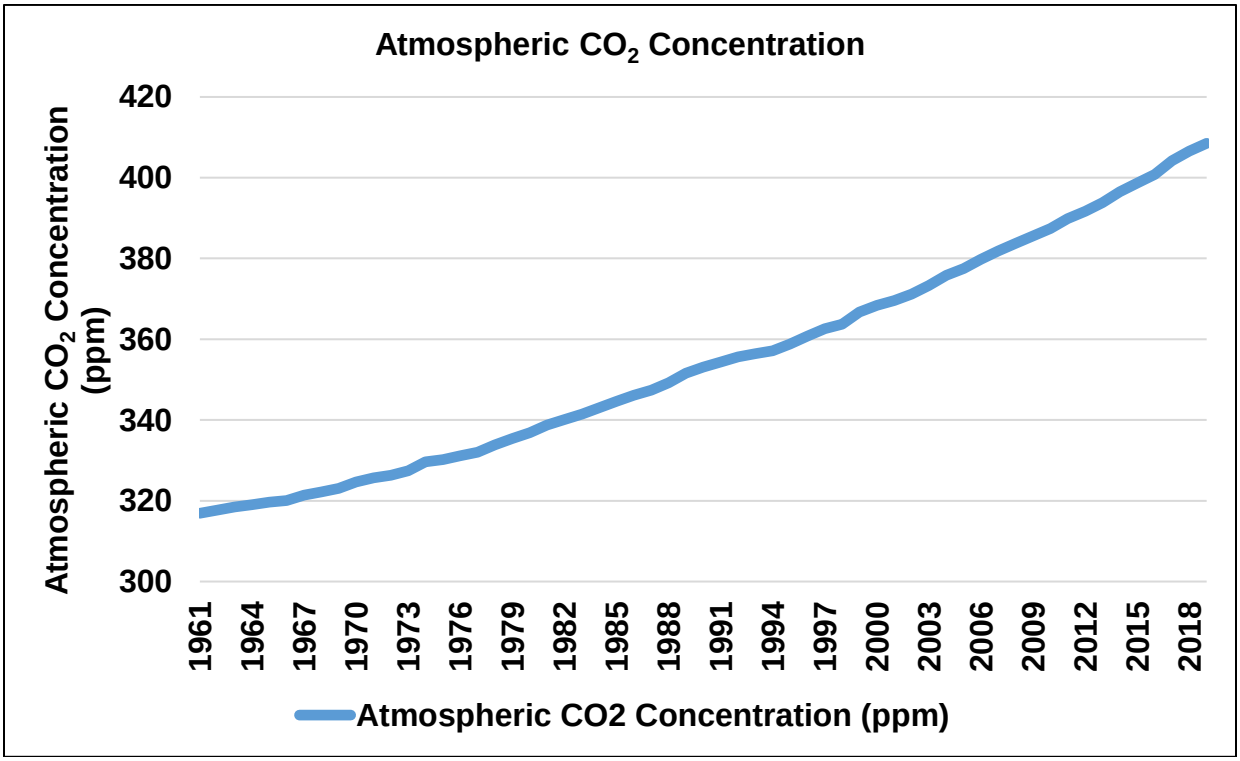

Figure 4. Atmospheric carbon dioxide concentration levels.

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ASAP's Analysis of the Effect of Human Caused Carbon Emissions on Global Temperature

ASAP demonstrates the effect of human carbon emissions on global temperature by analyzing human carbon emissions data, atmospheric carbon dioxide concentration data, and average global temperature data from the sources listed in the reference section below. These are the same data sets used by major climate change organizations and are available to the public.

As previously mentioned, the carbon emissions effect on global temperature occurs in two steps. The first step is that increases in carbon emissions cause an increase in atmospheric CO_2 concentration levels. The second step is that increases in atmospheric CO_2 concentration levels cause an increase in global temperature. ASAP tests these cause and effect pathways with regression methods.

Two regression runs test the following two hypotheses:

1) humans burn fossil fuels releasing carbon dioxide into the atmosphere, which causes an increase in the atmospheric concentration of carbon dioxide

2) the increase in the atmospheric concentration of carbon dioxide causes an increase in global temperature

The regression results provide strong support for the two hypotheses. Human carbon emissions account for 98% of the observed increase in atmospheric carbon dioxide concentration levels. The increases in atmospheric carbon dioxide concentration account for 70% of the observed increase in global temperature. The regression results are provided in the appendix.

ASAP is using a simplified climate model, but the results are consistent with scientific analyses that apply a full range of climate factors. Climate scientists attempt to measure all the factors that affect the amount of energy that reaches and remains in the Earth's climate system, which are referred to as "radiative forcings." A list of the radiative forcing mechanisms includes the effect of aerosols, atmospheric ozone, volcanic activity, oceans, forestation, land use, variations in solar radiation, natural climate cycles, and others in addition to fossil fuel carbon emissions. The climate forcing effects of many of these factors can be found in the reference section under "Carbon Brief," and it should be noted that fossil fuel carbon emissions are by far the largest radiative forcing factor.

How Is the U.S. Faring in the Reduction of Fossil Fuel Carbon Emissions:

In 2018, U.S. carbon dioxide emissions were 6,677 Mt (million metric tons). The peak in U.S. carbon dioxide emissions occurred in 2007 at 7,416 Mt of CO_2 equivalent and have declined 10% to the 2018 level as shown in Fig. 5. In other words, the U.S. has reduced carbon emissions by 10% over the past eleven years. Much of the U.S. reduction in recent years has been the result of retiring coal power plants and replacing them with combined-cycle natural gas power plants. However, U.S. carbon dioxide emissions in 2018 are still 4% higher than the 1990 level.

The two sectors with the highest CO_2 emissions are transportation with 28% of total emissions and electricity generation with 27% of total emissions, refer to Fig. 6. With the phase-out of all fossil fuel power plants and 100% adoption of electric vehicles, the U.S. can realize a 56% reduction in CO_2 emissions. Electric vehicles (EV) sales in 2019, which include plugin hybrid EVs, were somewhat less that the 360,000 vehicles sold in 2018. At present, U.S. EV sales represent 2% of the vehicle market. In conclusion, the U.S. needs a dramatic increase in the annual adoption rate of zero emissions technologies if global CO_2 emissions reduction goals are to be realized.

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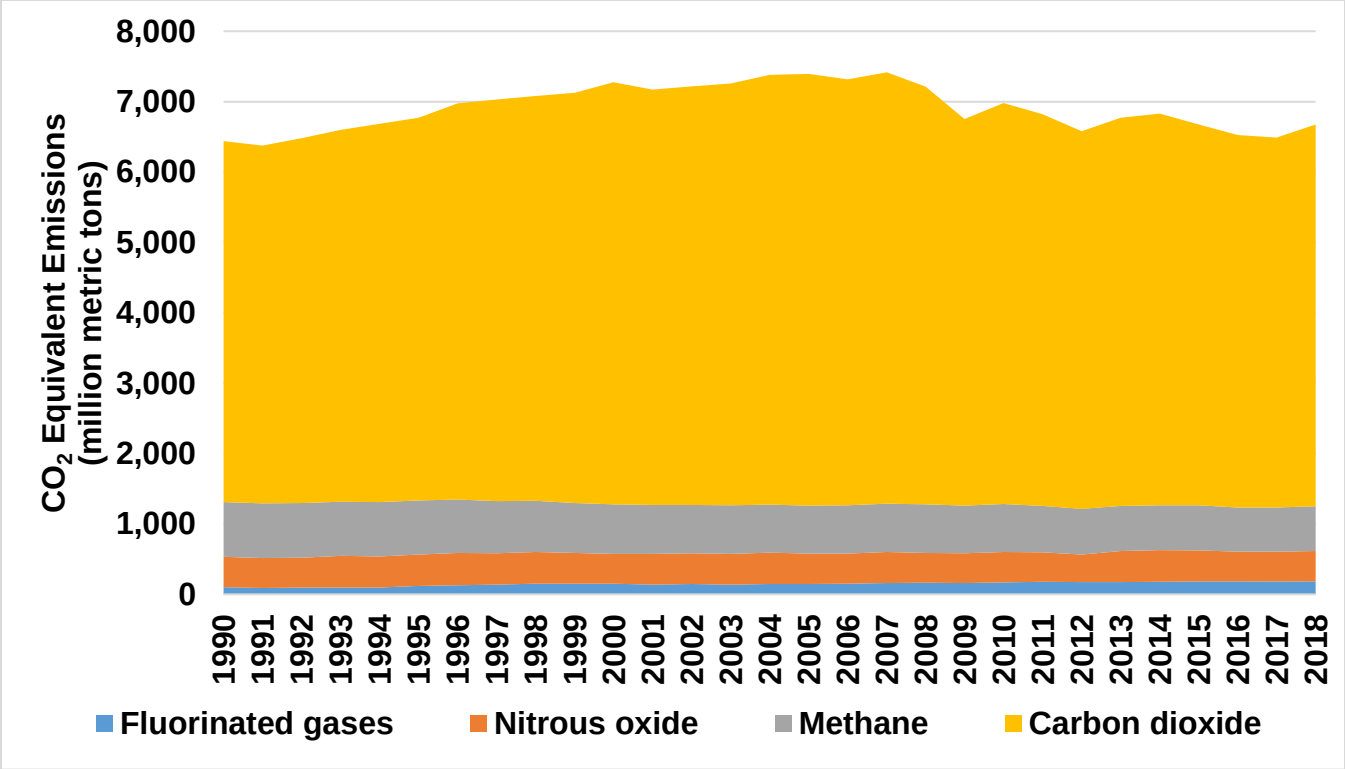

Figure 5. U.S. carbon dioxide equivalent emissions (Data Source: EPA).

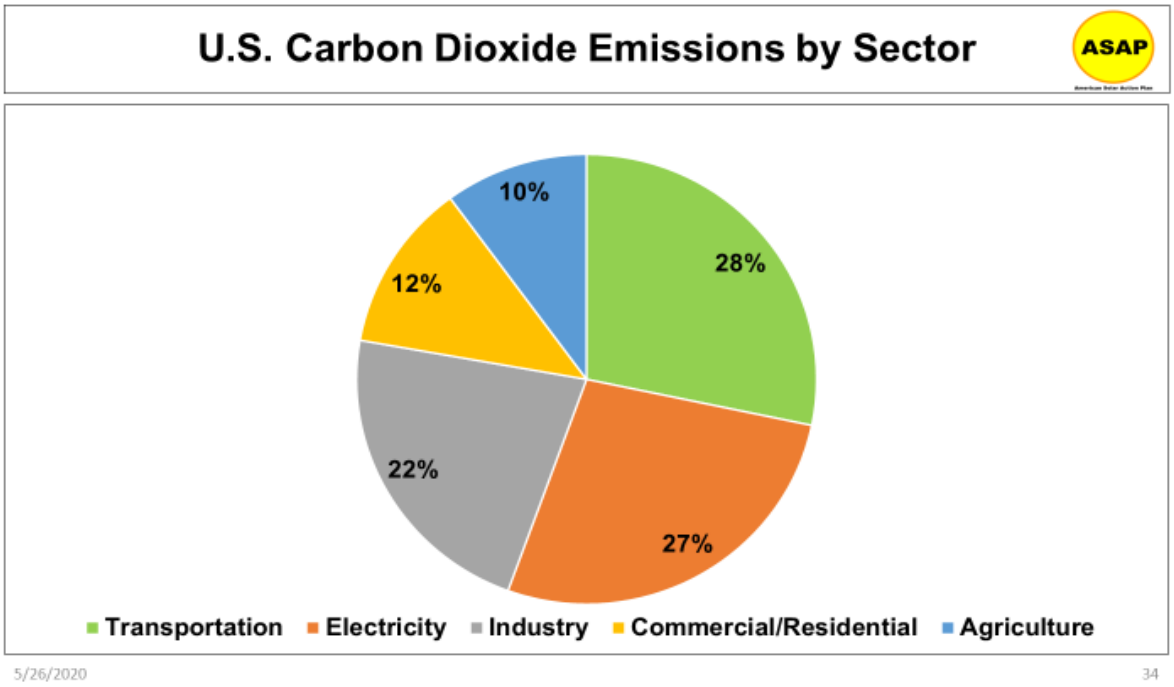

Figure 6. U.S. carbon dioxide emissions by sector (Data Source: EPA).

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References for Climate Data

1. Global Temperature Data:
Hadley Centre for Climate Prediction and Research, UK Meteorological Office, Bracknell, Berkshire, UK. Temperature (C) is relative to 1961-1990 average global temperature.
https://www.metoffice.gov.uk/hadobs/hadcrut4/data/current/download.html

2. $C0_2$ Concentration Data:
National Oceanographic and Atmospheric Administration (NOAA). Atmospheric CO_2 Concentration data, 2020.
https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html

3. Carbon Emissions Data:
Integrated Carbon Observation System (ICOS). Global Carbon Project, 2020.
https://www.icos-cp.eu/global-carbon-budget-2019

4. Carbon Brief – Clear on Climate Organization
https://www.carbonbrief.org/analysis-why-scientists-think-100-of-global-warming-is-due-to-humans

Appendix

A-1. Hypothesis Tests and Regression Results

1) Effect of Carbon Emissions on Atmospheric Concentration of CO2

Regression Statistics	
Multiple R	0.9932
R Square	0.9865
Adjusted R Square	0.9860
Standard Error	3.2577
Observations	60

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-1,794.431	305.582	-5.872	0.000
Year	1.068	0.157	6.784	0.000
Carbon Emissions (Mt)	0.004	0.001	3.196	0.002

Interpretation of Regression Results:

1) For each million metric ton increase in carbon emissions, there is a 0.004 part per million increase in atmospheric CO_2 concentration. The adjusted R^2 indicates that change in carbon emissions explains over 98% of the change in atmospheric CO_2 concentration. The low P-value of 0.002 indicates high statistical confidence in the results.

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2) Effect of Atmospheric Concentration of CO_2 on Global Temperature

Regression Statistics	
Multiple R	0.844
R Square	0.713
Adjusted R Square	0.702
Standard Error	0.094
Observations	28

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-2.909	0.418	-6.965	2.14E-07
Atmospheric CO2 Concentration	0.009	0.001	8.038	1.62E-08

Interpretation of Regression Results (low P-values indicate high statistical significance):

2) For a one part per million increase in atmospheric CO_2 concentration, there is a 0.009 degree Celsius increase in average global temperature relative to the 1960-1990 average global temperature. The adjusted R^2 indicates that change in atmospheric CO_2 concentration explains 70% of the change in average global temperature. The very low P-value of 1.62E-08 indicates high statistical confidence in the results. The time trend variable is omitted because it is not statistically significant, and the reduced model provides a much better fit between the observed values and the predicted values. Also, this regression model covers the period 1991-2018 since temperature are recorded as anomalies (difference) to the 1961-1990 average temperature.

A-2. Food for Thought. What Is Sea Level Rise If Antarctic and Greenland Ice Sheets Completely Discharge into Oceans. How Long Would It Take?

Below are the best estimates of the ice volumes on the major polar ice sheets and the impact on sea level if they should completely discharge into oceans.

West Antarctic Ice Sheet	11 feet	(will be the first major polar ice sheet to disappear and likely by 2200, however could it happen by 2100?)
- Thwaites Glacier	2 feet	(it is collapsing, and the question is how fast?)
Greenland Ice Sheet	23 feet	(sections showing instability; negative ice balance)
East Antarctic Ice Sheet	190 feet	(critics claim EA will be minimal but recent evidence is a cause of concern)
Total Sea Rise Potential	224 feet	

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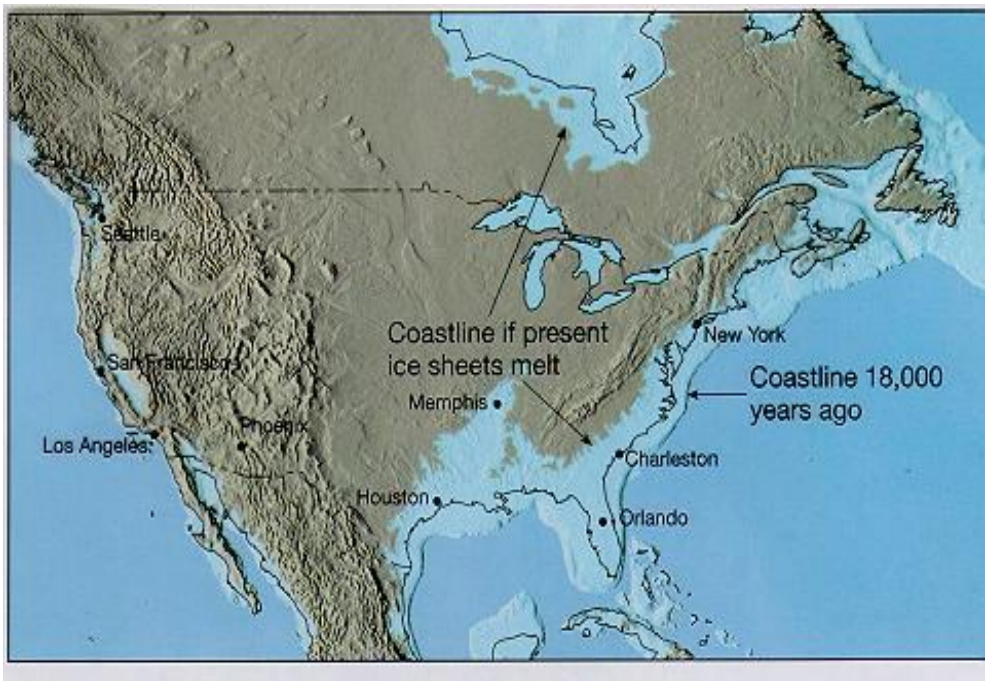
Map Below Shows the U.S. Coastline if Polar Ice Sheets Completely Discharge into Oceans



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