Vice President's Conversation on the Future

Trend Research: Climate Change

Descriptor Definition

There are two key issues that Ohioans face with respect to climate change. The first issue relates to the potential impacts of climate change. How will warming of the earth's atmosphere affect those of us living in Ohio over the next 20-30 years? The second issue relates to climate change policy. As policies emerge to address climate change, they will have important implications for Ohioans given the make-up of our economy, which currently is very carbon intensive. How will these potential policies meant to help avert climate change by reducing our carbon dioxide emissions affect Ohio's economy?

Author Insights[i]: Descriptor Relevance

An inescapable issue related to climate change is the certainty of the science. The term "climate change" refers to an increase in the world's average temperature that is caused by human activity, namely an increase in carbon dioxide, methane and nitrogen oxide emissions from industrial and agricultural activities. The scientific hypothesis is that these as these gasses accumulate in the atmosphere, they will cause an increase in temperatures across the world. Other impacts could occur as well, such as shifts in precipitation patterns, changes in the intensity of storms, droughts, hot-spells, longer summers and shorter winters, and sea level rise, among other things.

The link between humans and climate change is controversial to some, although it is fairly well accepted among climate scientists. It is important to understand what this debate is and is not about. There is virtually no debate that carbon dioxide emissions have risen over the past century, and there is virtually no debate that this increase in carbon dioxide is due to human activity. The use of fossil fuels – oil, natural gas, and coal—to power our economy means that practically everything we do, from driving our cars and tractors to working in offices, farm fields, and factories, emits carbon dioxide. There is also virtually no debate that the world's average global temperature has risen over the past century, by about 1.4° Fahrenheit. Sea level has risen, the number of cold nights has fallen and the number of warm days has increased.

The debate on climate change revolves around the conclusion of many scientists that our carbon dioxide emissions are causing observed changes in the climate system. The debate also revolves around the extent to which future carbon dioxide emissions will cause the future climate to change, and the damages that a changing climate will cause. It goes without saying that is not a trivial debate since so much of our wealth and well-being is linked to fossil fuel consumption.

This paper assumes the science of climate change is accurate and our carbon dioxide emission are causing climate change now, and will cause climate change in the future. It will present trends in

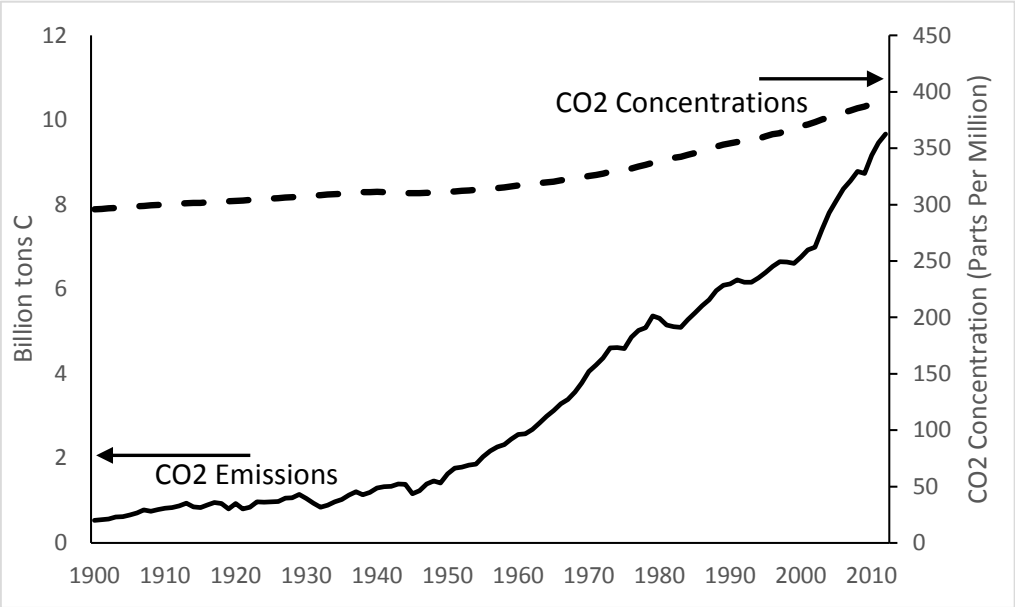
emissions and trends in climate for the world and for Ohio. The paper will discuss potential future changes that could occur based on climate modeling studies. The paper also will discuss policy trends and how those trends may affect the Ohio economy. The overall picture these trends and future projections paint is an Ohio that is fairly resilient to climate change, but also an Ohio that, maybe surprisingly for some, is quickly reducing its carbon footprint. Ohio's economy has undergone enormous changes in the past 20 years, and although we will continue to rely on fossil fuels for years to come, we are becoming substantially more sustainable.

Trend Information and Interpretation

Global carbon dioxide emissions and concentrations

Carbon dioxide emissions rose relatively slowly at the beginning of the 20th century, but began rising rapidly after World War II as the global economy expanded rapidly (Figure 1). Carbon emissions slowed considerably during the 1970s and early 1980s, due to the Arab oil embargo, the Iranian hostage crises, and an economic slowdown. Carbon emissions also slowed during recessions in the 1990s and early 2000s. Since the start of the 21st century carbon emissions have risen as the Chinese economy grew rapidly. As emissions have increased, carbon dioxide has accumulated in the atmosphere. The pace of this accumulative of carbon dioxide, recorded as the concentration in the atmosphere, has increased in the past 40 years due the rapid rise in emissions (Figure 1).

Figure 1: Carbon dioxide emissions from fossil fuel use, and carbon dioxide concentrations in the atmosphere, 1900-2012. Fossil fuel emissions from Boden et al. (2012); CO2 concentrations from National Oceanic and Atmospheric Administration (2012).



Interpretation: There is little doubt that economic growth historically has been tied to consumption of fossil fuels as an energy source, with the resulting carbon dioxide emissions. Periods of growth have seen rapid increases in emissions, and recessions have seen annual emissions fall. There is modest

but emerging evidence, however, that economic growth and carbon dioxide emissions may be decoupled, at least for wealthier countries. That is, as incomes rise, societies demand energy sources that emit less carbon dioxide, and economic growth in those countries occurs with lower rates of carbon emissions. It is not hard to see how this is true. When most people in Ohio, for example, buy a new car, they will buy a more fuel efficient car and thus reduce their emissions. The problem is that this calculation applies only to about 10% of the world's 7 billion inhabitants. Most people in other parts of the world do not even have cars. Their next automobile, often their first, will absolutely increase emissions. Consider this, the growing middle class in the developing world is busy buying their first car, buying new appliances for their house, installing air conditioning, and taking trips to distant places. Thus although the idea of decoupling carbon emissions from economic growth seems to be taking hold in rich countries, this likely will not be enough to slow carbon emissions globally.

Trends in temperature and precipitation

Global average temperature has increased 1.4°F since the late 1800s (Intergovernmental Panel on Climate Change, 2014). Ohio's temperatures also are increasing at about the same rate, by 1.5°F since 1900 (Figure 2). The rate of change has increased since the 1950s. Most of the change in temperature has been observed in winter, with average winter-time temperatures increasing 2.8°F since 1900. Summertime temperatures have not changed appreciably. Precipitation has also increased in Ohio since the late 1800s (Figure 2), rising from 37" per year in 1900 to over 41" per year at present. All of this change in precipitation has occurred in spring, summer and fall, with virtually no change in winter precipitation.

Interpretation: These changes in temperature and precipitation have provided benefits to the agricultural sector in Ohio, likely contributing to the strong gains in crop yields, and the shift from wheat to soybeans, that occurred in Ohio over the past century. These changes have had little impact on the industrial sectors that provided most of the economic growth in the state in the 20th century. Given all the other important changes that have occurred in Ohio, it would be hard to show whether these trends have in fact had any additional impact.

Figure 2: Ohio average annual temperature and precipitation, 1895-1914 (National Oceanic and Atmospheric Administration, 2014)

Figure 2a: Ohio Temperature

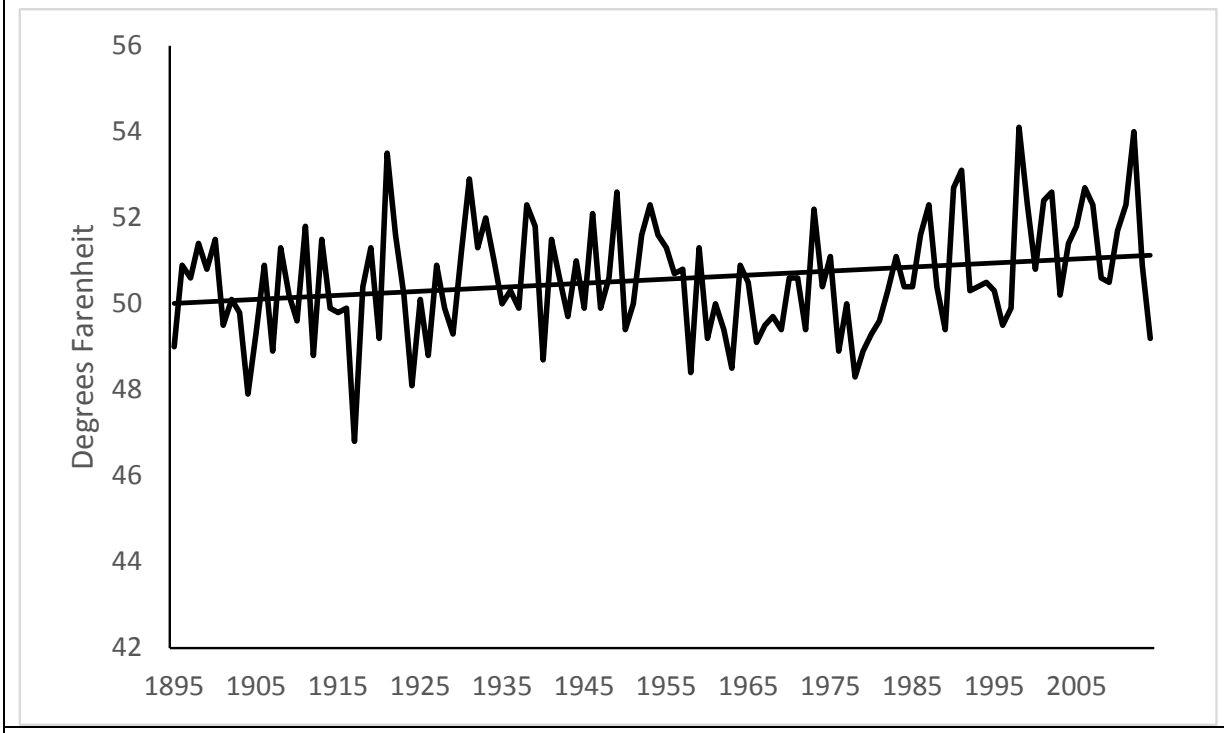
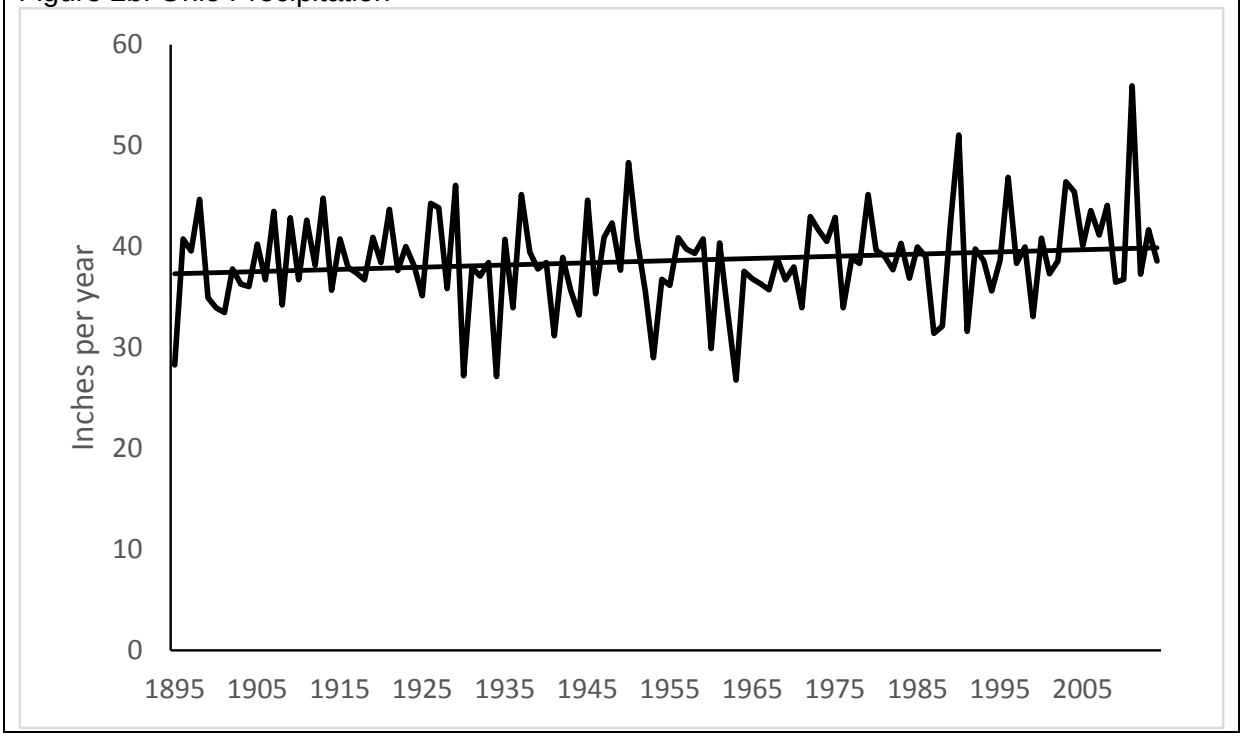


Figure 2b: Ohio Precipitation

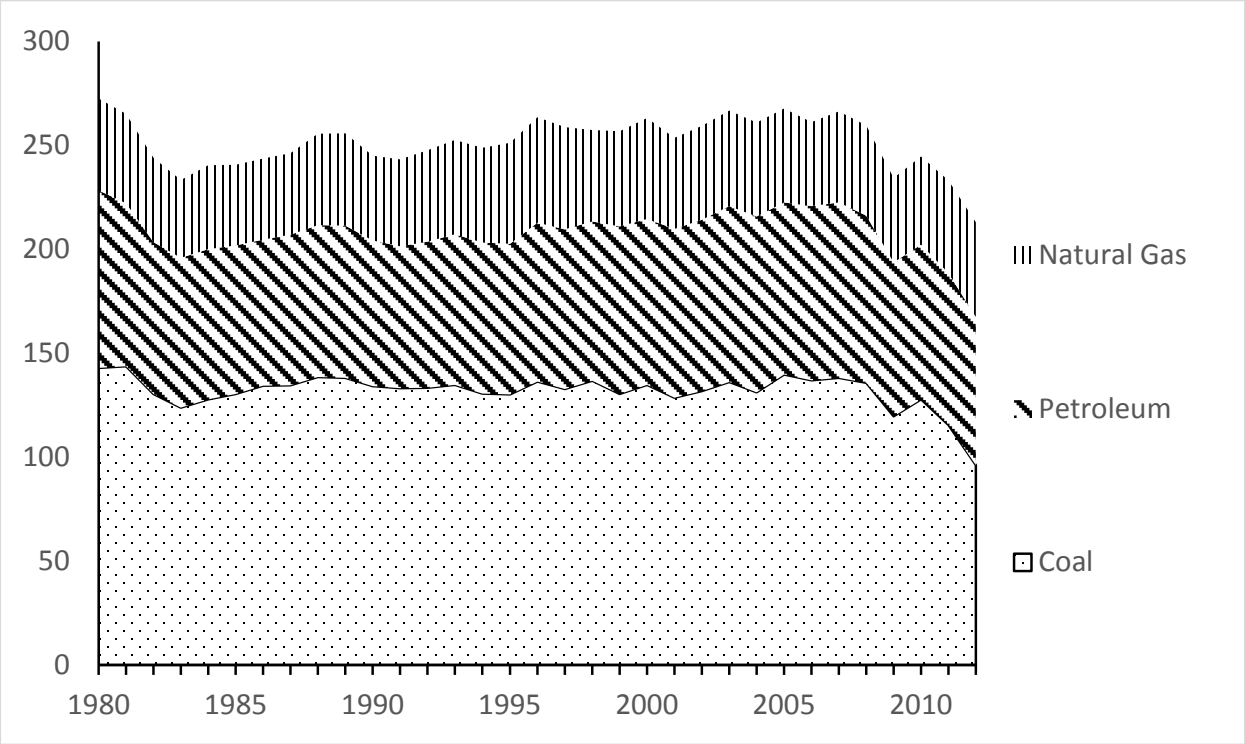


Ohio State University Extension

Ohio's contribution to global carbon emissions

Ohio emits around 213 million tons of CO2 per year from households, transportation, and the industrial sector. The largest share of emissions is due to electricity production from coal (Figure 3). The overall trend in carbon dioxide emissions in Ohio has been down since 2007. The reduction in carbon dioxide emissions that has occurred in Ohio is related to broad economic trends and policies. First, the economic contraction that occurred in 2007-2009, and the slow rate of recovery caused emissions to fall. This reduction in demand, followed by the restructuring of the Ohio economy away from heavy industries, has had the largest effect by far on our carbon emissions in the past decade. Second, the shale gas boom has lowered natural gas prices, and there are increasingly stringent environmental regulations on using coal for energy. These factors have reduced the cost of natural gas for electricity production relative to coal, and as a result, there is an ongoing shift from coal to natural gas for electricity production. Third, Ohio's renewable energy standards increased the share of renewable energy in Ohio, although this has had small impacts so far. And finally, national automobile fuel efficiency standards have reduced our fuel use.

Figure 3: Ohio's carbon dioxide emissions, 1980-2012 (Energy Information Administration, 2014)



Interpretation: Since the 1970 amendments to the Clean Air Act were passed ushered in comprehensive federal regulations on the types of stationary sources of air pollution common in Ohio, our state has been in the cross-hairs of most major air pollution regulation. While there have been costs, these regulations have provided benefits to Ohioans in terms of better air and water quality, as

well as better health. The large reduction in emissions since 2007 is due mainly to the slowdown in economic growth and the restructuring of Ohio's economy away from heavy industries. This shift was underway well before the economic slowdown, but the pace quickened with the financial crises. As Ohio's economy has achieved sustained, albeit slow growth since 2010, carbon dioxide emissions have continued to fall. Economic growth is occurring in sectors that are less carbon intensive than historically, and these trends will continue.

Economic Damages from Climate Change

In recent years, evidence presented by the Intergovernmental Panel on Climate Change (2014) suggests that climate change has reduced the number of cold days, increased the number of warm days, increased the probability of heat waves, increased the number of large storm events, increased sea-level, and had other impacts. These trends will continue if carbon emissions continue to increase at rates seen in the past. A number of economists have developed models to calculate the potential economic implications of the damages from climate change. Their estimates suggest that the potential damages range from $12-$40 per ton of CO2 emitted.

It is important to put these numbers in context. Each ton of CO2 we emit globally generates $1600 in economic benefits for society. In Ohio, the number is even bigger, with each ton of CO2 emitted from Ohio sources providing around $2300 in economic benefits for Ohioans. Not surprisingly to most of us, it turns out that burning CO2 provides enormous economic benefits. We could increase global output by $12 to $40 per ton (0.8 to 2.5%) if we could convert our energy sources from those that emit carbon (e.g., coal, natural gas, or oil) to those that do not (e.g., wind, solar, nuclear). Therein lies the difficulty – it will not be easy, or cheap, to quickly change our energy system to provide power to produce the economic output our current energy system produces. Thus, the trend in economic damages from climate change has been increasing over the past half century, and it will continue to increase in the future.

Interpretation: The news often reports stories of untold damage that climate change will cause. Economic assessments of the damages that could occur with climate change, however, suggest less urgency than reported in the news. That said, economic estimates do suggest that there is significant scope for implementing policies and measures that reduce CO2 emissions, and the benefits of these policies and measures would outweigh the costs. Most economists argue strongly for a measured set of responses that start to control CO2 emissions, but that do not imperil global economic output. There are also a number of acknowledged limitations in the economic estimates that need to be considered. First, economic studies focus heavily on impacts in developed countries, where damages are likely to be lower anyways, and strong institutions will aid adaptation. Impacts in developing countries could be large, although they will have less economic impact. Second, economic studies do not fully quantify non-market benefits in many regions. Third, economic estimates do not fully capture uncertainty in the climate system. When this uncertainty is considered, economic damages are almost always found to be higher than the range provided above.

Global and US policies to address climate change

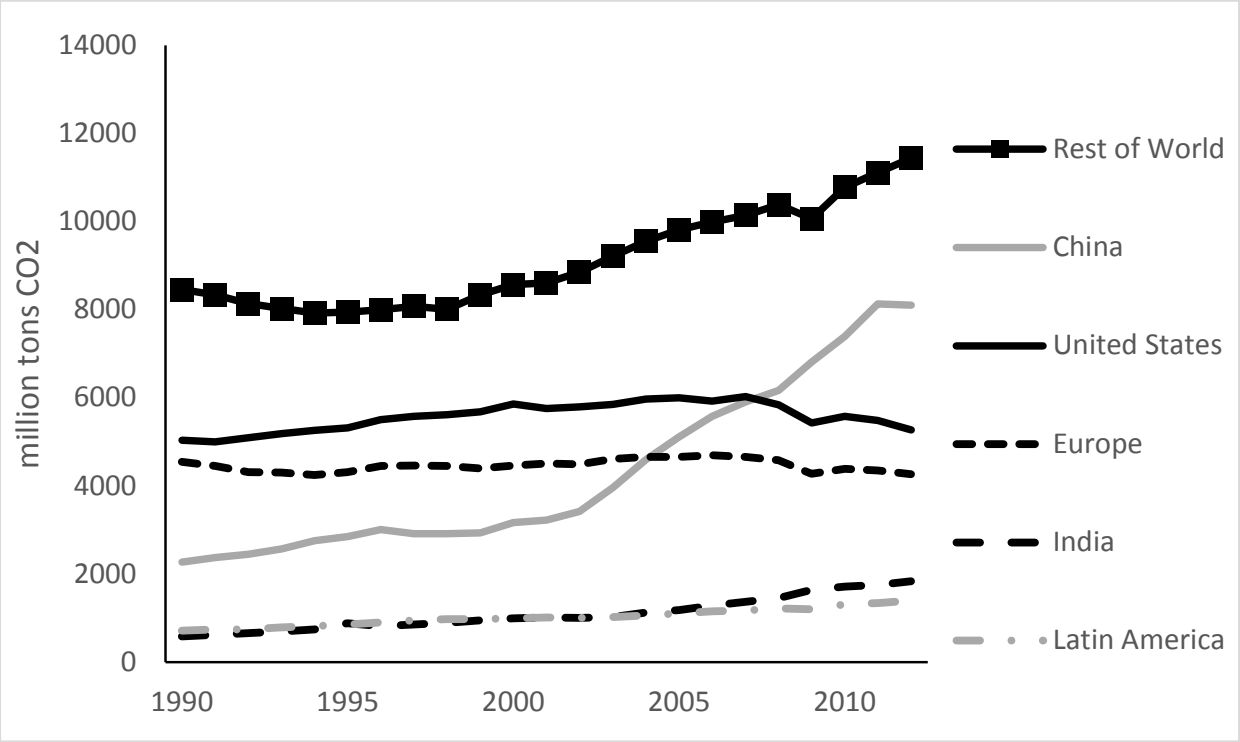
The US has long been involved in policy to address climate change. President George H.W. Bush signed, and the US Senate ratified, the United Nations Framework Convention on Climate Change in 1992 (UNFCCC). This treaty called for voluntary reductions in carbon emissions in the US and other countries. In 1997, President Clinton signed the Kyoto Protocol to the 1992 Framework Convention, but the Senate never ratified this treaty, and George W. Bush famously removed the US signature in 2000. Although other countries had adopted the Kyoto Protocol, it did little to nothing to slow carbon emissions globally. No successor treaty has yet been negotiated, although most countries remain signatories to the original 1992 treaty.

While we are not bound by treaty to cut carbon emissions, the US Supreme Court found, in a famous 2007 decision, *Massachusetts versus the US EPA*, that CO2 was a pollutant under the Clean Air Act, and could be regulated as such. Following that decision, in 2009, the USEPA issued an endangerment finding that CO2 did indeed cause damage in the United States and thus could be regulated under the Clean Air Act. Subsequently, the EPA has imposed more stringent automobile fuel efficiency standards, and most recently, the EPA has proposed additional regulations on large stationary sources of greenhouse gases, like large coal-burning power plants.

Many US states have also engaged independently in climate policy. Most famously, California passed Assembly Bill 32, which regulates greenhouse gases in that state. A number of eastern states have banded together in the Regional Greenhouse Gas Initiative. More importantly though, over 35 states now have renewable energy standards in place to promote the conversion of traditional sources of energy towards renewable sources of energy. These trends have been driving US emissions downward (Figure 4). In fact, US emissions have declined 13% since their 2007 peak. Europeans also have policies in place to address climate change and have similarly been decreasing their emissions. The rest of the world is a different story. With no regulation in place, and little incentive to slow carbon dioxide emissions, emissions in those countries keep growing at 2-4% per year.

Interpretation: There is emerging evidence that emissions have peaked in the US and most European countries, and in the future economic growth will be decoupled from carbon dioxide emissions. This is partly due to policy efforts, such as the Clean Air Act in the US, but it appears also to be due in part to shifting preferences among citizens in wealthier countries. Technological change has also helped, with costs for installing renewable energy sources falling dramatically in recent years, allowing citizens to more easily engage in carbon savings while also reducing their costs. The same cannot be said for developing countries, however, as the appetite for economic growth appears strong. While emissions in the developed world looks to be stable or falling, emissions in the developing world look likely to continue rising for years to come.

Figure 4: Global carbon dioxide emissions by region, 1990-2012 (Energy Information Administration, 2014b)



Overall Summary of Trend Information

There is little to no debate that climate change is occurring and carbon dioxide emissions are increasing. The Intergovernmental Panel on Climate Change (2014) presents credible evidence suggesting that if carbon dioxide emissions continue rising with few efforts to curb them, the world's average temperature could increase by an additional 1.4° Fahrenheit by 2035. This projects the same amount of warming over the next 20 years as occurred in the past 110 years. The Intergovernmental Panel on Climate (2014) also predicts that precipitation will increase in Ohio by 5-10% by 2035. As with temperature, this is a similar increase as occurred over the past 110 years.

These changes likely will have little effect on Ohio's economy. Of Ohio's $548 billion in Gross State Product in 2012, 0.8% was derived from agriculture, forestry, and fisheries. These sectors are the most climate sensitive, and they are a small part of the economy. This proportion has remained fairly stable for several decades and economic models suggest that climate change could increase the value of the agricultural industry in Ohio (Mendelsohn et al., 1994; Massetti and Mendelsohn, 2011). This certainly seems plausible given an increase in both temperature and precipitation.

The rest of Ohio's economy focuses on manufacturing, logistics, construction, and finance, among other things. Those sectors are not very climate sensitive. In fact, many of these sectors may benefit

indirectly from climate change. For instance, if climate change indeed causes an increase in extreme events, insurance itself will become more valuable, and insurance companies in Ohio, an important sector in the state, could benefit. Further, the impacts of climate change in Ohio actually are milder than those that may occur in other regions, particularly since Ohio is not on a coast. Ohio thus will maintain a cost of living advantage over many regions where the costs of protection from climate change liabilities will drive up the overall costs of living. All of these factors suggest that climate change itself could benefit Ohio's economy in general.

Ohio does bear some risks of climate policy. Carbon dioxide emissions are being regulated under the Clean Air Act, and these regulations will affect Ohio in both positive and negative ways. The costs of carbon dioxide regulations fall heavily on factories that use coal for their power source. Ohio still gets over 70% of its electricity from burning coal, so the costs of these regulations will fall heavily on coal burning utilities. However, Ohio is quickly shifting its primary source of energy from coal to natural gas. Companies are making this shift because natural gas prices are relatively low, and likely to remain low for some time, due to the expanding supply of natural gas from shale deposits. Companies are also making this shift in response to current environmental regulations on burning coal, and potential future liabilities due to future climate change regulations. This shift will have important environmental benefits, reducing air pollution and reducing carbon dioxide emissions.

Ohio also has been increasing its share of renewable energy, mainly due to renewable energy regulations. While the implementation of these regulations has been stalled by the legislature, as of the writing of this document, around 3% of total energy in Ohio is supplied by renewable sources, such as wind, solar, and biomass. Under the state's renewable energy regulations, this will grow to 12.5% by 2025.

These renewable energy regulations will increase electricity costs modestly, but they will put us on a path towards lower carbon emissions. We project that if the state fully implements the renewable energy regulations and continues the trend towards substituting natural gas for coal, by 2035, we will achieve a 35% reduction in carbon emissions from electricity production by 2035. As a result of continued improvements in fuel efficiency standards in automobiles, we will achieve a 30% reduction in transportation related automobile emissions from light duty vehicles (Ohio Wedges, 2014).

Author Insights – Possible Trends for the Future

Alternative States for the Future by 2035.

Alternative 1: *Business as usual – climate change continues unabated, but Ohio reduces it carbon footprint (90% probability)*

The most likely path forward is business as usual, with climate change continuing on its current path. As a result of changes in the economy and federal policies related the Clean Air Act, however, the emissions profile of the state of Ohio evolves to look very different from what it looks like today. Specifically, Ohioans substantially reduce their carbon footprint.

Consider first potential future changes in climate in Ohio. The most likely outcome is that climate change will continue on the current path, suggesting that the average temperature in Ohio will increase 1-2°F over the next 20-30 years, and precipitation in spring, summer and fall will increase. Crop yields for corn and soybeans will continue to rise at 1-2% per year. Ohio will see additional acres of land devoted to soybeans, mainly at the expense of wheat and other cool-season crops. Because most trees in Ohio are able to grow under a wide range of climatic conditions, forests are unlikely to be heavily affected by climate change over the next 20-30 years. The main concern in forests in Ohio will result from invasive species, which may be conferred competitive advantages in a warmer climate. Plant hardiness zones will continue to move northward, although over the next 20-30 years, this change is unlikely to have large effects on most Ohio landowners. In general, it is very unlikely that Ohio natural resource sectors will have harmed by climate change over the next 20-30 years.

Most of the economy in Ohio is industrial, service, and finance related. These sectors are unlikely to be negative affected by climate change here. Some of these sectors may be affected because the bulk of their operations are outside of Ohio, and these operations may be exposed to climate change elsewhere. For example, the insurance industry may be more heavily exposed to changes in storm events along coastlines in other parts of the United States. As long as the insurance industry adapts its insurance policies to climate change, however, these changes will not have a negative financial impact on the financial sector.

One area where Ohioans will need to be prepared to adapt to climate change will be in the area of sewer and waste-water management. Many of Ohio's larger cities are already improving their sewage systems to reduce waste-runoff, and these new systems should be sure to include future predictions of rainfall that incorporates climate change. As other cities replace aging infrastructure, they should also be using future predictions of climate change to determine the right size for drainage infrastructure.

Under the business as usual path, the federal government will continue taking action to reduce greenhouse gas emissions under the legal authority of the Clean Air Act. As a result, Ohioans will be on track to substantially reduce their greenhouse gas footprint in the transportation and electric power sector over the coming decades. Besides reducing greenhouse gas emissions, these changes will have additional air quality and health benefits. These changes are not expected to be all that costly, since they mainly rely on shifting from coal-fired electricity production to natural gas and wind, which have similar costs.

Why won't lower carbon emissions in Ohio and elsewhere in the US alter the effects of climate change? One reason is that the changes that occur over the next 30 years are already determined by past carbon emissions. A second reason is that poorer countries will not undertake similar emission reductions. For less wealthy economies, it is more difficult to reduce carbon dioxide emissions. Consider this, the next car that most of us in the US will buy likely will have better gas mileage than the car we currently drive (not to mention more conveniences like cameras to help us back up). The "next" car most people in developing countries will buy will be their first. You will go from 600 to 500 gallons of gasoline for the 15,000 miles you drive every year, but most people in other parts of the world will be going from 0 gallons to 200 gallons for the 2000-5000 miles per year they drive just because they bought their first car. Similarly, as the household appliances you and I have come to rely on become

more widely used by a global middle class, energy consumption will increase, and with it carbon emissions.

Alternative 2: *Climate change causes a large increase in the number of extreme events in Ohio (10% probability)*

Extreme events, include, but are not limited to, droughts that occur over multiple years, significant wind storms, a preponderance of extremely hot days, etc. With or without climate change, these events can and do happen in Ohio. It is unlikely, however, that climate change will cause a large increase in the number of these events over the next 30 years. We will definitely have large wind storms and rainfall events, as well as some very hot summers, over the next 30 years, but the events that do occur will not be caused by climate change.

The damage caused by the events that do occur is likely to be greater than when those events occurred in the past. There are a number of reasons for this that are completely unrelated to climate change. First, we continue to build more infrastructure and more valuable infrastructure, meaning that the damages from wind and rain events will be greater in the future no matter what. With or without climate change, with windstorms or rainstorms in the future, we should expect greater damages just because we have built more stuff to be damaged. Second, public investments in infrastructure to adapt sewage and other city systems to historic changes in precipitation patterns already are behind. It's not clear how public decision processes will change in the future to bring those systems up to current precipitation levels, let alone future levels. Third, we have subsidized insurance in flood plains, in agriculture, and elsewhere, which encourage over investment and mal-adaptation. Unfortunately, by trying to help different segments of society out through subsidy programs, we likely have exposed our economy to more damage from climate change than we would otherwise face.

References

Boden, T, G. Marland, and B. Andres. 2012. Global, Regional, and National Annual CO2 Emissions from Fossil-Fuel Burning, Cement Production, and Gas Flaring: 1751-2010. Carbon Dioxide Information Analysis Center, NDP-030, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830-6290 USA http://cdiac.ornl.gov/ftp/ndp030/

Energy Information Administration. 2014a. State CO2 Emissions. http://www.ncdc.noaa.gov/cag/time-series/us

Energy Information Administration. 2014b. International Energy Statistics. http://www.eia.gov/countries/data.cfm

Intergovernmental Panel on Climate Change. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Mendelsohn, R., Nordhaus, W. D., & Shaw, D. (1994). The impact of global warming on agriculture: a Ricardian analysis. *The American economic review*, 753-771.

Massetti, E., & Mendelsohn, R. (2011). Estimating Ricardian models with panel data. *Climate Change Economics*, *2*(04), 301-319.

National Oceanic and Atmospheric Administration. 2012. ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_mlo.txt

National Oceanic and Atmospheric Administration. 2014. National Climate Data Center, Climate at a Glance. http://www.ncdc.noaa.gov/cag/time-series/us

Author(s) and Date
B. Sohngen
Rev. 5/8/2015

1[i] Along with the research-based data and statistics included in this document, is information provided by the research paper author(s). Although these author insights are not directly cited with research references, they reflect research, observation, logic, intuition, and well-considered expectations compiled by the author(s). The Author Insights sections of this paper are offered for discussion and to help provide a wider perspective for incorporating the descriptor data into the possible future trends. These conclusions are drawn by the author(s) using their knowledge of the scholarly references and their years of professional experience related to the descriptor, and are provided to help the reader more effectively envision the future impact and effects of the descriptor.