Economic Impacts of Climate Change on Pennsylvania

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The Center for Integrative Environmental Research
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INTRODUCTION

Policymakers across the country are now seeking solutions to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions. The debate to date has primarily focused on the perceived costs of alternative solutions, yet there can also be significant costs of inaction. Climate change will affect our water, energy, transportation, and public health systems, as well as state economies as climate change impacts a wide range of important economic sectors from agriculture to manufacturing to tourism. This report, part of a series of state studies, highlights the economic impacts of climate change in Pennsylvania and provides examples of additional ripple effects such as reduced spending in other sectors and resulting losses of jobs, wages, and even tax revenues.

A Primer on Climate Change

Earth's climate is regulated, in part, by the presence of gases and particles in the atmosphere which are penetrated by short-wave radiation from the sun and which trap the longer wave radiation that is reflecting back from Earth. Collectively, those gases are referred to as greenhouse gases (GHGs) because they can trap radiation on Earth in a manner analogous to that of the glass of a greenhouse and have a warming effect on the globe. Among the other most notable GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Their sources include fossil fuel combustion, agriculture, and industrial processes.

Each GHG has a different atmospheric concentration, mean residence time in the atmosphere, and different chemical and physical properties. As a consequence, each GHG has a different ability to upset the balance between incoming solar radiation and outgoing long-wave radiation. This ability to influence Earth's radiative budget is known as climate forcing. Climate forcing varies across chemical species in the atmosphere. Spatial patterns of radiative forcing are relatively uniform for CO_2, CH_4, N_2O and CFCs because these gases are relatively long-lived and as a consequence become more evenly distributed in the atmosphere.

Steep increases in atmospheric GHG concentrations have occurred since the industrial revolution (Figure 1). Those increases are unprecedented in Earth's history. As a result of higher GHG concentrations, global average surface temperature has risen by about 0.6°C over the twentieth century, with 10 of the last 12 years likely the warmest in the instrumental record since 1861 (IPCC 2007).

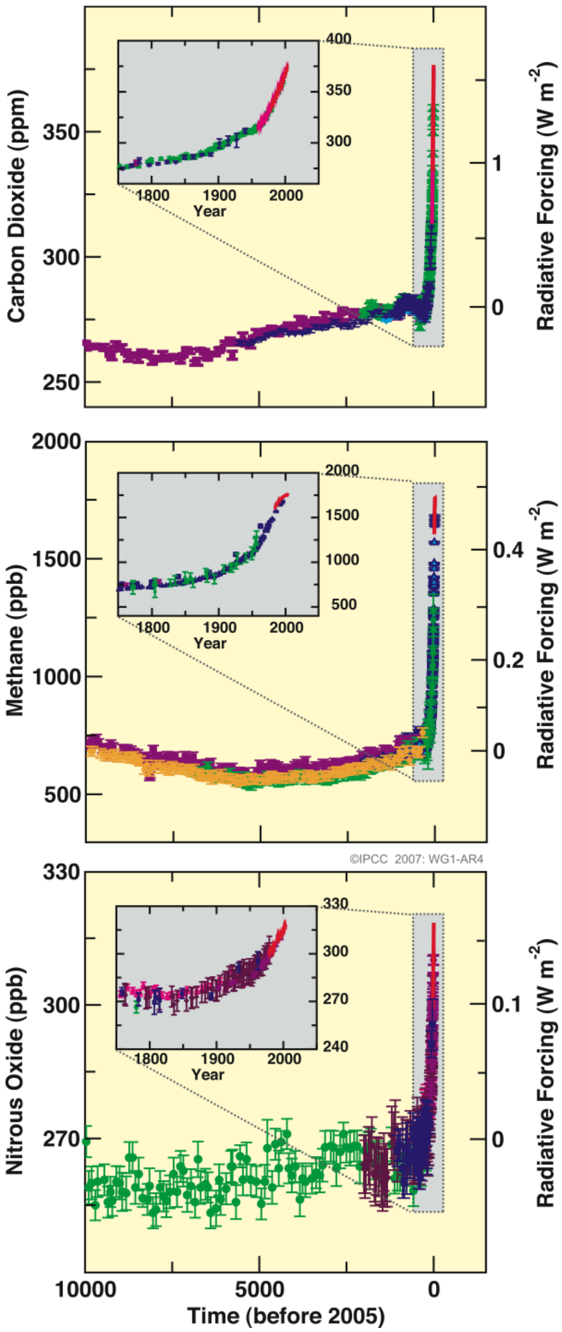

Figure 1: Atmospheric Concentrations of Carbon Dioxide, Methane and Nitrous Oxide (Source: IPCC 2007)

A change in average temperatures may serve as a useful indicator of changes in climate (Figure 2), but it is only one of many ramifications of higher GHG concentrations. Since disruption of Earth's energy balance is neither seasonally nor geographically uniform, effects of climate disruption vary across space as well as time. For example, there has been a widespread retreat of mountain glaciers during the twentieth century. Scientific evidence also suggests that there has been a 40 percent decrease in Arctic sea ice thickness during late summer to early autumn in recent decades and considerably slower decline in winter sea ice thickness. The extent of Northern Hemisphere spring and summer ice sheets has decreased by about 10 to 15 percent since the 1950s (IPCC 2007).

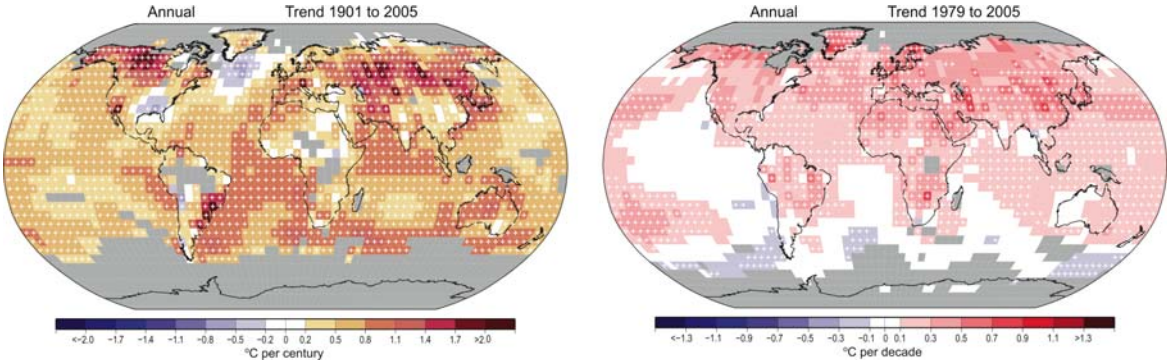

Figure 2: Annual Temperature Trends (Source: IPCC 2007)

The net loss of snow and ice cover, combined with an increase in ocean temperatures and thermal expansion of the water mass in oceans, has resulted in a rise of global average sea level between 0.1 and 0.2 meters during the twentieth century, which is considerably higher than the average rate during the last several millennia (Barnett 1984; Douglas 2001; IPCC 2001).

Changes in heat fluxes through the atmosphere and oceans, combined with changes in reflectivity of the earth's surface, may result in altered frequency and severity of climate extremes around the globe (Easterling, et al. 2000; Mehl, et al. 2000). For example, it is likely that there has been a 2 to 4 percent increase in the frequency of heavy precipitation events in the mid and high latitudes of the Northern Hemisphere over the latter half of the twentieth century, while in some regions, such as Asia and Africa, the frequency and intensity of droughts have increased in recent decades (IPCC 2001). Furthermore, the timing and magnitude of snowfall and snowmelt may be significantly affected (Frederick and Gleick 1999), influencing among other things, erosion, water quality and agricultural productivity. And since evaporation increases exponentially with water temperature, global climate change-induced sea surface temperature increases are likely to result in increased frequency and intensity of hurricanes and increased size of the regions affected.

Impacts of Climate Change Throughout the US

This study on the economic impacts of climate change in Pennsylvania is part of a series of state-focused studies to help inform the challenging decisions policymakers now face. It builds on a prior assessment by the Center for Integrative Environmental Research, US Economic Impacts of Climate Change and the Costs of Inaction, which concluded that throughout the United States, individuals and communities depend on sectors and systems that are expected to be greatly affected by the impacts of continued climate change.

The **agricultural sector** is likely to experience uneven impacts throughout the country. Initial economic gains from altered growing conditions will likely be lost as temperatures continue to rise. Regional droughts, water shortages, as well as excess precipitation, and spread of pest and diseases will negatively impact agriculture in most regions.

Storms and sea level rise threaten extensive **coastal infrastructure –** including transportation networks, coastal developments, and water and energy supply systems.

Current **energy** supply and demand equilibria will be disrupted as electricity consumption climbs when demand grows in peak summer months. At the same time, delivering adequate supply of electricity may become more expensive because of extreme weather events.

Increased incidence of asthma, heat-related diseases, and other respiratory ailments may result from climate change, affecting **human health** and well-being.

More frequent and severe **forest fires** are expected, putting ecosystems and human settlements at peril.

The reliability of **water supply networks** may be compromised, influencing agricultural production, as well as availability of water for household and industrial uses.

As science continues to bring clarity to present and future global climate change, policymakers are beginning to respond and propose policies that aim to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions.

While climate impacts will vary on a regional scale, it is at the state and local levels where critical policy and investment decisions are made for the very systems most likely to be affected by climate change – water, energy, transportation and public health systems, as well as important economic sectors such as agriculture, fisheries, forestry, manufacturing, and tourism. Yet, much of the focus, to date, has been on the perceived high cost of reducing greenhouse gas emissions. The costs of inaction are frequently neglected and typically not calculated. These costs include such expenses as rebuilding or preparing infrastructure to meet new realities and the ripple economic impacts on the state's households, the agricultural, manufacturing, commercial and public service sectors.

The conclusions from our nation-wide study highlight the need for increased understanding of the economic impacts of climate change at the state, local and sector level:

- Economic impacts of climate change will occur throughout the country.
- Economic impacts will be unevenly distributed across regions and within the economy and society.
- Negative climate impacts will outweigh benefits for most sectors that provide essential goods and services to society.
- Climate change impacts will place immense strains on public sector budgets.

- Secondary effects of climate impacts can include higher prices, reduced income and job losses.

Methodology

This report identifies key economic sectors in Pennsylvania, which are likely affected by climate change, and the main impacts to be expected for these sectors. The report provides examples of the direct economic impacts that could be experienced in the state and presents calculations of indirect effects that are triggered as impacts on individual sectors in the economy ripple through to affect others.

The study reviews and analyzes existing studies such as the 2000 Global Change Research Program National Assessment of the Potential Consequences of Climate Variability and Change which identifies potential regional impacts. Additional regional, state and local studies are used to expand on this work, as well as new calculations derived from federal, state and industry data sources. The economic data is then related to predicted impacts of climate change provided from climate models. To standardize the results, all of the figures used in this report have been converted to 2007 dollars (BLS 2008).

Since the early 1990s, and especially during the 21st century, significant progress has been made in understanding the impacts of climate change at national, regional, and local scales. The Canadian and Hadley climate change models are cited most frequently and we look first to these, yet there are many other valuable models used by some of the specialized studies we cite in this report.

In addition to looking at data that illustrates the direct economic impacts of climate change, the report also provides examples of the often overlooked ripple economic effects on other sectors and the state economy. To calculate these, we employed a modified IMPLAN™ model from the Regional Economic Studies Institute (RESI) of Towson University. This is a standard input/output model and the primary tool used by economists to measure the total economic impact by calculating spin-off impacts (indirect and induced impacts) based upon the direct impacts which are inputted into the model. Direct impacts are those impacts (jobs and output) generated directly by the project. Indirect economic impacts occur as the project (or business owners) purchase local goods and services. Both direct and indirect job creation increases area household income and results in increased local spending on the part of area households. The jobs, wages, output and tax revenues created by increased household spending are referred to as induced economic impacts.

After reviewing climate and economic information that is currently available, the study identifies specific data gaps and research needs for further understanding of the significant economic impacts. There is no definitive total cost of inaction. Given the diversity in approaches among existing economic studies and the complexity of climate-induced challenges faced by society, there is a real need for a consistent methodology that enables more complete estimates of impacts and adaptation costs. The report closes with basic recommendations and concluding lessons learned from this series of state-level studies.

Not all environmentally induced impacts on infrastructures, economy, society and ecosystems reported here can be directly or unequivocally related to climate change. However, historical as well as modeled future environmental conditions are consistent with a world experiencing changing climate. Models illustrate what may happen if we do not act now to effectively address climate change and if adaptation efforts are inadequate. Estimates of the costs of adapting environmental and infrastructure goods and services to climate change can provide insight into the very real costs of inaction, or conversely, the benefits of maintaining and protecting societal goods and services through effective policies that avoid the most severe climate impacts. Since it is typically at the sectoral and local levels where those costs are borne and benefits are received, cost estimates can provide powerful means for galvanizing the discussion about climate change policy and investment decision-making.

These cost estimates may understate impacts on the economy and society to the extent that they simply cover what can be readily captured in monetary terms, and to the extent that they are calculated for the more likely future climate conditions rather than less likely but potentially very severe and abrupt changes. The broader impacts on the social fabric, long-term economic competitiveness of the state nationally and internationally, changes in environmental quality and quality of life largely are outside the purview of the analysis, yet likely not trivial at all. Together, the monetary and non-monetary, direct, indirect and induced costs on society and the economy provide a strong basis on which to justify actions to mitigate and adapt to climate change.

CLIMATE CHANGE IN PENNSYLVANIA

The Intergovernmental Panel on Climate Change (IPCC) has been the main scientific assessment body on climate change since 1988. The Fourth Assessment Report by the IPCC, released in 2007, includes more detailed and improved analysis of regional climate change scenarios.

Since 1955, much of the northeastern United States has experienced around a 0.5º C (1º F) temperature increase. If climate change continues to progress unmitigated, carbon dioxide concentrations could double relative to current levels during the 21st century. Annual temperature in Pennsylvania could rise by between 2º and 7º C (3.6º and 12.6º F); the range in forecasts depends on development choices, technological progress, and the type of climate model used (IPCC 2007). A business-as-usual scenario will result in higher temperature increases. Even with technological advances and controlled growth, Pennsylvania will be “locked into” the lower end of the temperature range increase due to the high residence time of carbon dioxide in the atmosphere. The IPCC’s mean annual estimate is an increase of 3.5º C (6.3º F) as shown in Figure 3. The temperature increase will manifest itself primarily as higher minimum temperatures in winter, but also as higher maximum temperatures in summer. It is very likely that Pennsylvania will experience increased warming relative to the global average, as is the case with most mid-latitude locations.

Precipitation is more difficult to predict, but IPCC has improved its modeling, producing more reliable results. On an annual basis, Pennsylvania could see precipitation changes range from a decrease of 3 percent to an increase of 15 percent relative to current levels, with an average increase of around 7 percent (Figure 4). Much of the increased precipitation will occur during the winter and spring seasons (an increase of nearly 15 percent), with near neutral conditions in the summer.

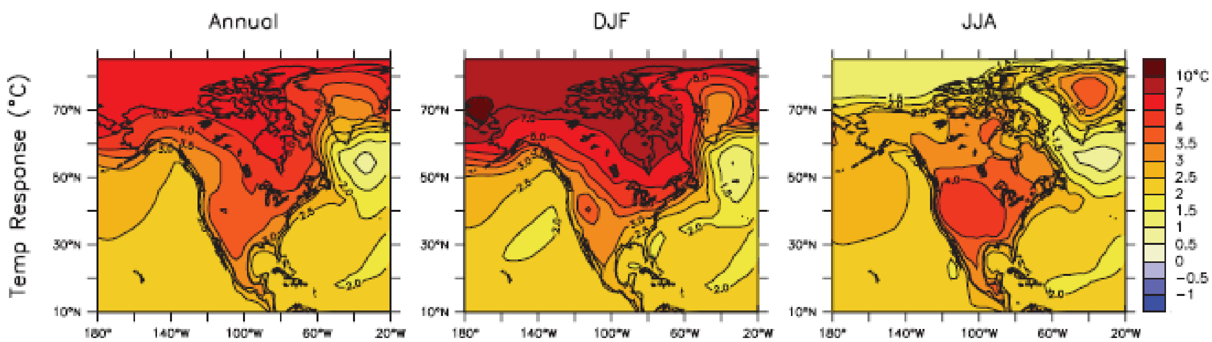

Figure 3: IPCC Fourth Assessment Report temperature projections for annual climate, winter (Dec-Jan-Feb) climate, and summer (Jun-Jul-Aug) climate (Source: IPCC 2007).

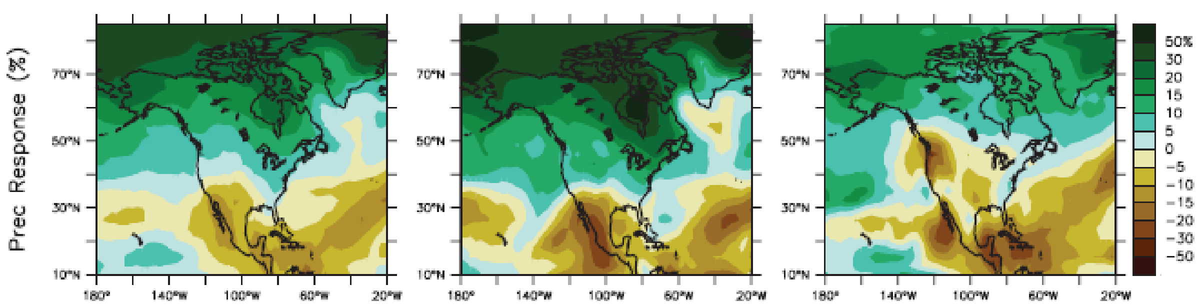

Figure 4: IPCC Fourth Assessment Report precipitation projections for annual, winter, and summer climate (Source: IPCC 2007).

Other likely climate responses are increases in precipitation extremes (droughts and severe storms), and temperature extremes (e.g. heat waves). The distribution of these events for the nation and Pennsylvania is unclear, although the projected increases in their frequency are more certain.

Despite these unknowns, projected trends of continued climatic change will likely have significant economic costs throughout the state with effects on infrastructural integrity, potentially disrupting energy and water services. Other sectors dependent on the current conditions in Pennsylvania, such as agriculture, forestry and infrastructure, will likely be impacted as well. This report presents a partial picture of the extent of the economic damages. All figures have been adjusted to 2007 dollars using the Bureau of Labor Statistics inflation calculator.

The major economic impacts from the effects of climate change will likely be to infrastructure, undermining its reliability, as well as the vital water and electricity supplies. The movement of people and goods may also be affected, as Pennsylvania's ports and its shipping infrastructure may be vulnerable to projected changes in the state's climate. The three economic sectors most likely impacted directly by impending climate change are forestry, hunting, and agriculture.

MAJOR ECONOMIC IMPACTS

Infrastructure

Climate change may increase precipitation in Pennsylvania, as well as the frequency and severity of extreme weather events (IPCC 2007).

A look at damages associated with historical precipitation events could provide a window into the future, if such events increase in frequency. According to the National Climatic Data Center, Pennsylvania has had a moderate history with extreme weather events relative to other states. The state has experienced 13-15 major storms that resulted in over a billion dollars worth of damages since 1980 (National Climatic Data Center 2008).

The most recent weather disaster was the Northeast flooding in June 2006. Storms produced rainfall in excess of 12 inches (see Figure 5) in Eastern Pennsylvania over the course of three days. High rainfall occurred in the Susquehanna River basin, causing flooding and the evacuation of over 200,000 people in the Wilkes-Barre region. The associated flooding reportedly killed 16 individuals and caused over $100 million in damages. These damages, in turn, led to the diversion of resources from other productive uses in the state economy (National Climatic Data Center 2008a).

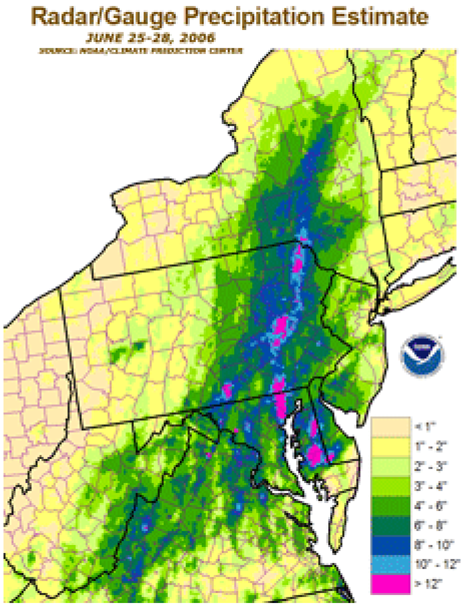

Figure 5: Precipitation totals, June 28-28, 2006 (Source: National Climatic Data Center 2008a).

Since October 1954 (when data collection began) to November 2007, Pennsylvania has experienced 85 major floods (Pennsylvania Emergency Management Agency 2008). The total damages are estimated at over $16 billion from 1955 to 2003 (Flood Damage in the United States 2003). The State is fourth in the nation with highest overall flood losses (Flood Safety 2008).

The Pennsylvania Emergency Management Agency has recently published estimates of projected losses for flood events for the state and the counties. For the nine most populated counties[a] in the state (accounting for over 50 percent of total population), a ten-year flood is expected to inflict $9.2 billion in damages to buildings – about 20 percent of the cost will be to residential homes and around 50 percent of the cost will be to commercial businesses. A fifty-year flood will cost over $12 billion to those counties (Pennsylvania Emergency Management Agency 2008).

As climate change progresses unchecked, the floods are likely to become more frequent – more than once every ten years – causing large recurrent damages. For example, a study of economic impacts of severe weather events in the Mid-Atlantic region showed that a 1 percent increase in annual precipitation results in a 2.8 percent increase in annual flood and hurricane economic losses, as measured by historical insurance loss data (Choi and Fisher 2003). If precipitation increases by around 10 percent in the state, a 10-year flood would cost the most-populated counties an additional $2.5 billion per event.

With climate change, experts project hurricanes to become more frequent and/or more intense. If hurricanes do become a larger issue in the future, rainfall, storm surges, and associated flooding could cause major damages, particularly in the eastern part of the

[a] Philadelphia, Allegheny, Montgomery, Bucks, Delaware, Lancaster, Chester, York, and Berks Counties

state, which is often in the path of hurricanes that made landfall in other parts of the country.

Hurricanes can easily track inland and bring heavy rains and tornados to all parts of the state. In September 2004, Hurricanes Jeanne and Ivan caused flood and wind damage. Isabel in 2003 tracked through western Pennsylvania and with it brought heavy rains to the central and eastern parts of the state. Tropical storm Allison wreaked havoc in Philadelphia and Wilkes-Barre, Pennsylvania in June 2001 (National Climatic Data Center 2008). While most of the $5 billion in damages occurred during landfall in Houston, heavy rains and flooding (some due to storm surge) caused several hundred thousand dollars in damage to Pennsylvania and 7 deaths. The remnants of Allison dumped 3 inches of rainfall overnight in most parts of Eastern Pennsylvania on June 18th; Doylestown, PA received over 10 inches. Likewise, 1999's Hurricane Floyd also tracked up the eastern coast and caused heavy rains throughout Pennsylvania (Hurricanes and Middle Atlantic States 2008). The $6 billion storm hit North Carolina hardest, but also 8 deaths in Pennsylvania. Over 400,000 were without electricity at one point, 4000 went homeless, and 2000 homes were damaged (National Climatic Data Center 1999).

Shipping Infrastructure

Pennsylvania is ranked fourth in the nation in domestic and foreign cargo volume going through its ports, which include a Great Lakes port in Erie, an inland port in Pittsburgh, and a seaport in Philadelphia. The ports collectively handled around 125 million tons of cargo in 2001, and waterborne commerce provided 280,000 direct, indirect, and induced jobs in 1999. The total financial impact is estimated at near $30 billion (Pennsylvania Department of Community & Economic Development 2003). This valuable shipping infrastructure could be negatively impacted from changes to water levels in the Great Lakes and the state's river ways – changes caused by climate change.

Warmer temperatures from climate change are likely to increase evaporation, contributing to declining water levels in Lake Erie, inland waterways and channels, necessitating expensive dredging. For example, the Delaware River is currently undergoing dredging to expand the depth of its main channel near the Port of Philadelphia by 5 feet. The cost of the project is estimated at $264 million (PRPA 2008). Expensive dredging will likely become routine as water levels decline with higher temperatures.

Dredging in the Great Lakes-St. Lawrence shipping channels has an expected annual cost of $85-$142 million. The movement of goods along this shipping route is responsible for around 60,000 jobs and $3.5 billion annually. As a result of decreasing water levels we could expect to see an increase in freight costs for the area if higher priced railroad transportation becomes necessary as shipping channels became impaired. System connectivity could be impaired by 25 percent, which would create an estimated annual cost of $995 million.

While the inland waterways may see reduced depths, the rising sea levels could require alterations of the Philadelphia port to adapt to higher water levels.

Water Resources

Projected climate change impacts may cause disruptions to Pennsylvania's municipal water supply networks. More intense precipitation events may create conditions that concentrate pollution in waterways and exacerbate water treatment needs, as heavy runoff washes contaminants into surface waters. In addition, higher temperatures combined with more pollutants can increase the amount of harmful bacteria and algae that occur in surface waters, increasing water treatment needs and increasing the risk of illness for swimmers and others that use the water for recreation (Frumkin 2008).

Water resources in the state are already under strain. For example, the National River Restoration Science Synthesis project reports that there are nearly 1,500 stream and river restoration projects in the State with a total cost of nearly $100 million (NRRSS 2006). This cost and others associated with water pollution and treatment may increase dramatically with time. For example, a study in Texas found that increased contamination of surface raw water raised the treatment costs by 27 percent (Dearmont et al. 1997).

Sea-level rise along the Atlantic coast may impact the freshwater supplies in the state. For example, Philadelphia relies on the Delaware River for its freshwater needs. The river may see increases in its salinity levels and impact the city's water supply (EPA 2008). Desalinization is very expensive and costs around five times as much as regular supply sources (USGS 2008).

OTHER ECONOMIC IMPACTS

Forestry

Pennsylvania is rich in forest resources – hardwood forests constitute around 58 percent of state's land cover, enclosing 16.6 million acres (US Forest Service 2004). Pennsylvania leads the nation in hardwood lumber production, accounting for 10 percent of the nation's total output. Over $5.5 billion of lumber-derived products are produced annually, representing around 1 percent of the state's GSP. The industry directly employs more than 86,000 people. The majority of those are employed in the value-added industries of wood product manufacturing, paper manufacturing, and furniture production. An additional 48,000 self-employed (non-NAIC classified) workers are involved in the forest product industry. Four of Pennsylvania's 67 counties rely on forest products for more than half of their employment; an additional 13 counties have between 25 and 50 percent of their employment in the industry (Pennsylvania Forest Products Association 2003).

Forest growth is impacted by a variety of climate factors, two of which are temperature and precipitation. Given the IPCC estimates of an increase in temperature of around 3.5 º

C (6.3º F) and an increase in precipitation of approximately 7 percent, forest growth could actually be stimulated temporarily under this climate change scenario. Higher temperatures increase the metabolic rates of plants, and enhanced precipitation will also positively impact growth. Furthermore, higher concentrations of carbon dioxide will likely increase photosynthesis, an effect called “carbon fertilization.” Some studies have indeed predicted that forest growth in Pennsylvania could increase due to climate change. One such study concluded that a 50 percent increase in carbon dioxide emissions resulted in a 23 percent increase in forest productivity in Great Smoky Mountain National Park (Zhang et al. 2007). Although some of the growth will go to leaf and root development, an increase in wood growth will also conceivably occur. Thus, a portion of the increase in productivity will likewise increase economic output of the $5.5 billion industry. The positive economic benefit may reach over $850 million with over 5,000 indirect jobs created as a result of greater productivity yields (RESI 2008).

There are other potential climate change impacts and resulting environmental factors that could dampen or reverse these gains in forest productivity. An increase in the levels of ozone in the atmosphere, coupled with higher temperatures could offset any gains from carbon fertilization. Surface-level ozone causes cellular damage in vegetation and can reduce photosynthetic rates. Increased emissions of carbon dioxide could increase yields, but in combination with concomitant increases in ozone, the net positive effect on yield could be lessened (Sitch 2007). Additional adverse effects may become more relevant as climatic changes continue. Invasive pests, for example, may become more prevalent in the region (PA DCNR 2002).

Pennsylvania’s forests can be classified as mature, since little regeneration—or growth of sapling trees—is occurring. One major concern is that over-browsing of tree saplings by the white-tailed deer species is damaging the economic resource. According to the Pennsylvania Department of Conservation and Natural Resources Bureau, even with a deer management plan to control browsing, less than 25 percent of managed plots had desirable regeneration, and half had no regeneration (Pennsylvania Department of Conservation and Natural Resources Bureau of Forestry 2006). Regeneration is the pressing issue in discussions about the long-term sustainability of Pennsylvania’s forests. The projected increases in snow depth may decrease white-tailed deer populations, helping forests to recover and regenerate from overgrazing. However, lower deer populations may mean economic losses to the profitable hunting industry in the state.

Hunting

Hunting is an important cultural asset in Pennsylvania. More than 1 million hunters (in-state and out-of-state residents) participate in hunting activities in the state, and 900,000 Pennsylvanians hunt in other areas of the country as well. In-state fishing and hunting expenditures totaled almost $4 billion in 2006. Wildlife watching activities, of which around 85 percent of Pennsylvanians participate, contributed nearly $1.5 billion to the state’s economy the same year (US Fish and Wildlife Service, 2006). Though this is a fraction of the state’s $510 billion gross domestic product, hunting is a large part of

Pennsylvania's identity, and the potential impacts of climate change on the distribution of wildlife should be considered.

A balance of deer population is essential to both the economy and the environment. In absence of predators, white-tailed deer populations have grown exponentially in some parts of the country, including Pennsylvania. Large deer populations can be unhealthy for forests, since overgrazing can cause damages to the habitat (PA DCNR 2008). Pennsylvania supports deer hunting, in part, to control the state's deer population. Deer hunting is also an important part of Pennsylvania's economy and identity.

The spatial distribution of white-tailed deer is widespread throughout the United States, southern Canada, and Central and South America. Because of its wide range, it is improbable that changes in temperature or precipitation due to climate change would eliminate deer from Pennsylvania. However, changes in snow cover could alter the population density of deer within the state. The IPCC predicts winter snows will come later in the year and the spring melt will occur sooner. Despite this shorter winter season, winter precipitation in the form of snowfall is predicted to increase for the mid-Atlantic and snow depth could increase. As snow depth increases, it is not only hard for deer to find food but also difficult for them to walk. Thus, snow-depth should have a negative effect on deer density (Shi et al. 2006). While lower deer populations are good news for forest management, the hunting industry may suffer economic losses as fewer deer may mean fewer hunters. In fact, the cumulative impact on the industry from the migration of species may be around $181 million, and lost direct and indirect jobs may reach over 2,000 (RESI 2008).

Agriculture

Pennsylvania has annual agricultural sales of nearly $5 billion (less than 1 percent of the state's GSP). One third of sales are in dairy products; the rest is split among poultry/eggs and high-value nursery products. Grains, vegetables, and fruits contributed around 10 percent of total sales (USDA 2002). The predicted higher temperatures due to unmitigated climate change will likely have a negative impact on the dairy industry; prolonged heat stress decreases milk production. One study shows that above a critical temperature threshold of 77° F, dairy cows produce less milk – up to 22 percent less (PNAS 2007). Such an impact on the dairy industry of Pennsylvania would also affect related economic activities, such as manufacturing and sales of dairy products, which annually account for nearly $16 billion and over 20,000 jobs (Census 2002; 2007 $s). Decline in dairy production may inflict around $480 million in direct and indirect economic costs; and the number of direct and indirect jobs affected may reach 5300 (RESI 2008).

Similar to forestry, agricultural impacts—particularly crops—will be dependent on temperature, precipitation, and carbon dioxide levels amongst other climate variables. Due to the projected increase in all three variables, crop productivity is likely to increase for certain crops (e.g. soybeans). Other crops – like corn –do not respond as favorably. Agricultural yields attributable to the carbon fertilization effect could be counteracted by increased ozone levels. One researcher predicts a net 10 percent reduction in crop yields when ozone is considered (Reilly et al. 2007). If crop yields decline by 10 percent, as projected, the state stands to lose nearly $150 million in direct economic costs – without considering indirect losses and impacts on jobs.

MISSING INFORMATION AND DATA GAPS

There is much uncertainty in the impacts of climatic changes on agriculture and forestry in the state. Modeling studies suggest increased carbon dioxide will increase photosynthesis and forest and crop yields. However, this projection is critical on the availability of timely precipitation, lack of disease-causing pests, and sufficient soil moisture, all of which are questionable under climate change scenarios. Furthermore, other gases such as ozone could counteract the carbon fertilization effect. Relatively little is known on the impact of climate change on the dairy industry.

Further studies of the impact of climate change on the deer-forest-tick relationship are also needed. Regeneration of old forests is essential to the sustainability of Pennsylvania's forestry, and white-tailed deer are detrimental to sapling growth. At the same time, a healthy deer population is needed to support the hunting economy. Further research on the distribution of forest pests would also be useful.

Better forecasts of Lake Erie's water level, shoreline changes, and associated water quality changes are needed. An increase in extreme precipitation events could be devastating to many sectors, including infrastructure, agriculture, and forestry amongst others. The IPCC is much more confident in its temperature forecasts, less confident in precipitation forecasts, and even less so for the frequency of precipitation events. Therefore, it would behoove Pennsylvania to proceed with caution and develop adaptation and mitigation plans for its most vulnerable industries.

CONCLUSIONS

Pennsylvania is projected to experience an average temperature increase of 6.3° F by the end of the century and a 7 percent average increase in precipitation levels. These climatic changes, along with the resulting impacts, stand to inflict economic costs on important sectors of Pennsylvania's economy. Although greater concentrations of carbon dioxide in the atmosphere may contribute to higher growth productivities in forest and agricultural species, the benefits are projected to be temporary and will likely be offset by the projected spread of harmful pests and diseases as temperatures continue to increase and habitats alter.

Dairy production, a significant agricultural sector in the state, is likely to decline as temperatures continue increasing. Changes in the distribution of forest types are predicted to affect the hunting and other recreational industries. Pennsylvania is already vulnerable to extreme weather events, and its infrastructure, distribution of utility services, such as water and energy, and the shipping industry may be impacted, if greater rates of precipitation and more frequent and intense hurricanes occur as projected in climate change models.

Lessons Learned

As we begin to quantify the potential impacts of climate change and the cost of inaction, the following five lessons are learned:

1. There are already considerable costs to society associated with infrastructures, agricultural and silvicultural practices, land use choices, transportation and consumptive behaviors that are not in synch with past and current climatic conditions. These costs are likely to increase as climate change accelerates over this century.

2. The effects of climate change should not be considered in isolation. Every state's economy is linked to the economies of surrounding states as well as to the national and global economy. While the economic costs of climate change are predicted to vary significantly from state to state, the negative impacts that regional, national and global markets may experience are likely to affect all states and many sectors.

3. While some of the benefits from climate change may accrue to individual farms or businesses, the cost of dealing with adverse climate impacts are typically borne by society as a whole. These costs to society will not be uniformly distributed but felt most among small businesses and farms, the elderly and socially marginalized groups.

4. The costs of inaction are persistent and lasting. Benefits from climate change may be brief and fleeting -- for example, climate does not stop changing once a farm benefited from temporarily improved growing conditions. In contrast, costs of inaction are likely to stay and to increase.

5. Climate models and impact assessments are becoming increasingly refined, generating information at higher spatial and temporal resolutions than previously possible. Yet, little consistency exists among studies to enable "summing up" impacts and cost figures across sectors and regions to arrive at a comprehensive, state-wide result.

6. To provide not just a comprehensive state-wide assessment of impacts and cost, but to develop optimal portfolios for investment and policy strategies will require support for integrative environmental research that combines cutting-edge engineering solutions with environmental, economic and social analysis. The effort and resources required for an integrative approach likely pales in comparison to the cost of inaction.

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