

**CHAPTER THREE**

# **Climate Change Impacts on Maryland and the Cost of Inaction**

**A REVIEW AND ASSESSMENT  
BY THE CENTER FOR INTEGRATIVE ENVIRONMENTAL RESEARCH  
(CIER) AT THE UNIVERSITY OF MARYLAND**

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**Commission on Climate Change**

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## INTRODUCTION

### Climate Change and the Cost of Inaction

**P**olicymakers 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 Chapter highlights the economic impacts of climate change in Maryland and provides examples of additional ripple effects of climate impacts, such as impacts on reduced spending in other sectors and resulting losses of jobs, wages, and tax revenues.

It is a key premise of this Chapter that climate will continue to change even if emissions of greenhouse gases will be drastically reduced. This is because the interdependent physical, chemical and biological processes in the oceans, atmosphere and on land do not respond instantly to changes in greenhouse gas emissions and because those greenhouse gases have mean residence times in the atmosphere of decades to over a century. While it is imperative that humans reduce their disruptive impact on climate and ecosystems, they must begin to prepare themselves for the changes they have kicked off since the industrial revolution.

Responses to climate change in the public, private and nonprofit sectors typically are separated conceptually into mitigation and adaptation actions. These two kinds of responses have often been perceived as fundamentally different: mitigation reduces emissions of greenhouse gases with benefits to the larger global community, whereas adaptation reduces vulnerabilities of individual sectors or regions, without necessarily addressing the root causes of climate change. However, considerable overlap between climate change mitigation and adaptation actions exists (Pielke et al. 2007, Ruth et al. 2006), and spending on one can simultaneously advance the goals of the other. Furthermore, mitigation and adaptation can promote broader goals of social, economic and environmental resilience, which will be essential to preparing society for a wide range of future changes, including those associated with climate.

Past research and modeling have concentrated on the quantification of costs for specific mitigation measures and, to a much smaller extent, on cost of adaptation actions. The narrow focus on mitigation was prompted because mitigation is essential to address the root causes of human-induced climate change. The focus on mitigation cost was justified by the fact that benefits of mitigation efforts are frequently diffuse and hard to quantify. The discussion of adaptation strategies has long been relegated to the sidelines, largely because adaptation was perceived to simply provide local benefits without taking on global responsibilities. Similar to mitigation, quantification of adaptation costs concentrated on the up-front financial burden to those who take action.

Not all environmentally induced impacts on infrastructures, economy, society and ecosystems reported here can be directly related to climate change. However, historical as well as modeled future environmental conditions are consistent with a world experiencing changing climate (Ruth 2006).

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 sector 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. 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 are not likely 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.

The remainder of the first section provides a primer on the science of climate change, the

subsequent effects expected to manifest globally, in the Northern Hemisphere, and in Maryland, and the methodology used in this Chapter. The second section focuses specifically on Maryland and discusses the physical changes expected to play out in the state over the coming century. The third section suggests the impacts of climate change on Maryland's coastal infrastructure. The fourth section elaborates on economic costs and benefits expected to be incurred by Maryland tourism, agriculture, natural resources, and human health as a result of climate change. The fifth and final section assembles and recaps the expected economic costs, identifies specific data and knowledge gaps, and highlights the need for further understanding of the significant economic impacts of climate change.

### 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<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) 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<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and CFCs because these gases are relatively long-lived and as a consequence become more evenly distributed in the atmosphere.

Step 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 2007a).

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 per cent decrease in Arctic sea

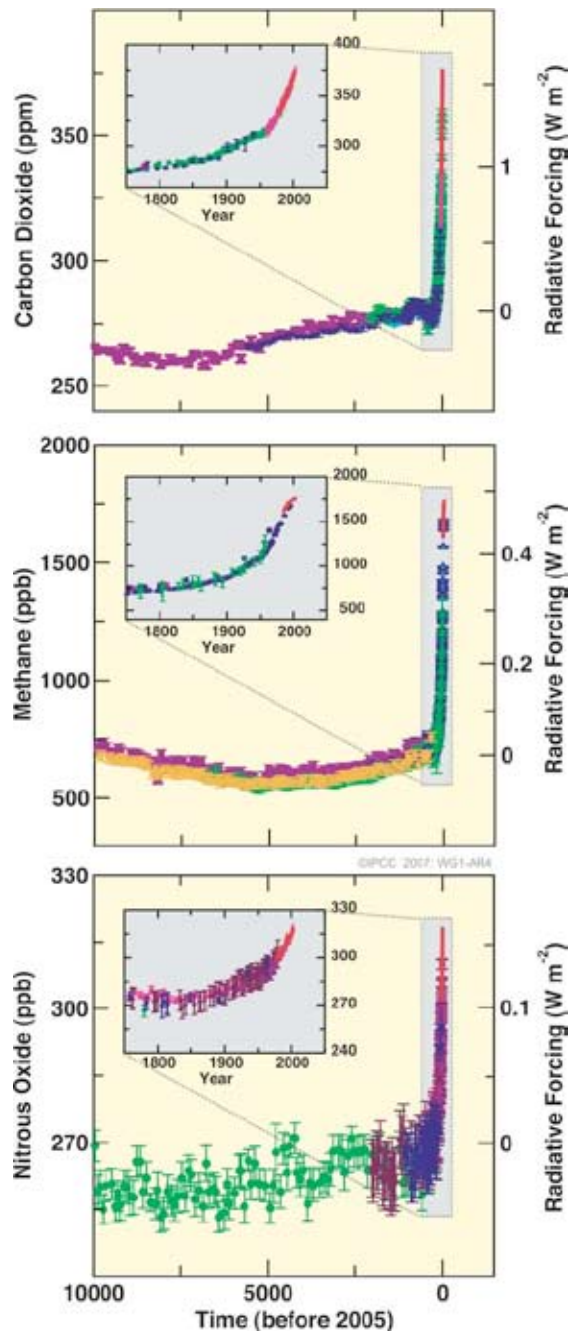
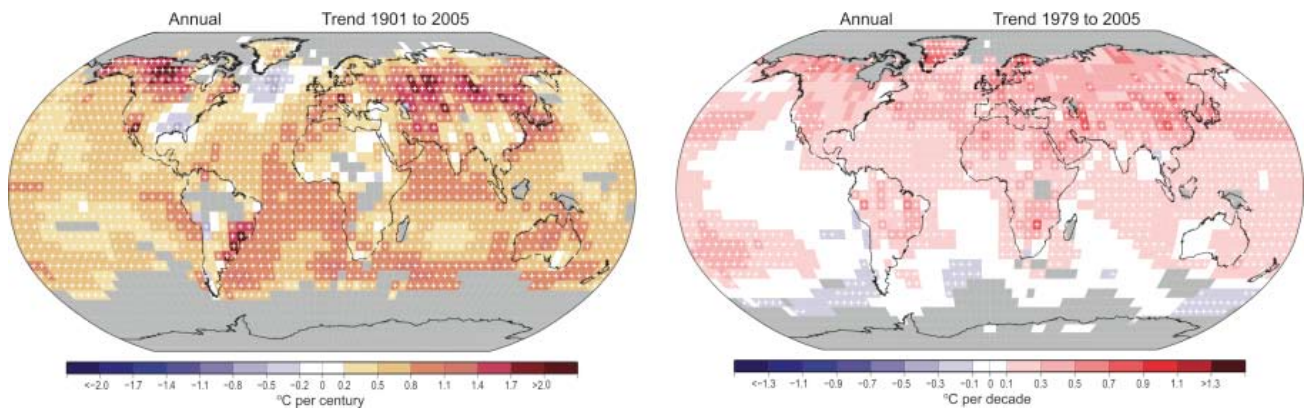


Figure 1: Atmospheric concentrations of carbon dioxide, methane and nitrous oxide (Source: IPCC 2007a)





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 per cent since the 1950s (IPCC 2007a).

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 per cent 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 erosion rates, water quality agricultural productivity, and many other attributes of our biophysical environment. 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.

The physical changes in Maryland resulting from climate change will generally be similar to

changes in the Northern Hemisphere, but the local-scale changes that are tightly correlated to Maryland's geography, hydrology, and ecology will be of the utmost significance to the state's natural resources, economy and its people. Maryland can expect temperatures to be warmer during every season, with the largest deviations from average temperature occurring during the summer months. Annual precipitation will increase and more winter precipitation will fall as rain; there will also be more frequent and intense storms. Sea level rise will inundate and alter much of the Maryland coastline.

### Impacts of Climate Change Throughout the United States and Maryland

This study on the economic impacts of climate change in the State of Maryland is intended to help inform the challenging decisions policymakers now face. It builds on a prior assessment by the Center for Integrative Environmental Research, entitled *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 (Ruth et al. 2007).

- 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.

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 Chapter identifies key economic sectors in Maryland, which are likely affected by climate change, and the main impacts to be expected. The Chapter 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 one sector in the economy ripple through to others. While we do not suggest that any of the past weather-related impacts on the state are, unequivocally, climate change induced, observations of past impacts can help illustrate the kinds of challenges to be faced in the future, and the kinds of costs to be incurred, should the state not be adequately adapt to climate change.

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 Chapter have been converted to 2007 dollars (Inflation Calculator 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 Chapter. These models can, at coarse spatial and temporal scales, illustrate how climate change may manifest itself in Maryland. Combining the insights from these models with observations of impacts in the past helps illustrate the nature and magnitude of changes that may lie ahead. One particular issue of interest at the state level are economic ramifications of climate change, including often overlooked ripple economic effects on other sectors and the state economy. To calculate these, we employed a modified IMPLANTM 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

## Maryland Temperature Anomaly

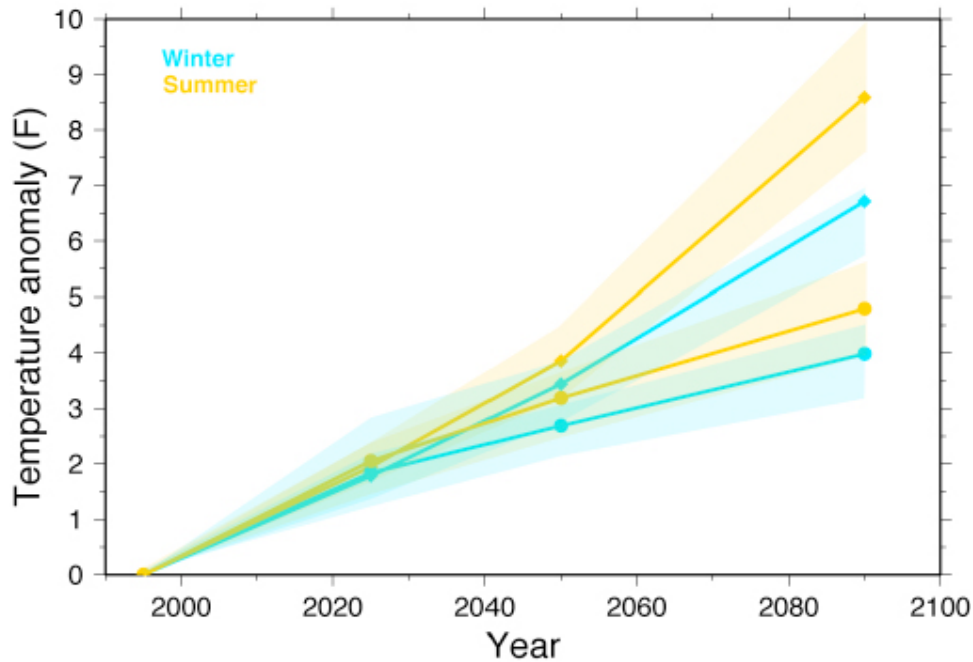


Figure 3. Temperature anomalies in Maryland under two emission scenarios (Source: MCCC – STWG 2008)

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.

### CLIMATE CHANGE IN MARYLAND

In the last century, Maryland has experienced rising temperatures, increased precipitation, more severe weather events, and a rise in sea level. Average annual temperatures for the Mid-Atlantic region have increased by .5-1° F (.3-.6° C) since 1900, which is more than the global average, while Maryland's average annual temperature has increased about 2° F (1° C) (Fisher et al., 1997; US EPA 1998; NOAA 2008a). The average temperature of the Chesapeake Bay has warmed by 2° F over the same time period (MCCC 2008). The greatest temperature increases have occurred during the winter months and all other seasons have increased slightly less (NOAA 2008a). Average precipitation has increased by 10 per

cent throughout most of Maryland and the entire Mid-Atlantic region of the US has received 12-20 per cent more major weather events relative to the previous century (US EPA 1998; NOAA 2008a; IPCC 2001). The sea level along the Maryland coastline has risen at a rate of 3-4 mm/year (.14 inch/year) over the last century – nearly twice the global average of 2 mm/year (.08 inch/year) (MDNR 2008; Oppenheimer et al. 2005).

These trends are predicted to continue or worsen if climate change progresses unchecked. Average yearly temperatures are expected to increase by 3-6° F (2-4° C) in the winter and by 4-8° F (2.2-4.4° C) in the summer (See Figure 3) (US EPA 1998; IPCC 2007b; MCCC – STWG 2008). Precipitation will increase by 20 per cent in Maryland with more rainfall in the winter and less in the spring (US EPA 1997; Fisher et al. 1997; IPCC 2007b). As climate change raises ocean temperatures, alters weather patterns, and contributes to the melting of polar icecaps and subsequent sea level rise, Maryland can expect significant coastal impacts. Major coastal storms will be more intense and more frequent (EPA 1998, IPCC 2007b). By century's end, 5-15 per cent more late-winter storms may develop in the Northeast as storm systems move further north in response to warmer ocean surface temperatures (Frumhoff et al. 2007).

Perhaps most significant to Maryland, sea level rise will increase by .6-1.22 m (24-48 inches) over the next century along the coast (MCCC 2008; MDNR 2008; IPCC 2007b).

## MAJOR ECONOMIC IMPACTS

The largest economic impact of climate change for Maryland will be on its coastal infrastructure and development. By the end of the century, expanding ocean water and melting polar ice caps will raise sea levels and expedite shoreline erosion; an estimated 6.1 per cent of Maryland's 4,360 miles of coastline is vulnerable to inundation by 2100 (US EPA 1998; MCCC 2008). Further coastal impacts will come in the form of more frequent and intense storms as well as flooding. Considerable strain will be placed on Maryland's coastal infrastructure and development, not to mention the estimated 6.3 million people that will live in Maryland's counties by 2020 (MDNR 2002; USCB 2006).

Population and economic growth trends will likely place more people and infrastructure at risk of negative climate change impacts in Maryland in the coming decades. Maryland's state gross domestic product has increased nearly 70 per cent from 1997-2007 (Figure 4) and average per capita income has increased 60 per cent in the same time period (Figure 5) (US BEA, 2007). The population of Maryland grew 33 per cent between 1980 and 2005, and Maryland Department of Planning projects another 20 per cent increase in population between 2005 and 2030 (Figure 6) (MDP, 2007). These growth trends will require commensurate increases in development of residential and commercial areas, utilities, roads, and public services, all of which increase the amount of assets in Maryland that are vulnerable to damage from climate change.

Development patterns in the Chesapeake Bay watershed show a trend towards higher population density and urban land use, which could exacerbate the effect of climate change on groundwater aquifers by increasing water runoff rates. There was a 21 per cent increase in urban land use and a 5.6 per cent increase in mixed land use in the Chesapeake Bay watershed from 1985 to 2002. Higher residential densities and associated commercial development raise the imperviousness of ground surfaces, increasing area runoff (Nelson, 2005).

Coastal areas are becoming more susceptible to

the effects of climate change as developments and populations grow in those areas. The population density of Maryland's eastern shore increased 30 per cent from 1985 to 2002. The total number of people living along the coastline in the United States is predicted to increase from 139 million in 1998 to 165 million in 2020 (Nelson, 2005). These developments put more properties at risk of flooding and storm damage from rising sea levels and more intense weather events.

Maryland Gross Domestic Product, 1997-2007

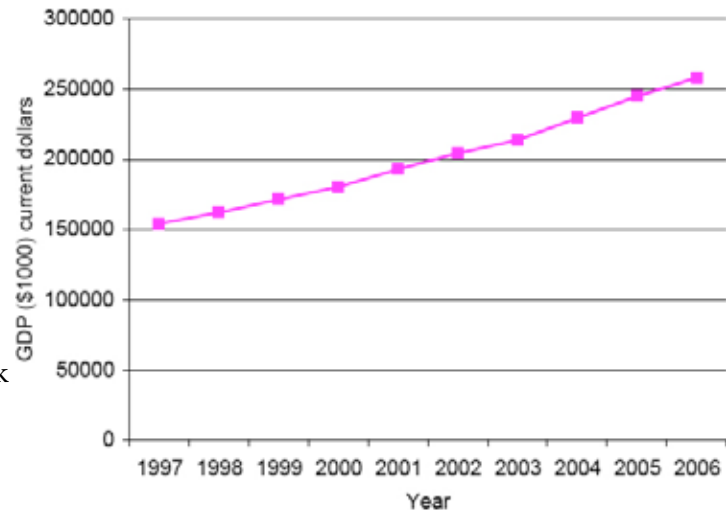


Figure 4. (Source: Bureau of Economic Analysis, 2007)

Currently, Maryland's coastal counties and Baltimore City are home to 67 per cent of the state's population in addition to hosting numerous tourist destinations, industrial sites, extensive commercial and residential development, and diverse ecosystems (MDNR 20028a). Because of the economic and geographic differences between Maryland's Baltimore – Washington corridor and its more rural and coastal regions, the effects of climate change will not be uniform across the state. Altogether, sea level rise, flooding, and major storm events will take an exacting toll on Maryland's multi-faceted and economically valuable coastal communities.

Average per capita income in Maryland, 1990-2007

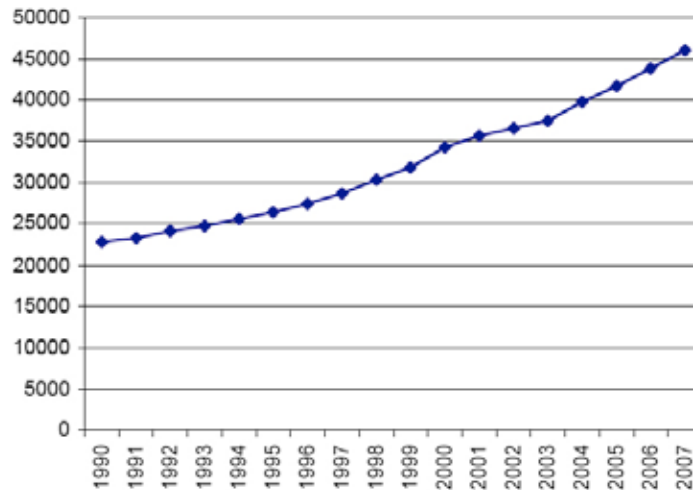


Figure 5. (Source: Bureau of Economic Analysis, 2007)

Maryland Population and Census Projections through 2030

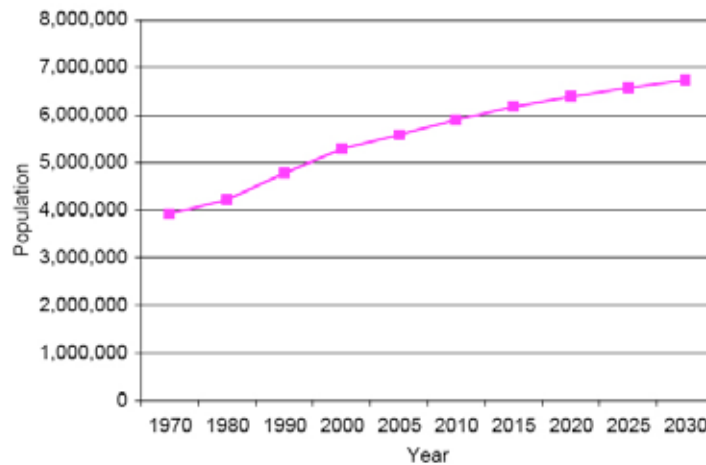


Figure 6. (Source: Maryland Department of Planning, 2007)

### Industrial and Urban Coastal Impacts

Among all Baltimore – Washington corridor counties, only Calvert, Anne Arundel, Baltimore, Harford, and Charles counties are coastal, but because of the connectedness of the corridor, it is useful to consider the region in its entirety. The Baltimore – Washington corridor is the most economically valuable region in Maryland with 86 per cent of the population and 90 per cent of the wages (USEPA 2004). Climate change, and more specifically sea level rise and extreme weather events, will significantly impact *transportation and trade* in the corridor.

The trade, transportation, and utilities sector accounts for \$3.4 billion (2007) in wage earnings in the Washington – Baltimore corridor region (USEPA 2004). At the end of FY 2007, the Maryland Department of Transportation calculated it had \$13.2 billion (2007) in total assets; among the capital assets are critical arteries for transportation including the Baltimore Harbor Tunnel, the Fort McHenry Tunnel, the Chesapeake Bay Bridges, and the Francis Scott Key Bridge (MDOT 2007). Although inundation in Baltimore and Annapolis is expected to be minimal, the increasing rate of shoreline erosion resulting from sea level rise could weaken bridge support systems,

limit access for maintenance, and deteriorate low-lying roads (Titus and Richman 2000). Extreme weather events such as hurricanes and tropical storms have the potential to create drastic impacts for Maryland's urban transportation and commerce. For instance, 2003's Hurricane Isabel brought 4-12 inches of rain and storm surges of 6 to 8 feet to Baltimore and Annapolis (Bennett 2005; NOAA 2008b). Water flooded Baltimore's Pratt and Light Streets in addition to numerous local businesses and homes, and the Baltimore Harbor Tunnel was closed for a period of time; the ultimate toll throughout Maryland from Hurricane Isabel was \$462 million (2007) (Bennett 2005; Roylance 2006). Such extreme weather events will likely be more intense under a scenario of undeterred greenhouse gas emissions (IPCC 2007).

As for coastal **shipping**, sea level rise poses a serious threat to accessing and operating Maryland ports. The Port of Baltimore produces \$1.98 billion (2007) in annual economic benefits and provides for 127,000 maritime related jobs (EPA 2004). Keeping the appropriate water depth is a critical aspect of port maintenance, and the Port of Baltimore dredges its waterway regularly to keep the flow of goods unimpeded. However, if increased levels of trash and sediment continue to deposit in Baltimore Harbor due to increased levels of runoff upstream from flooding, dredging operations could become both more costly and environmentally damaging (Moss et al., 2002). Low-lying access roads are at risk to flooding while shipping ports will have to adjust infrastructure to establish a working land-sea interface. Commercial fishing and crabbing in Maryland generates more than \$207 million (2007) annually and manufacturing contributes \$1.76 billion (2007) in wages – both of which are dependent on reliable access to ports from both land and sea (USEPA 2004; BEA 2007). Steadily rising sea levels as well as abrupt non-linear sea level increases could create economic hardships for Maryland's shipping, fishing, and manufacturing industries. A 1 per cent decrease in shipping activity at the Port of Baltimore between now and 2018 would result in an indirect economic impact of roughly \$361 million on Maryland's GDP and a loss of more than 3,600 jobs (RESI, 2008).

## Residential and Rural Coastal Impacts

The economic impacts manifesting from climate change will be significant along the industrial and urbanized Baltimore – Washington corridor, but the most visible, and possibly more expensive economic impacts, will occur along the residential and rural portions of Maryland's coast. Sea level rise in Maryland is predicted to claim more land than the national average due to local conditions that make the shoreline particularly vulnerable to soil erosion and land subsidence. Maryland is the fourth most vulnerable state with an estimated 6.1 per cent of its land likely to be inundated by a rise in sea level (MCCC 2008). Currently, an estimated 30 per cent of the state's coastline undergoes erosion and an average of 260 acres are lost each year (EPA 2004). Maryland's Southeastern counties are most vulnerable to sea level rise and inundation due to their low-lying topography and exposure to the ocean (See Figure 7).

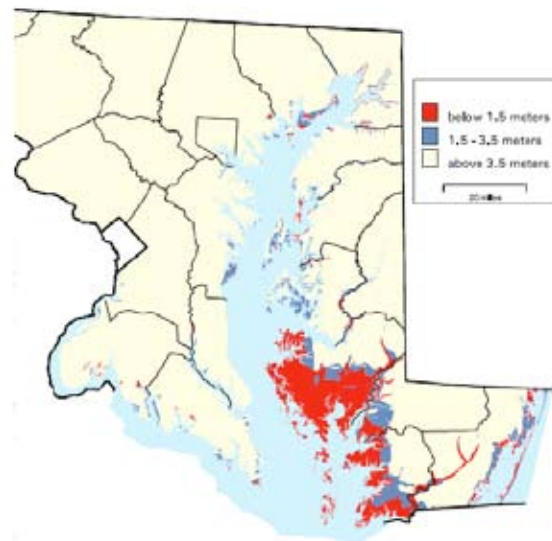


Figure 7. Inundation scenarios resulting from sea level rise and episodic flooding (Source: Titus and Richman 2000)

In Maryland, much of the vulnerable land below 3.5 meters is undeveloped barrier island or tidal wetlands (USEPA 2007). Nonetheless, Ocean City and other developed areas along the Eastern shore are very susceptible to rising sea levels. Furthermore, although less than 10 per cent of Maryland's population lives on the Eastern shore, the area is culturally significant for the state, it is growing rapidly (i.e., 32.9 per cent in Dorchester County), and it is a popular destination for summer vacationers (USEPA 2004). An Environmental Protection Agency study (1985) on Ocean City beaches suggested that without preventative measures, a 15-inch increase in sea level would result in a 216 – 273 feet loss of shoreline (USEPA 2007). With an estimated 3,750 households in Ocean City and property values that likely exceed one million dollars, such a loss in shoreline and land availability would easily translate into a several billion-dollar loss (USCB 2000). Protecting coastal development from inundation, beach erosion, and salt-water intrusion will be costly and uncertain. Ocean City benefited from a beach replenishment project in the late 1980's, which cost \$38 million (2007), but more replenishment will need to occur if Ocean City beaches are to endure increasing sea levels (USEPA 1998).

Rural Maryland will not only incur economic costs from a rise in sea level and increased flooding, but also from more intense storms. Once the wetlands and barrier islands that serve as a buffer between communities and the ocean are deteriorated, damage from extreme events will be enhanced. Hurricane damage along the Northeast US coast has cost an estimated \$5 billion (2007) per year with much of this cost coming from single major storm events (Frumhoff et al. 2007). For example, Hurricane Floyd ravaged the Eastern shore of Maryland in 1999 when storm water discharge rates reached 100-year levels and total property damage totaled \$17.76 million (2007) (Tallman and Fisher 2000). Last, the insurance sector will likely face unstable periods as property succumbs to flooding and shoreline inundation. For instance, flooding from heavy rains in June of 2006 cost insurers in the Baltimore-Washington region over \$25 million (Cohn, 2006). Maryland's finance and insurance sector accounts for \$8.5 billion (2007) in wages and salary and supplies 4.2 per cent of the state's employment base (USBEA 2007). It is predicted that by 2080, insurers' capital requirements to cover the cost of hurricane

damage in the US will increase by 90 per cent (Association of British Insurers 2005).

It should be noted, that the construction sector benefits from flooding or the destruction of infrastructure, as it will be involved in the rebuilding effort. But while jobs are created in the rebuilding effort, those construction workers are not available to build new buildings and infrastructures elsewhere. As a result, the state's infrastructure and building stock cannot expand to accommodate new economic growth. The insurance sector maybe impacted, but it would likely adjust its rates to reflect new probabilities of flooding and storm damage. This increase in rates would divert disposable income from consumption to that sector.

### **ADDITIONAL ECONOMIC IMPACTS**

In addition to the economic hurdles that will impair Maryland's coastal development and transportation infrastructure, tourism, agriculture and health-related economic losses will likely transpire as a result of climate change.

#### **Tourism**

In 2006, Maryland's tourism generated roughly \$11.72 billion (2007) in visitor spending, directly supported 116,000 jobs, and created \$920 million (2007) in state and local tax revenue (MOTD 2008). Based on tourism-derived state tax revenue from each county, roughly 62 per cent of tourist activity takes place in the state's coastal counties, renowned for the public beaches, beachfront real estate, and tourist hotspots, such as Ocean City (MOTD 2008). However, with a weakening coastal infrastructure, beach erosion, and the very real threat of seawater inundation in locations like Ocean City, tourism is likely to suffer in Maryland.

Increasing beach erosion and more major storms may render the Maryland coast a less attractive tourist destination. It is estimated that beaches will erode at a rate of 50 to 100 times faster than the rate of sea level elevation and that the cost of replenishing the coastline after a 20-inch rise in sea level would be between \$35 and \$200 million (Zhang 2002; USEPA 1998). As the cost of maintaining and protecting beaches from erosion increases, both residents and tourists may find locations like Ocean City are too expensive. As with coastal infrastructure and development, we can expect extreme weather events to be associated with a loss in economic activity in the tourism sector as well. Barrier islands and other tourist

destinations around the Eastern Shore are major targets for hurricanes and tropical storms and as storms occur more often and are more intense, tourists may be less willing to risk their vacation.

Maryland is also an ideal location for eco-tourism because of the Chesapeake Bay, which harbors an estimated 2,700 species. In 2006, an estimated 166,000 non-Marylanders spent more than \$30 million (2007) on wildlife watching in Maryland (USFWS 2006). However, losses in eco-tourism are likely to result as a 21 per cent reduction in mid-Atlantic wetlands between now and 2100 hinders shorebird nesting and fish nurseries (Najjer et al. 2000). Hunting and fishing is also big business in Maryland. The US Fish and Wildlife Service (2006) estimated 43,000 people hunted waterfowl in Maryland in 2006, generating \$26.23 million (2007) in economic activity (USFWS 2006). As a result of wetlands loss, the economic activity generated by waterfowl hunters will likely decrease. Climate change is a multi-dimensional problem for the Chesapeake Bay's aquatic life. Loss of wetlands will restrict species habitat locations, warmer and saltier water will

restrict the range of cold, fresh-water species, and hypoxic conditions may be exacerbated, as a longer summer season will support more algae growth cycles (See Table 1) (Glick et al. 2007). In 2006, \$308 million (2007) was spent on recreational saltwater fishing in Maryland (USFWS 2006). A 2 per cent decrease in out-of-state wildlife watchers between now and 2018 would result in an indirect losses to Maryland's GDP of \$10 million and a loss of almost 100 jobs (RESI, 2008).

### Agriculture

Agriculture is the second-largest land use category in the Mid-Atlantic region after forests (Alber, 2000). The total value of agricultural products in Maryland totaled nearly \$1.5 billion (2007) in 2002, with crops accounting for 35 per cent of that value (USDA, 2002). Corn and soybeans make up the two largest volume crops by acreage (USDA, 2002). While an increase in CO<sub>2</sub> concentrations could increase the yields of corn and soybeans, other climate changes will have a net negative effect on yields in the Appalachian region, which includes

<i>Species</i>	<i>Likely Trend</i>	<i>Climate Change Impacts</i>
Winter flounder	High Loss <sup>1</sup>	Temperatures could exceed habitable range
Soft-shelled clam	High Loss	Temperatures could exceed habitable range
Rockfish	Medium / Low Loss <sup>2</sup>	Water temperatures could reach near upper limit of habitable range; increased chance of mycobacterial infections
Atlantic Sturgeon	Medium / Low Loss	Water temperatures could reach near upper limit of habitable range
Blue crab	Medium / Low Loss	Declining eelgrass habitat with rising sea level and exacerbated eutrophication
Atlantic menhaden	Medium / Low Loss	Warmer water more conducive to mycobacterial infections
Eastern oyster	Medium / Low Loss	Warmer water more conducive to <i>Dermo</i> and <i>MSX</i>
Brown shrimp	Potential Gain <sup>3</sup>	Warmer water more favorable
Southern flounder	Potential Gain	Warmer water more favorable
Black Drum	Potential Gain	Warmer water more favorable
Grouper	Potential Gain	Warmer water more favorable
Spotted seatrout	Potential Gain	Warmer water more favorable

Table 1. Projected aquatic species changes as result of climate change<sup>4</sup> (Source: Glick et al. 2007).

<sup>1</sup>Potential loss of species altogether in the Chesapeake Bay

<sup>2</sup>Likely decline in species range or viability in the Chesapeake Bay

<sup>3</sup>Likely expansion of species range or viability in the Chesapeake Bay

<sup>4</sup>These probable effects were identified based on available information, but significant changes in key parameters such as temperature and salinity are likely to have wide-ranging unpredictable effects on life cycles and food webs



Crop	50% increase in CO <sub>2</sub> (365 to 560 ppm)			Change from 1961 - 90 climate to 2025 - 34 climate		
	Northeast	Appalachian	Corn Belt	Northeast	Appalachian	Corn Belt
Unirrigated corn	10.5*	11.1*	9.0*	14.3*	-1.7	5.6*
Soybeans	18.6*	18.5*	17.0*	4.6	-7.0	-7.4*
Unirrigated alfalfa	—	—	19.2*	—	—	14.4*

Table 2. Per cent changes in regional crop yields under two scenarios (Source: Abler, 2000)

Maryland (See Table 2) (Abler, 2000). As the values of production of corn and soybeans were \$204 million and \$108 million respectively in Maryland in 2007, future climate changes would have resulted in a loss of \$11 million (USDA, 2008).

Droughts caused by climate change could also take a severe toll on the agricultural sector. Although Maryland is expected to receive more precipitation, droughts may develop because warmer, more arid temperatures tend to draw moisture out of soil at a rate that offsets increased precipitation. Maryland has suffered through two regional droughts in the past ten years – one from 1998-1999, and another from 2001-2002. The first drought caused \$800 million in crop losses throughout the mid-Atlantic region (Kunkle, 1999). Consumers and livestock farmers feel the effects of crop loss in the form of higher food and feed prices. The price of a bushel of corn increased from \$2.18 to \$2.85/bushel, or 30 per cent, in Maryland between 2001 and 2002 (USDA, 2008).

Another detrimental effect of climate change on agriculture will be the northern expansion of *invasive species* due to higher temperatures, including warm-season weeds, nematodes, and insects (Abler, 2000). Maryland farmers spent \$39 million (2007) on pesticides in 2002 (USDA, 2002) and that price will likely increase, but the cost of using more pesticide includes environmental degradation, as well. Runoff from pesticides contributes to degrading freshwater and coastal ecosystems (Rogers, 2000). In addition to pesticide runoff, 64 per cent of farms in Maryland have tested positive for cryptosporidiosis, which can reach shellfish populations in the Chesapeake Bay (Moss, 2002).

In addition to invasive species, sea level rise due to climate change may cause saltwater intrusion into agricultural waterways and groundwater aquifers. Both rivers and the ocean feed water into the Chesapeake Bay, making it a body of brackish water. The level and extent of salinity in surrounding area groundwater and waterways

is mostly a function of sea level (Heywood). Important Maryland crops such as corn and soybeans require very low salinity to grow (less than 2 parts per thousand for corn and less than 3/10 parts per thousand for soy) (Moss, 2002). Also, groundwater aquifers that supply potable water might need to invest in desalination technology, which can increase the cost of water by over 50 per cent (Kranhold, 2008).

The composition of Maryland forests could change as a result of warmer temperatures. The hardwoods currently found in Western and Northern Maryland could be replaced by more heat tolerant southern pines and oaks (US EPA 2008). The threat of forest fires could also increase during the summer as a result of warmer temperatures, though this is dependent on annual precipitation fluctuations. The density of Maryland forests may change little or decrease by as much as 10 per cent (USEPA 1998). Maryland's forest industry is the state's fifth largest providing for 18,000 jobs and \$2.48 billion in economic activity (MDNR 2008b). Moreover, forestry is the number one industry in Western Maryland and the second largest industry after agriculture on the Eastern shore. With just a 1 per cent decrease in harvestable trees as a result of decreased forest density between now and 2018, we can expect an indirect economic loss of over \$263 million on Maryland's GDP and a loss of over 1,600 jobs (RESI, 2008).

## Health

Health impacts related to warmer temperatures and water quality will likely develop in Maryland over the coming century. Higher temperatures can have particularly acute respiratory health effects in cities, where heat islands develop because of concrete and asphalt cover and non-point source pollution causes poor air quality and high concentrations of ground level ozone (Moss, 2002). Maryland can also expect higher rates of heat-related deaths during the summer months. A study by the Johns Hopkins School of Public Health correlated daily mortality rates and temperatures for eleven east coast U.S. cities from 1973-1994 and found that there is a “Minimum mortality temperature” (MMT) above which heat-related deaths increase steadily. The study found that Baltimore ranks first among east coast cities for the rate of increased mortality at temperatures above the MMT (see Table 3) (Curriero et al., 2002). As summer days grow hotter due to climate change, Baltimore and other Maryland cities should be prepared to deal with higher rates of heat-related health effects.

Higher temperatures will also increase demand for water supplies used for both drinking and irrigation. To be sure, low quantities of water are a serious threat to human health, but perhaps more insidious is the problem of impaired water associated with a reduced supply and flooding. Reduced water supplies lead to a higher

concentration of bacteria, pesticides and other unwanted biological organisms as well as chemical substances than would be present under normal conditions. Moreover, warmer water and longer seasons facilitate the growth of algae and harmful bacteria that lead to fish kills and generally poor water quality. Where warmer temperatures do not impair water quality, flooding from an elevated sea could potentially introduce bacteria, harmful chemicals and salt water into fresh drinking water sources (Frumhoff et al. 2007). In 1992, for example, salt water recharged the Potomac-Raritan-Magothy aquifer and the chloride concentrations increased from 10mg/liter to 70mg/liter; a higher than ideal amount of chloride for drinking water (Oppenheimer et al. 2005).

In addition to sea level rise, increased precipitation will take a toll on public health in Maryland. Another study from the Johns Hopkins School of Public Health shows a positive correlation between higher-than-average precipitation events and outbreaks of waterborne diseases (Curriero et al., 2001). Greater intensity runoff events can increase particulate and chemical concentrations in aquifers for drinking water, as well. Runoff can damage water and sewage treatment plants and cause septic tanks to fail, both of which increase the risk of drinking water contamination (Neff et al., 2000).

City	Minimum mortality temperature (MMT) <sup>5</sup>	Cold slope <sup>6</sup>	Hot slope <sup>7</sup>
Boston, Massachusetts	69.71	-4.34	5.83
Chicago, Illinois	65.17	-2.25	2.45
New York, New York	66.42	-3.59	6.28
Philadelphia, Pennsylvania	70.58	-4.37	6.11
Baltimore, Maryland	70.46	-2.65	6.56
Washington, D.C.	70.56	-3.13	3.67
Charlotte, North Carolina	90.38	-3.27	NA
Atlanta, Georgia	76.29	-2.91	5.41
Jacksonville, Florida	76.75	-3.76	3.71
Tampa, Florida	80.71	-7.12	1.43
Miami, Florida	80.92	-5.46	4.01

<sup>5</sup>Percentage change in mortality per degree centigrade

<sup>6</sup>Cold slope = average slope of the estimated relative risk curves at temperatures lower than MMT

<sup>7</sup>Hot slope = average slope of the estimated relative risk curves at temperatures hotter than MMT

## CONCLUSION

### Recap of Climate Change Impacts

The economic impacts of climate change on Maryland will depend on the exact physical changes that manifest. Although there is a degree of uncertainty, the consensus scientific literature agrees that annual average temperatures will increase by 3-8° F, annual average precipitation will increase by roughly 20 per cent, there will be more frequent and intense late-winter storms, and sea levels will rise by 24-48 inches in Maryland, throughout this century (Fisher et al., 1997; US EPA 1998; NOAA 2008a). The physical changes that develop will significantly alter the State's coastline, beachfront, agricultural productivity, species biodiversity, weather patterns and other factors that are tightly correlated with economic conditions.

Another critical factor dictating how the economic impacts of climate change play in Maryland is population growth and development. As Maryland's population grows by 20 per cent between now and 2020 and as the State's GDP grows at a rate between 60-70 per cent, economic losses from climate change will run in parallel (US BEA, 2007; MDP, 2007). By becoming a more populated, developed, and economically interconnected State, there will be more avenues for direct and indirect effects of climate change to impact the State. The growing and interconnected nature of the State could potentially make it more vulnerable to the cascade effects of climate change if there isn't a strong effort now to stimulate a resilient and robust economy that can cope with the expected impacts of climate change.

### Missing Information and Data Gaps

This study is subject to the uncertainties inherent in measuring global climate change impacts and climate change itself and attempts to reflect this as best as possible through use of scenarios and ranges of confidence. Additionally, quantifying the economic impacts of climate change deserves significantly more focus as this chapter and much of the literature on the topic primarily address the potential impacts from a qualitative perspective. Further, data gaps exist between the effects of climate change in one particular sector and the ripple effects that manifest in interconnected sectors. Analysis of this sort would be useful to policy-makers and businesses at all levels and sizes. Information that would be especially useful for

policy makers would be more precise figures, e.g., for land and property along the highly threatened portions of Maryland's coast.

### Recommendations and Considerations

Maryland's greatest challenge is likely to be in adapting to climate change along its expansive coast, as this is where the most significant economic and ecological impacts will occur. The State's economy is particularly vulnerable because of the scale of development along the coast and the high rate at which coastal erosion and subsequent water elevation will afflict its shoreline. Further development along the State's shoreline needs to be carried out with the understanding that the shoreline is not stationary and will steadily move inwards throughout the coming century. Lastly, legislators may want to consider legislation to circumvent health related impacts of climate change related to the urban heat island effect and decreases in fresh drinking water quality and quantity. The urban heat island effect can be mitigated through careful city planning and smart growth (e.g., incorporating more green space into development sites). One tactic for maintaining water quality is to encourage streamside tree planting and plant buffer strips as they absorb harmful pollutants as well as reduce water warming.

### Lessons Learned

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

- First, 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 the century to come.
- Second, 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.
- Third, benefits from climate change may

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

- Fourth, 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, statewide result.
- Fifth, to provide not just a comprehensive statewide 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 pale in comparison to the cost of inaction.

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