SCIENCE

CLIMATE CHANGE: COST OF INACTION FOR MARYLAND'S ECONOMY

CENTER FOR CLIMATE AND ENERGY SOLUTIONS

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The *American Climate Prospectus* addressed several key climate impacts over the coming century, including increases in heat-related mortality, increases in the amount of coastal property exposed to flooding, declines in labor productivity, increases in energy expenditures, and declines in agricultural output. In this paper, we explore impacts not explicitly presented by the *American Climate Prospectus*, which include estimates of how climate change might affect infrastructure, tourism, ecosystems, agriculture, water resources, or aspects of human health beyond heat-related mortality (e.g., respiratory ailments associated with lower air quality, and changes in the range of disease vectors). Additionally, we provide an update to the costs of inaction previously listed in Chapter 4 and Appendix F of the 2011 *Maryland Plan to Reduce Greenhouse Gas Emissions* (Appendix A; Table 1). Where available, data are provided by various state agencies. Data that could not be updated, or have not significantly changed since 2011, have been copied from the 2011 report. Additional regional data are supplied by the EPA report, *Climate Change in the United States: Benefits of Global Action*. In all cases: 1) risks and costs grow with increasing severity of climate change impacts, and 2) risks and costs can be significantly reduced through immediate actions to mitigate the impacts of climate change.

ABOUT EPA CIRA PROJECT AND UPDATES TO MARYLAND'S ECONOMIC DATA

OVERVIEW AND METHODOLOGY

Climate Change in the United States: Benefits of Global Action estimates the physical and monetary benefits of reducing greenhouse gas emissions and summarizes results from the U.S. Environmental Protection Agency's (EPA) Climate Change Impacts and Risks Analysis (CIRA) project.[1] Overall, the report demonstrates that significant economy-wide benefits are possible.

The CIRA project uses a three-step approach for assessing benefits: developing greenhouse gas (GHG) emissions scenarios, simulating a future climate under each scenario, and applying the projections to a series of impact analyses over multiple economic sectors, including infrastructure, health, and ecosystems. Two primary emissions scenarios were chosen for the project using the National Center for Atmospheric Research's (NCAR) IGSM – Community Atmosphere Model (CAM). The first was a business-as-usual "reference" scenario and the second a global emissions reduction "mitigation" scenario. These two scenarios are similar to the Intergovernmental Panel on Climate Change (IPCC) RCP 8.5 emissions scenario and a blend of the RCP 2.6 and RCP 4.5 emissions scenarios, respectively.[2]

To quantify impacts, statistical models were applied using socio-economic and climate scenarios to ensure each model was driven by the same inputs, which enables an apples-to-apples comparison across all sectors. Results under the IGSM-CAM projections, which estimate a wetter future for most of the United States, are also complemented with drier model projections to investigate that influence on impact estimates.[3]

FINDINGS BY SECTOR

This section highlights the anticipated impact of climate change on Maryland as well as on a broader Mid-Atlantic and Northeast regional scale, for which Maryland is included. The costs of inaction or the benefits of mitigation listed in this section are not defined using explicit probabilities as in the *American Climate Prospectus* report. However, the general value placed on man-made and natural resources combined with the impacts of climate change does indicate an associated level of economic risk. The following sectors are analyzed: infrastructure, tourism, agriculture, and public health.

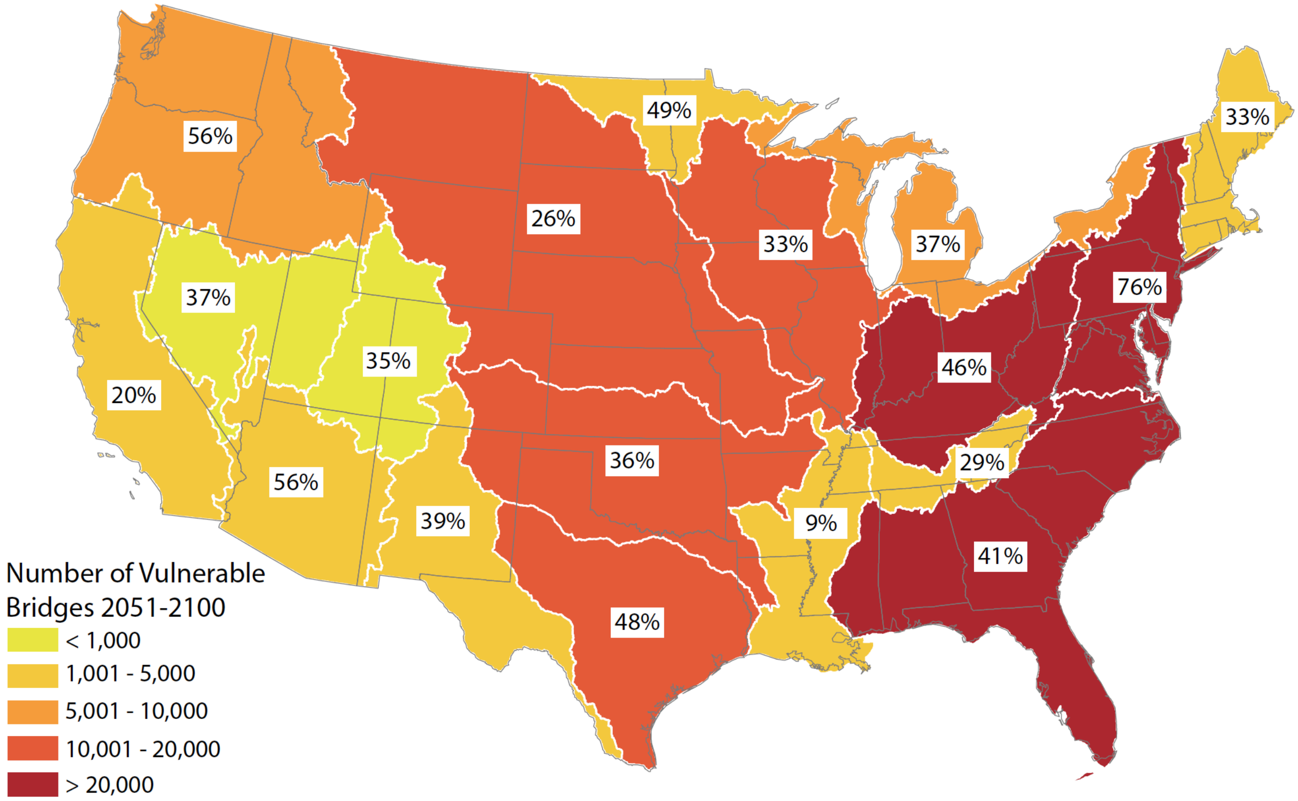
INFRASTRUCTURE

Infrastructure makes up the basic physical and organizational structure of society. It is both interdependent and interconnected, and includes bridges and roads, ports and airports, energy systems, drainage, and water treatment. Maryland's infrastructure has enormous value, both as a capital asset and by providing social well-being and economic security. In 2014, trade, transportation, and utilities accounted for $47.6 billion (14 percent) of Maryland's gross domestic product (GDP), with manufacturing contributing an additional $18.8 billion to the state GDP.[4]

Recent extreme weather events such as Superstorm Sandy in 2012 provide evidence of how vulnerable the state's infrastructure is to the effects of climate change, including sea level rise, storm surge, rising temperatures, and inland flooding due to increased precipitation. Sea level rise and storm surge are already impacting Maryland's coastlines - 13 islands within Chesapeake Bay have been submerged.[5] By 2100, it is projected that sea level rise could increase between 2.1 and 4.4 feet.[6] This will place an additional 6.1 percent of Maryland's coast in jeopardy and potentially submerge over 400,000 acres along the Eastern Shore, a region expected to see a 27 percent increase in population by 2040.[7] Additionally, sea level rise could alter shipping lanes within Chesapeake Bay and the Port of Baltimore, placing one of the largest ports along the Eastern United States at risk. In 2014, the Port of Baltimore generated over $6 billion in business revenue and wages while moving over $52.5 billion of cargo.[8] Furthermore, FEMA estimates an additional 36 to 58 percent increase in annual storm damage costs for every one foot rise in sea level and a 102 to 200 percent increase in damage costs for a three foot increase.[9]

The average age of bridges in the United States is now over 40 years old. Inland flooding and extreme hot and

FIGURE 1: Bridges Identified as Vulnerable by 2100 due to Unmitigated Climate Change



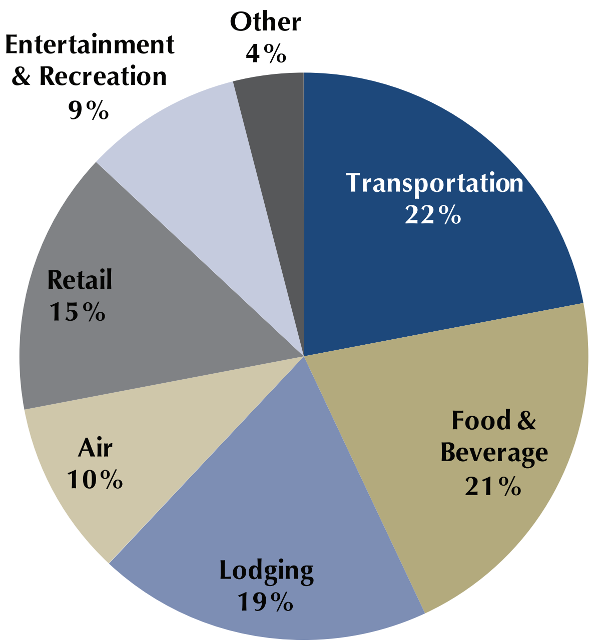
Source: EPA, Climate Change in the United States: Benefits of Global Action; Infrastructure, Fig. 1

cold temperatures pose the largest risks to bridges. Under the reference scenario an additional 190,000 bridges across the country are identified as vulnerable.[10] The costs of adapting bridges to climate change are estimated at $170 billion from 2010 to 2050, and $24 billion from 2050 to 2100 (discounted at 3 percent).[11] The large initial costs come as a result of initial investments to strengthen the bridges to minimize later climate impacts. The IGSM-CAM identifies the Mid-Atlantic as one of the most vulnerable regions, with 76 percent (over 20,000) of bridges at risk by 2100.[12] Through mitigation efforts, adaptation costs in the Mid-Atlantic region are reduced by as much as $57 billion through 2100.[13] Mitigation efforts also reduce the number of vulnerable bridges in the Mid-Atlantic region to 35 percent, or between 10,000 and 20,000 bridges.[14]

Without reductions in GHG emissions, the costs of maintaining, replacing, and repairing roads is also projected to increase. Rutting of paved roads and erosion of unpaved roads due to increased precipitation and rutting and cracking of roads due to higher temperatures and increased freeze-thaw cycles are the largest risks. Using the reference scenario, costs in the United States are projected to range from $5.8 to $10 billion dollars in 2100, with costs of over $1 billion alone in the Northeast U.S.[15] Global GHG mitigation is projected to avoid an estimated $4.2 to $7.4 billion of the damages under the reference scenario in 2100.[16]In the Northeast U.S., mitigation efforts limit projected road maintenance costs to between $100 and $250 million in 2100.[17]

Inland flooding is also projected to result in increased adaptation costs for urban drainage infrastructure. Under the reference scenario, the IGSM-CAM model determined projected costs for 50 modeled cities in 2050 and 2100 for a once-every-10-year, once-every-25-year, and once-every-50-year storm event. The result is a weighted average per-square-mile adaptation cost which is aggregated to a given region. Baltimore was one of

FIGURE 2: Breakdown of 2013 Tourism Spending ($15.4 billion) by Category



Source: Maryland Office of Tourism Development, 2013 Annual Report

four cities modeled in the Northeast region. Here, costs are projected to range between $200,000 and $500,000 per storm by 2050, depending on storm intensity.[18] These costs increase to between $300,000 and 600,000 per storm by 2100.[19] Using the mitigation scenario, cost savings for urban drainage systems are projected as high as 55 percent, with the largest amount of savings from the 50-year storm in 2100 (the highest intensity storm).[20]

TOURISM

In 2013, roughly $15.4 billion was generated within Maryland's tourism sector.[21] This resulted in $2.1 billion in tax revenue which directly supported over 138,500 jobs with a payroll of $4.6 billion.[22] Maryland saw growth in business and leisure travel, as well as an increase in the number of day trips. Tourism in Maryland outperformed the national trend and led the Mid-Atlantic region in visitor growth.

Much of Maryland's tourism is dependent on short-duration trips made by local and regional residents during the summer months. Barring efforts to mitigate the impacts of climate change, the number of days above 95 degrees by 2050 could reach five times the current 30 year average of 6 days.[23] By 2100, the number of days above 95 degrees could increase tenfold. Longer and more intense heat waves could make Maryland less pleasant to visit during prime summer tourist season. Warmer weather may increase the length of the tourist season, but more frequent extreme weather events could offset any potential gains, fostering economic uncertainty within the tourism sector. If the increase in extreme weather shrank the tourism sector by 5 percent, this would translate to an annual loss of $770 million.[24]

Rising sea levels and storm surge will also adversely impact the tourism sector for coastal communities. Both climate impacts will place further strain on already vulnerable coastal infrastructure, such as bridges, roads, and boardwalks. Not only will this impact travel for tourist, but it will increase maintenance costs for local communities and the state. Costs of beach replenishment can range from $35 million to $200 million dollars, depending on the amount of erosion.[25] Repair and maintenance work also increases the risks to fragile coastal ecosystems.

Changes in temperature and precipitation patterns, along with the increased frequency of extreme weather events, will also increase the vulnerability of the state's ecosystems. While maintaining a diverse and resilient ecosystem is important for a myriad of environmental reasons, it is also vital for Maryland's tourism economy. In 2011, $282 million was spent on hunting, $755 million on recreational fishing, and $623 million on wildlife viewing, especially along coastal waterways.[26]

AGRICULTURE

Agriculture continues to play a significant role in state's economy. In 2012, the market value of agricultural products sold by farms was $2.27 billion[27]. Of this total, $1.05 billion was in the form of crop sales and $1.22 was in livestock. Of the latter, $923 million was for poultry and eggs.[28]

Because agriculture plays a large role in the state's overall economy, it is important to understand how the impacts of climate change will impact this sector. Poultry and eggs represent a large proportion of sector revenue. Many of the chickens and turkeys on poultry farms are raised in enclosures. Projected three to tenfold increases in days above 95 degrees, along with projected average summer temperatures over 10 degrees higher than the current 30-year average, will increase the health risk to these and other livestock and potentially stunt growth. Furthermore, the increase in temperatures will require more energy to cool enclosures and retrofits to increase ventilation.

Vulnerability will also extend to crops as temperatures rise and precipitation patterns become more unpredictable. Immediate benefits of warmer temperatures and increased carbon dioxide in the atmosphere will turn to losses by mid-century as average summer temperatures rise above critical growing thresholds for corn, soy, and wheat. Under business-as-usual conditions, median annual losses could approach $150 million by 2100.[29]

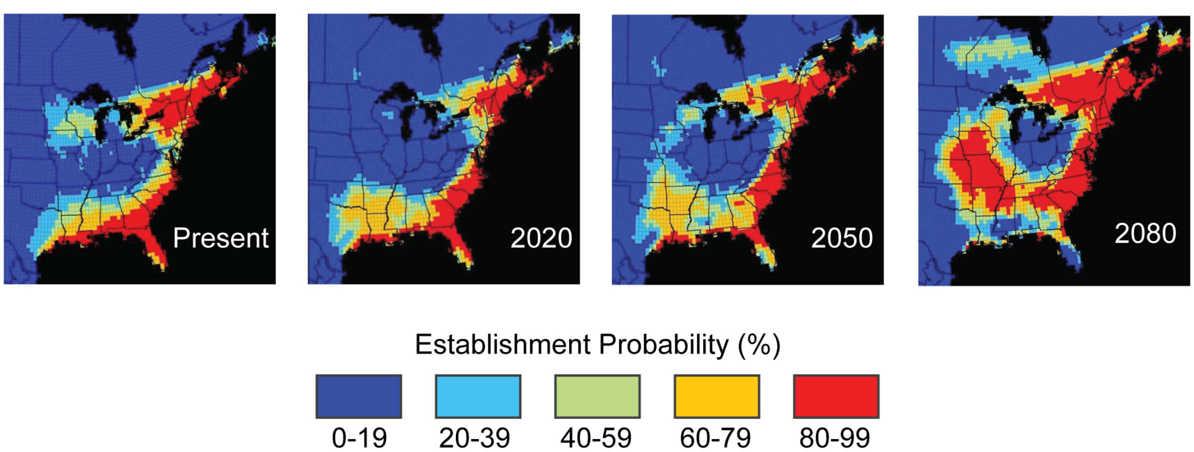
Additionally, projected increased rainfall could lead to flooding of fields and nutrient runoff. Projected increases in spring and summer precipitation could result in flooded fields, delaying planting or ruining crops. Furthermore, Maryland farmers currently spend approximately $30 million on crop nutrients.[30] Flooding will cause these nutrients to run off of the soil, requiring farmers to purchase additional nutrients. Nutrient runoff into waterways can also impact water quality, which can have implications for aquatic ecosystems and aquaculture farming, as well as public health.

PUBLIC HEALTH

Without GHG mitigation, climate change is projected to have a substantial effect on air quality. Under the reference scenario, ozone and particulate matter concentrations are projected to increase in densely-populated regions, including the state of Maryland. By 2100, the U.S. average 8-hour maximum ozone concentration during the summer months is projected to increase by 4.7 ppb.[31] Regarding particulate matter suspended in the atmosphere, the U.S. average PM2.5 concentration is projected to increase by 0.7 micrograms per cubic meter.[32] Under the mitigation scenario, air quality changes are much smaller. By reducing the impacts of climate change, the mitigation scenario is projected to prevent an estimated 57,000 premature deaths throughout the United States in 2100.[33] The economic benefit in avoiding these deaths is estimated at $930 billion, due to the decrease is respiratory- and cardiovascular-related hospital admissions.[34] Furthermore, there is a large environmental justice co-benefit to improving air quality, as many of the state's minorities and poorest citizens live in the most densely-populated urban areas.

Additionally, the change in water flow due to changes in sea level and inland flooding from extreme precipitation events will adversely affect water quality (e.g., harmful algal blooms, costs to treat water, impacts on drinking water). The Water Quality Index (WQI) is a measure that includes several key quality constituents, including temperature, dissolved oxygen, total nitrogen, and total phosphorus. The higher the WQI, the higher the water quality. Under the reference scenario, the WQI for the Mid-Atlantic decreases by 5 to 10 percent by 2100.[35] Mitigation efforts are projected to decrease water temperature and increase oxygen levels. Under the mitigation scenario, the Mid-Atlantic is projected to avoid between $100 million and $300 million in costs.[36]

FIGURE 3: Percentage of Established Lyme disease carrying Tick Habitat



Source: 2014 National Climate Assessment, Fig. 9.5

Stagnant water from inland flooding along with higher temperatures can also increase the likelihood of water-borne disease and extend the range of vector-borne disease. Diarrheal disease due to pathogens in water are of serious concern given projected increases in temperature and extreme rainfall events. Increases in tick- and mosquito-carried viruses such as Lyme disease, West Nile virus, and Dengue fever are also projected throughout the state. However, the degree of increase is not solely limited to climate change, but also to changes in pest control, access to health care, and other human responses to disease risk. Therefore, trends in disease rates may not necessarily correlate to climate change trends. Given this, established Lyme-disease carrying tick habitat in Maryland is projected to increase from a currently estimated 40 to 60 percent to 80 to 100 percent by 2080.[37] As with most diseases, young children, elderly, and those with inadequate access to healthcare are most susceptible.

CONCLUSION

Updated state economic data, combined with regional climate projections from EPR CIRA project, reveal additional costs of inaction and benefits of climate change mitigation not captured by the *American Climate Prospectus*. Climate change impacts ranging from increased temperatures, to higher sea levels, to more extreme precipitation events will have a profound effect on all sectors of Maryland's economy through the end of this century. By continuing business-as-usual activities, the climate of Maryland will resemble that of South Carolina by 2050 and northern Florida by 2100.[38] With mitigation efforts, the climate of Maryland will resemble that of northern Virginia by 2050 and northern North Carolina by 2100.[39] Understanding the magnitude of climate change impacts and how they can be reduced or avoided through mitigation efforts will help to inform the near- and long-term policies necessary to address these risks.

APPENDIX A

TABLE 1: A comparison of the climate change and economic data in Chapter 4 and Appendix F of the 2011 Maryland's Plan to Reduce Greenhouse Gas Emissions and updated data supplied by various state and federal agencies

CLIMATE IMPACTS	2011	2015
Sea Temperature	Average temperature of Chesapeake Bay has warmed 2F over the last 50 years.	Average temperature of Chesapeake Bay has increased 1.4C (2.52F) between 1960 and 2010. (USGS, 2015)
Air Temperature	Average annual temperature has increased 2F over last 50 years.	
	BAU forecasts indicate warming will surpass 3F by 2050, increasing further to 9F in the summer and 7F in the winter by 2100. (Boesch, 2008; Najjar et al., 2010)	Downgraded GCMs used for the ACP report show BAU warming projections of 9F in the summer and 7F in the winter by 2100 under the RCP 8.5 scenario. (ACP, 2014)
Extreme Temperature	BAU forecasts indicate the number of 90F days will triple to 90 days per year. By, 2050 it is expected the number of 100F will be between 25 and 35. (Boesch, 2008; Najjar et al., 2010)	ACP report indicates the median number of days above 95F to increase ten-fold by 2100. The number of days below 32F will decrease by more than 50 percent by 2100 (RCP 8.5). (ACP, 2014)
Record Temperatures	Study by NASA shows that land and ocean surface temperature in 2010 tied 2005 as warmest on record. (NASA, 2011)	Most recent study by NASA shows that land and ocean surface temperature in 2014 was the warmest on record. (NOAA, 2015)
Precipitation	Less clear. However winter and spring precipitation is likely to increase by 10% by 2100. No season should see significant decrease in precipitation.	There is a 90 percent probability that annual precipitation will increase by 2100. There is a greater than 67 percent probability of precipitation increase during the winter and spring months. (ACP, 2014)
Sea-Level Rise	By 2100, 6.1 percent of Maryland's 3,190 miles of coastline could be vulnerable to a 3.3ft (1m) increase in sea-level. An additional 2ft increase could inundate 550 square miles at high tide, including the homes of 60,000 peoples and 66 miles of road. (USEPA, 1998; MCCC, 2008; Wu et al., 2008)	ACP data suggests a likely range in sea-level rise for Baltimore through 2100 of 2.2 to 4.1 feet. (ACP, 2014)
	Already, 13 islands in the bay are submerged and 400,000 acres on the Eastern Shore are projected to join them. (Begley, 2011)	
Land Development	Since 1973, developed land area has increased by 135%	

ECONOMIC IMPACTS	2011	2015
Population	Between 1980 and 2010, population grew 37 percent. Population density along the Eastern Shore increased 50%. Projections show a 20% increase between 2010 and 2040 for Maryland and 36% percent increase for the Eastern Shore. (MDP, 2011)	Projections show a 19% increase between 2010 and 2040 for Maryland and a 27% percent increase for the Eastern Shore. (MDP, 2014)
Tourism	In 2009, the tourism sector generated $13.7 billion in spending; $1.6 billion in tax revenue; provided $3.8 billion in salaries and wages.	In 2013, the tourism sector generated $15.4 billion in spending; $2.1 billion in tax revenue; provided $4.6 billion in salaries and wages. (MOTD, 2015)
	An increase in extreme heat and prolonged heat waves could offset a longer tourist season. A 5% reduction in this sector would result in an annual loss of $685 million and 6700 jobs.	A 5% reduction in this sector would result in an annual loss of $770 million.
	Sea-level rise could result in a need to replenish shorelines. Replenishment costs would range from $35 to $200 million for a 20 inch rise in sea-level. (Zhang et al., 2004; USEPA, 1998)	
	In 2006, $633 million was spent on wildlife viewing, $568 million on recreational fishing, and $210 million on hunting. (USFWS & US Census, 2006).	In 2011, $623 million was spent on wildlife viewing, $755 million on recreational fishing, and $282 million on hunting. (USFWS & US Census, 2011).
Agriculture	In 2007, the market value of products sold by farms was $1.8 billion. Of this, $629 million was crop sales and $1.206 billion was livestock. Of the latter, $903 million was poultry and eggs. (USDA, 2009)	In 2012, the market value of products sold by farms was $2.27 billion. Of this, $1.05 billion was crop sales and $1.22 billion was livestock. Of the latter, $923 million was poultry and eggs. (USDA, 2014)
	For every 1°F increase in summer average, corn yield will decline 2 percent and wheat yield will decline 3.8 percent. Decreases are offset by increased CO_2. By 2030, annual corn production losses total $5.4 million. Soybean and wheat production gain $6.5 million and $53 thousand annually, respectively. Beyond 2030, temperatures climb beyond the optimal grown range, decreasing all yields. (CCSP, 2008)	ACP data indicates a median decrease in crop production of 25 percent by 2100 under the RCP 8.5 scenario. This corresponds to annual losses of approximately $150 million. (ACP, 2014)

ECONOMIC IMPACTS	2011	2015
Coastal Infrastructure	FEMA estimates an additional 36 to 58 percent increase in annual damage for every one foot in sea-level rise, and 102 – 200 percent increase for a three foot increase. (US EPA, 2011)	
	Trade, transportation and utilities account for $42 billion (14 percent) of Maryland's 2010 GDP. (US BEA, 2011)	Trade, transportation and utilities account for $47.6 billion (14 percent) of Maryland's 2014 GDP. (US BEA, 2015)
	Port of Baltimore generates $3.2 billion in business revenue and $3.7 billion in wages and salaries annually. Economic impact is estimated at $5.6 billion (Martin & Associates, 2008; MPA, 2010). Value of cargo moving through the harbor reached $41.5 billion in 2010 (Dresser, 2010).	Port of Baltimore generates $3 billion in business revenue and another $3 billion in wages and salaries annually. (MPA, 2011) Value of cargo moving through the harbor reached $52.5 billion in 2014 (MD State Archives, 2015).
	In 2009, Maryland's 2,800 commercial harvesters landed $76 million worth of crab and fish in ports.	In 2013, the catch of Maryland's fisheries was valued at $67 million. (MD State Archives, 2015)
	Manufacturing in 2009 contributed $9.9 billion toward Maryland's GDP. (MDP, 2011; NOAA, 2011; US BEA, 2011) – Not sure where this value originates. BEA indicates this value as $18.9 billion, MD State Archives as $15.6 billion	Manufacturing in 2014 contributed $18.8 billion toward Maryland's GDP. (US BEA, 2015)
Health	Baltimore ranks first among east coast cities for rate of increased mortality due to increase in temperature, with a 6.56 percent increase in heat-related mortality for every 1.8F increase. (Curriero et al., 2002)	ACP indicates an increase in median heat-related mortality of an additional 7 people per 100,000 by 2100 based on the RCP 8.5 scenario, costing the state between $450 million and $3.2 billion based on market or VSL value. (ACP, 2014)
Energy	Private companies and public entities spent $24 billion on energy in 2008. (EIA, 2011) Decreases in heating energy consumption due to a 3 – 4F increase by 2100 are projected to be offset by increases in cooling energy use and higher energy prices.	ACP indicates an increase in median residential and commercial energy expenditures of approximately $750 million by 2100 under the RCP 8.5 scenario. (ACP, 2014)

ENDNOTES

1 U.S. Environmental Protection Agency (US EPA), Climate Change in the United States: Benefits of Global Action, June 2015, available at: http://www2.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf.

2 IPCC Assessment Report 5 (AR5) Representative Concentration Pathways (RCP) 2.6 scenario assumes immediate mitigation efforts to provide at least a 70 percent chance of keeping the global average temperature below 2°C. The RCP 4.5 scenario assumes mitigation strategies to allow peak emissions by mid-century, allowing for a chance that the global average temperature remains below 2°C. RCP 8.5 assumes a business-as-usual trajectory with a 50/50 chance that the global average temperature climbs past 4°C.

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CENTER FOR CLIMATE
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The Center for Climate and Energy Solutions (C2ES) is an independent nonprofit organization working to promote practical, effective policies and actions to address the twin challenges of energy and climate change.

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