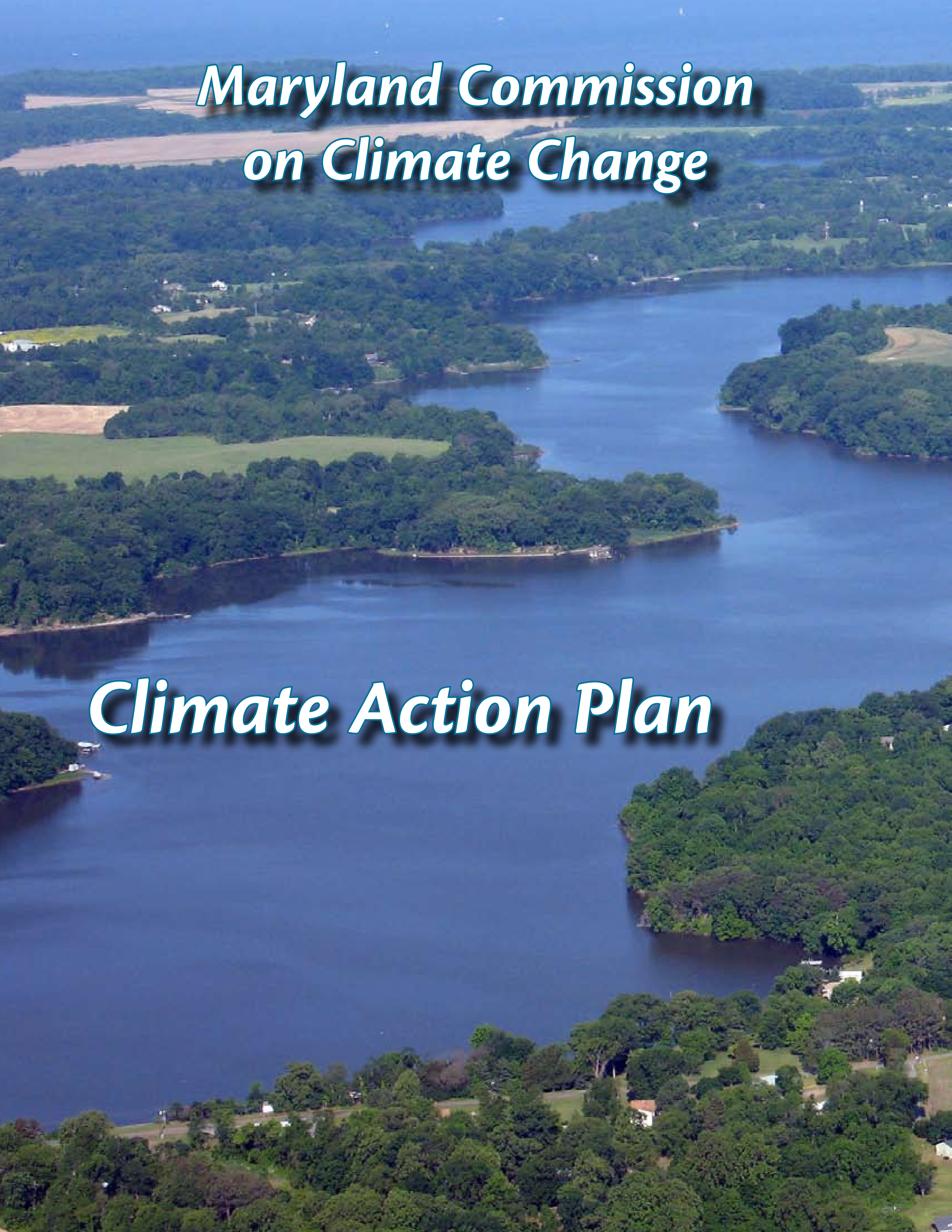
Maryland Commission on Climate Change



Climate Action Plan

Cover Photo: Still Pond Creek on the Upper Eastern Shore
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Climate Action Plan
Maryland Commission on Climate Change

Prepared for:
Martin O'Malley, Governor
State of Maryland

and the Maryland General Assembly

August 2008

The Commission and the Maryland Department of the Environment would like to acknowledge the dedicated services of the Center for Climate Strategies (CCS), which helped facilitate the Commission's stakeholder process and technical work. The CCS team, led by Ken Colburn and Gloria Flora, provided a forum for advanced discussion by diverse Commission stakeholders on climate strategies and solutions. The knowledge and expertise of the CCS professionals supported an environment that was science- and consensus-based and collaborative, and has resulted in a Climate Action Plan in which the Commission and Maryland citizens can take justifiable pride.

Climate Action Plan
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Climate Action Plan Executive Summary

Commission on Climate Change

August 2008

REPORT OVERVIEW

On April 20, 2007, Governor Martin O'Malley signed Executive Order 01.01.2007.07 (the Order) establishing the Maryland Commission on Climate Change (the Commission). Sixteen State agency heads and six members of the General Assembly comprise the Commission. The principal charge of the Commission is to develop a Plan of Action (the ***Climate Action Plan***) to address the drivers of climate change, to prepare for its likely impacts in Maryland, and to establish goals and timetables for implementation.

The Order emphasized Maryland's particular vulnerability to climate change impacts of sea level rise, increased storm intensity, extreme droughts and heat waves, and increased wind and rainfall events. It recognized that human activities such as coastal development, burning of fossil fuels, and increasing greenhouse gas (GHG) emissions are contributing to the causes and consequences of climate change. While noting Maryland's recent climate initiatives, the Order emphasized that continued leadership by example by Maryland State and local governments is imperative.

The Commission is supported by three Working Groups whose members were appointed by the Commission Chair, Shari T. Wilson, Secretary, Maryland Department of the Environment (MDE): Scientific and Technical Working Group (STWG), chaired by Donald Boesch, President, University of Maryland Center for Environmental Science, and co-chaired by Frank W. Dawson, Assistant Secretary of Maryland's Department of Natural Resources (DNR) and Robert M. Summers, Deputy Secretary of MDE; Greenhouse Gas and Carbon Mitigation Working Group (MWG), chaired by George (Tad) Aburn, Director of MDE's Air and Radiation Management Administration, and co-chaired by Malcolm Woolf, Director, Maryland Energy Administration (MEA); and Adaptation and Response Working Group (ARWG), chaired by John R. Griffin, Secretary of DNR, and co-chaired by Richard Eberhart Hall, Secretary, Maryland Department of Planning (MDP) and Don Halligan, Assistant Secretary of MDP. These Working Groups and the technical work groups (TWGs) that support them represent diverse stakeholder interests and bring broad perspective and expertise to the Commission's work. The Commission's work was facilitated by a consultant, the Center for Climate Strategies (CCS).

Governor Martin O'Malley Signs the Executive Order Creating The Maryland Commission on Climate Change

The Executive Order

Governor O'Malley's Executive Order charged the Commission and its three Working Groups to prepare a ***Climate Action Plan*** (this report) that addresses three key questions:

- What can the State's best scientists tell us about how and when climate change will affect Maryland's citizens and natural resources?
- What can Maryland do to adapt to the consequences of climate change?
- What can Maryland do to reduce emissions of GHGs and the State's carbon footprint to begin reversing global warming trends?

A very brief summary of the Commission's findings in these three areas follows. The summary of results by chapter, beginning on p. 11, provides a more detailed overview and summary of the Commission's process, the analyses that were completed, and the findings. Chapters 2, 4, 5 and the Appendices provide even greater detail on the efforts undertaken by each Working Group.

The Science

An important foundation for the ***Climate Action Plan*** (***Plan***) is the assessment of the likely consequences of the changing global climate to Maryland's agricultural industry, forestry resources, fisheries resources, freshwater supply, aquatic and terrestrial ecosystems, and human health. The *Comprehensive Climate Change Impact Assessment* (Chapter 2 of the ***Plan***), which was undertaken by the Commission's Scientific and Technical Working Group (STWG), based its efforts on extensive literature review and model projections. Supercomputer models were used to estimate the responses of climate to increased GHG concentrations and to project future conditions in Maryland.

Recent and Likely Climate Change

Maryland's climate warmed after the peak of the last Ice Age, 20,000 years ago, but has been relatively stable for the past 6,000 years. Atmospheric concentrations of GHGs, however, have dramatically increased since pre-industrial times. Carbon dioxide concentrations exceed those experienced over the last 650,000 years. Average global temperature and sea level began to increase rapidly during the 20th century. Annual average temperature is projected to increase by about 3°F by mid-century and is likely unavoidable.

The amount of warming later in the century is dependent on the degree of mitigation of GHG emissions, with summer temperatures projected to increase by as much 9°F and heat waves extending throughout most summers if GHG emissions continue to grow. Precipitation is projected to increase during the winter, but become more episodic. Projections of precipitation are much less certain than for temperature, but the mean projections indicated modest increases of about 10 per cent or so are likely in the winter and spring. Because of more intermittent rainfall and increased evaporation with warmer temperatures, droughts lasting several weeks are more likely to occur during the summer.

More specific analysis of the following areas was also conducted:

- Water resources & aquatic environments
- Farms & forests
- Coastal vulnerability
- Chesapeake Bay & coastal ecosystems
- Human health
- Mitigation & adaptation

WHY IS THE WORLD'S CLIMATE CHANGING?

KEY POINTS

Maryland's climate has been variable but stable for several thousand years.
Maryland's climate warmed after the peak of the last Ice Age and has been relatively stable for the past 6,000 years. Around these lang-term average conditions there have, of course, been variations in temperature and precipitation due to ocean current cycles, solar activity, and volcanic activity.

Atmospheric concentrations of greenhouse gases have dramatically increased.
Certain gases that trap the sun's energy from radiating back into space have increased since pre-industrial times. Carbon dioxide concentrations exceed those experienced over at least the last 650,000 years. Average global temperature and sea level began to increase rapidly during the 20th century.

Global warming is unequivocal.
The Intergovernmental Panel on Climate Change found the evidence for the warming of the Earth to be "unequivocal." The IPCC concluded that most of the observed temperature increase since the middle of the 20th century is very likely due to the observed increase in greenhouse gases.

Adaptation

The Commission's Adaptation and Response Working Group (ARWG) was charged with developing a *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change* (Chapter 5 of the ***Plan***).

With over 3,000 miles of coastline, Maryland is poised in a very precarious position when it comes to the impacts of climate change. Maryland's coast is particularly vulnerable to both episodic storm events, such as hurricanes and Nor'easters, as well as chronic problems associated with shore erosion, coastal flooding, storm surge, and inundation. Problems such as these are both driven by and exacerbated by climate change and sea level rise.

Climate change, sea level rise and associated coastal storms are putting Maryland's people, property, natural resources, and public investments at risk. To protect Maryland's future economic well-being, environmental heritage and public safety, and to guide the fundamental intent of its *Comprehensive Strategy*, the ARWG recommends that the Governor and the Maryland General Assembly take legislative and policy actions to:

- Promote programs and policies aimed at the avoidance and/or reduction of impact to the existing-built environment, as well as to future growth and development in vulnerable coastal areas;
- Shift to sustainable economies and investments; and, avoid assumption of the financial risk of development and redevelopment in highly hazardous coastal areas;
- Enhance preparedness and planning efforts to protect human health, safety and welfare;
- Protect and restore Maryland's natural shoreline and its resources, including its tidal wetlands and marshes, vegetated buffers, and Bay Islands, that inherently shield Maryland's shoreline and interior.

The ARWG also suggested that policies in the following areas be implemented. The Commission has adopted the ARWG recommendations. Chapter 5 provides a more detailed description of each policy.

Reduction of Impact to Existing and Future Growth

- Integrated Planning
- Adaptation of Vulnerable Coastal Infrastructure
- Building Code Revisions and Infrastructure Design Standards

Financial and Economic Well-Being

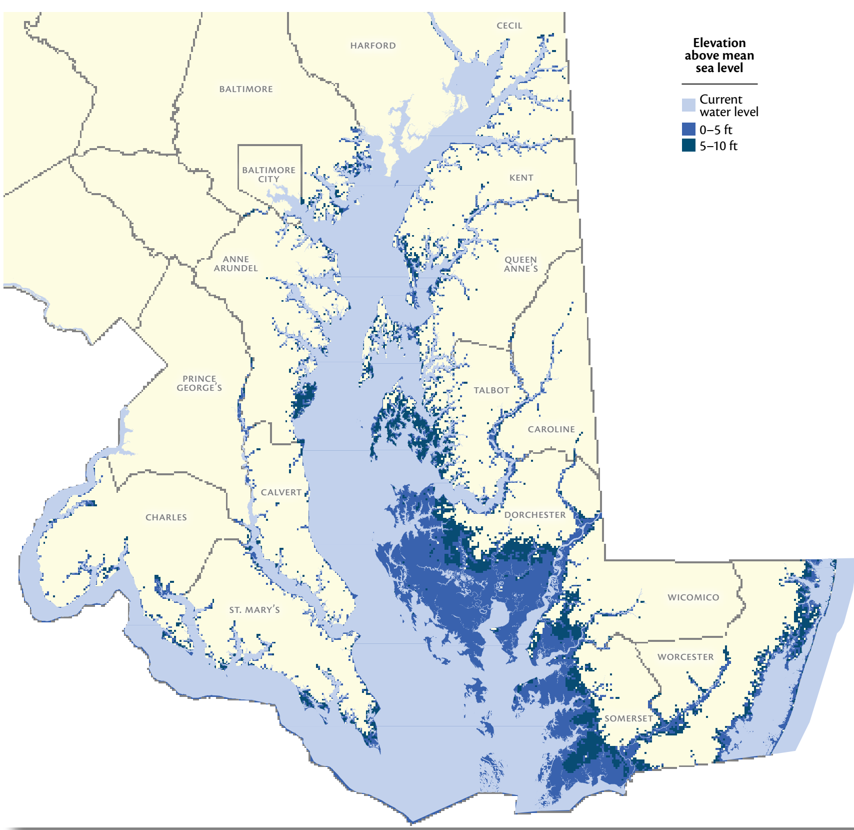
- Resource-Based Industry Economic Initiative
- Climate Change Insurance Advisory Committee
- Disclosure
- Green Economic Development Initiative

Protection of Human Health, Safety and Welfare

- Inter-Agency Coordination
- Health Impact Assessments
- Vector-borne Surveillance and Control

Natural Resource Protection

- Natural Resource Protection Areas
- Forest and Wetland Protection



Maryland Department of Natural Resources.

Sea-level rise vulnerability in the coastal areas of Maryland, calculated using LIDAR elevation data. Note: LIDAR elevation data were not available for Baltimore City, Harford County, and Prince George's County. Therefore, vulnerability data do not exist for those areas and cannot be shown on this map.

- Shoreline and Buffer Area Management

Adaptation and Response Toolbox

- Integrated Observation Systems
- GIS Mapping, Modeling and Monitoring
- Public Awareness, Outreach, Training and Capacity Building

Future Steps and Directions

- Local Government Planning Guidance
- Adaptation-Stat
- Future Adaptation Strategy Development

Smith Island—Maryland's last inhabited Chesapeake Bay island community—is vulnerable to sea-level rise. Photo by Tom Darden.

Mitigation

The Commission, based upon the recommendations of its Greenhouse Gas and Carbon Mitigation Working Group (MWG) in the *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy* (Chapter 4 of the ***Plan***), is recommending that Maryland begin implementing forty-two GHG reduction strategies to begin reducing global warming. Table ES-1, Mitigation Policies (p.10), lists the forty-two strategies and identifies the State lead agency responsible for implementation. Chapter 4 and Appendix D provide additional information on each strategy.

The Commission has established the following science-based goals for reducing GHG emissions in Maryland. All goals use a 2006 base year.

- 10 per cent reduction by 2012
- 15 per cent reduction by 2015
- 25 per cent to 50 per cent reduction by 2020
- 90 per cent reduction by 2050

Chapter 4 also discusses the goal setting process.

Figure ES-1, "GHG Reduction Potential from Maryland's Recent and Proposed Actions" (p.18) shows the potential reductions that Maryland projects based on the full implementation of the forty-two measures included in the *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy*. The figure shows that by 2020, the ***Climate Action Plan*** can achieve reductions that will be consistent with the goals established by the Commission. Because of the uncertainty in some of the analysis, the Commission expects the 2020 reduction levels to be between 40 and 55 per cent, approaching the higher-level target of a 50 per cent reduction by 2020.

Another key policy embodied in the ***Plan*** is that the current trend of continuing growth in GHG emissions should be reversed as quickly as possible. Figure ES-1 shows that Maryland can start reducing that trend soon if the MWG policies are implemented.

Figure ES-1 also shows that recent actions by Maryland, like the Regional Greenhouse Gas Initiative (RGGI) and the Clean Cars Program (CA LEV), and new programs adopted through legislation in 2008 will get the state close to the 25 per cent reduction target by 2020.

Figures ES-2 (p.19), ES-3 (p.19) and ES-4 (p.20) show the potential emission reductions from the forty-two strategies. Figures ES-2 and ES-3 show the aggregated benefits of the strategies in 2020 and 2012. Figure ES-4 shows the strategy-by-strategy reduction estimates in 2020 and 2012.

Figure ES-2, "Projected Emissions by 2020", shows that by 2020, the strategies are expected to achieve reductions that are consistent with the reduction goals set by the Commission. The Commission's 2020 goal is to achieve a 25 per cent to 50 per cent reduction from 2006 levels. The forty-two strategies are projected to achieve an approximate 40 per cent to 55 per cent reduction from 2006 levels by 2020. As discussed in Chapter 4, there is considerable uncertainty associated with calculating the aggregated benefits of the forty-two strategies. Figure ES-2 also shows that early actions, already taken in Maryland, will achieve about 60 per cent to 70 per cent of the reductions needed to meet the 25 per cent reduction goal.

Figure ES-3, "Projected Emissions by 2012", shows the same information for 2012. 2012 is an important milestone as early reductions are critical. The science tells us that a ton of reduction in 2012 is much more effective than a ton of reduction in 2050. The reductions from the forty-two strategies are expected to exceed the Commission's 2012 10 per cent reduction goal. They are projected to achieve an approximate 15 per cent to 22 per cent reduction from 2006 levels by 2012. Early actions also contribute significantly in 2012. Early actions are expected to achieve about 40 per cent to 50 per cent of the reductions needed to meet the 2012 goal.

Figure ES-4, "Annual Greenhouse Gas Reduction Potential of Maryland Policy Options in 2020 and 2012", shows the individual reductions from each of the forty-two strategies in 2020 and 2012.

Implementing the Commission's suite of forty-two mitigation reduction strategies is estimated to also provide a net economic benefit to the state. Preliminary analysis indicates that by 2020, implementation of these forty-two strategies could result in a net economic benefit to the state of approximately 2 billion dollars.

STEPS IN THE RIGHT DIRECTION

Maryland has already taken some important early actions toward reaching these goals.

- *The Healthy Air Act.*
  Adopted as State law in 2006, the Act included a provision for Maryland to join the Regional Greenhouse Gas Initiative (RGGI), a groundbreaking cap and trade program designed to reduce CO_2 emissions from power plants in participating states in the Northeast and Mid-Atlantic. The Maryland allocation in RGGI is expected to reduce CO_2 emissions by approximately 8.7 million tons by 2020. Maryland will participate in RGGI's historic first auction of CO_2 allowances in September 2008, the first ever in the U.S.

- *The Clean Cars Act.*
  Adopted as State law in 2007, this law requires implementation of the California Clean Cars program (CA LEV). By requiring more rigorous emissions standards beginning in vehicle model year 2011, it will start reducing GHG emissions in Maryland as early as 2010, achieving reductions of about 6 million metric tons by 2020.

- ***EmPOWER Maryland** Program.*
  Launched by Governor O'Malley in July 2007 and codified by the General Assembly in its 2008 Session, this program is designed to reduce per capita electricity use by Maryland consumers by 15 per cent in 2015. This could reduce GHG emissions by about 7 million tons in 2020.

- *Commission on Climate Change.*
  Governor O'Malley established the Commission by executive order in April 2007 to advise the Governor and General Assembly on matters related to climate change and to develop a ***Climate Action Plan***.

- *2008 Legislation*
  As summarized in Chapter 7 of this ***Plan***, nearly all of the Commission's Early Action recommendations for legislation were adopted as law in the General Assembly's 2008 Session. Significant early reductions will be achieved through the following 2008 laws:
  - ***EmPOWER Maryland** Energy Efficiency Act of 2008*
  - *Regional Greenhouse Gas Initiative – Maryland Strategic Energy Investment Program*
  - *High Performance Buildings Act of 2008*
  - *Renewable Portfolio Standard Per centage Requirements – Acceleration*

The General Assembly adopted other laws in 2008 designed to reduce GHG emissions that weren't part of the Commission's Early Action recommendations. These include increased grants and tax incentives for solar and geothermal installations, a law to spur development around transit stations, low interest loans for energy efficiency projects, and establishment of the Maryland Clean Energy Center. These are discussed in greater detail in Chapter 7.

Next Steps

The State agency leads will begin the implementation process for each of the forty-two mitigation strategies and nineteen adaptation strategies through the development of an implementation plan for each. These implementation plans will likely involve significant stakeholder processes. The Commission will be meeting in the Fall of 2008 and the Spring of 2009 to be briefed on the status of the policies in the ***Climate Action Plan*** and the implementation plan for each.

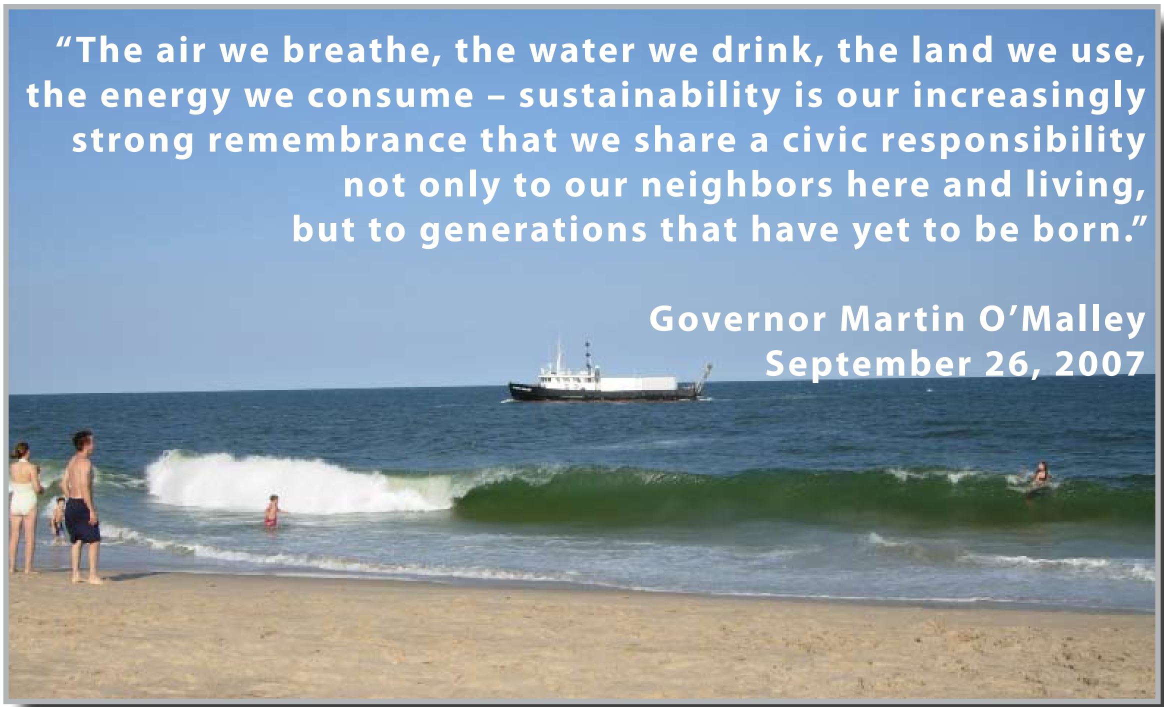


Table ES-1
Mitigation Policies

Policy Option	*Number*	*Agency*
Cross-Cutting (CC)		
GHG Inventory & Forecasting	CC-1	MDE
GHG Report & Registry	CC-2	MDE
Statewide GHG Reduction Goals & Targets	CC-3	MDE
State & Local Government Lead-by-Example	CC-4	MDE
Public Education & Outreach	CC-5	MDE
Review Institutional Capacity	CC-7	Commission
Participate in Regional, Multi-State & National Efforts	CC-8	MDE
Promote Economic Development Opportunities	CC-9	DBED
"After Peak Oil"	CC-10	MEA
Public Health Risks	CC-11	DHMH
Residential, Commercial & Industrial (RCI)		
Improved Building & Trade Codes	RCI-1	DHCD
Demand-Side Management & Energy Efficiency	RCI-2	MEA
Low-Cost Loans for Energy Efficiency	RCI-3	MEA
Improved Design, Construction, Appliances & Lighting	RCI-4	MDE
More Stringent Appliance / Equipment Efficiency Standards	RCI-7	MEA
Energy Efficiency Resource Standard	RCI-10	MEA
Promotion & Incentives for Energy Efficiency Lighting	RCI-11	MEA
Energy Supply (ES)		
Promotion of Renewable Energy	ES-1	MEA
Technology-Focused Initiatives for Electricity Supply	ES-2	MEA
GHG Cap-and-Trade	ES-3	MDE
Clean Distributed Generation	ES-5	MEA
Integrated Resource Planning	ES-6	PSC
Renewable Portfolio Standard	ES-7	PSC
Efficiency Improvements & Repowering Existing Plants	ES-8	MEA
Generation Performance Standards	ES-10	MDE
Agriculture, Forestry & Waste (AFW)		
Forest Management for Enhanced Carbon Sequestration	AFW-1	DNR
Managing Urban Trees & Forests	AFW-2	DNR
Afforestation, Reforestation & Restoration of Forests & Wetlands	AFW-3	DNR
Protection & Conservation of Agricultural Land, Coastal Wetlands & Forested Land	AFW-4	MDA
"Buy Local" Programs	AFW-5	MDA
Expanded Use of Forest & Farm Feedstocks & By-Products for Energy Production	AFW-6	DNR
In-State Liquid Biodiesel Production	AFW-7b	MEA
Nutrient Trading with Carbon Benefits	AFW-8	MDE
Waste Management & Advanced Recycling	AFW-9	MDE
Transportation & Land Use (TLU)		
Land Use & Location Efficiency	TLU-2	MDOT
Transit	TLU-3	MDOT
Intercity Travel	TLU-5	MDOT
Pay-As-You-Drive Insurance	TLU-6	MDOT
Bike & Pedestrian Infrastructure	TLU-8	MDOT
Incentives, Pricing & Resource Measures	TLU-9	MDOT
Transportation Technologies	TLU-10	MDOT
Evaluate GHG from Major Projects	TLU-11	MDOT

SUMMARY OF RESULTS BY CHAPTER

Chapter 1: Introduction

In April 2007, Governor Martin O'Malley established the Maryland Commission on Climate Change (Commission) through Executive Order 01.01.2007.07. The Commission was to develop a Plan of Action, or ***Climate Action Plan***, that discusses the drivers and consequences of climate change, necessary preparations for its ensuing impacts, and establishes firm benchmarks and timetables for policy implementation. The Commission is chaired by the Secretary of the Environment, Shari T. Wilson, and includes legislative and major State agency leaders. The Executive Order established three Working Groups within the Commission: the Greenhouse Gas and Carbon Mitigation Working Group (MWG), the Adaptation and Response Working Group (ARWG), and the Scientific and Technical Working Group (STWG). Each Working Group developed subgroups, called Technical Work Groups in MWG and ARWG.

As the facilitating agency for development of the ***Climate Action Plan (Plan)***, the Maryland Department of the Environment (MDE) produced an ***Interim Report*** on the ***Plan*** in January of 2008, with support from Maryland's Department of Natural Resources (DNR) and the University of Maryland Center for Environmental Science (UMCES). The ***Interim Report*** provided an update on the most current information emerging from each Working Group. Significantly, it included the Commission's recommendations for "Early Action" legislation, nearly all of which was adopted by the General Assembly in its 2008 Session.

The Commission and its Working Groups continued to assess climate change impacts in Maryland and fine-tune policy options in the ensuing months. The resulting reports: the STWG's *Comprehensive Climate Change Impact Assessment*; the MWG's *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy*; and the ARWG's *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change*, appear as Chapters 2, 4 and 5, respectively, in this ***Climate Action Plan***.

Scientific and Technical Working Group (STWG)

Under the leadership of UMCES within the University System of Maryland, the Commission's STWG developed an assessment of the likely consequences of the changing global climate to Maryland's agricultural industry, forestry resources, fishery resources, aquatic and terrestrial ecosystems, and human health. The *Comprehensive Climate Change Impact Assessment* informs Maryland citizens and policy makers of the likely consequences of global climate change on the places we live and resources we depend on and provides an estimation of the consequences of climate change in Maryland that could be avoided by global actions to reduce emissions of GHGs.

Greenhouse Gas and Carbon Mitigation Working Group (MWG)

Under the leadership of MDE, the Commission's MWG and its Technical Work Groups (TWGs) developed forty-two mitigation policy options that form the core of the Commission's *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy*. These policies cover the broad areas of energy supply; transportation and land use; agriculture, forestry and waste; residential, commercial, and industrial; and cross-cutting issues. For each policy option whose goals were amenable to quantification, the amount of GHG reductions and the cost or cost savings of implementation were calculated. Cost-effectiveness figures (in dollars per ton of GHG reduction) were then developed and used to compile an overall cost-effective suite of policy recommendations to include in the ***Climate Action Plan***.

Adaptation and Response Working Group (ARWG)

Under the leadership of DNR, the Commission's ARWG completed Phase 1 of the *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change*. Phase 1 focused on the development of adaptation and response strategies for impacts associated with sea level rise and coastal storms. Nineteen priority policy options were developed by the ARWG and its four TWGs. These focused on the broad categories of existing-built environment and infrastructure; future-built environment and infrastructure; human health, safety and welfare; and resources and resource-based industries. Each of the resulting policy option descriptions includes a detailed discussion of implementation mechanisms, related policies and programs in place, qualitative benefits and cost assessments and an overview of feasibility issues. The ***Climate Action Plan*** presents the final priority policy recommendations in support of the Commission's vision for protecting Maryland's future economic well-being, environmental heritage and public safety.

Chapter 2: Comprehensive Assessment of Climate Change Impacts in Maryland

An important foundation for the ***Climate Action Plan*** is the assessment of the likely consequences of the changing global climate to Maryland's agricultural industry, forestry resources, fisheries resources, freshwater supply, aquatic and terrestrial ecosystems, and human health. The assessment, which was undertaken by the STWG, based its efforts on extensive literature review and model projections. Supercomputer models were used to estimate the responses of climate to increased GHG concentrations and to project future conditions in Maryland. Changes in temperature and precipitation were projected through the 21st century. In order to estimate the degree of climate change in Maryland that could be avoided by actions to reduce emissions of GHGs, two emissions scenarios were employed. The higher emissions scenario assumes continued growth in global emissions throughout the century, while the lower emissions scenario assumes slower growth, a peak at mid-century, and thereafter a decline to about 40 per cent of present levels by the end of the century.

Recent and Likely Climate Change

Maryland's climate warmed after the peak of the last Ice Age, 20,000 years ago, but has been relatively stable for the past 6,000 years. Atmospheric concentrations of GHGs, however, have dramatically increased since pre-industrial times. Carbon dioxide concentrations exceed those experienced over the last 650,000 years. Average global temperature and sea level began to increase rapidly during the 20th century. Annual average temperature is projected to increase by about 3°F by mid-century and is likely unavoidable. The amount of warming later in the century is dependent on the degree of mitigation of GHG emissions, with summer temperatures projected to increase by as much 9°F and heat waves extending throughout most summers if GHG emissions continue to grow unchecked. Precipitation is projected to increase during the winter, but become more episodic, with more falling in extreme events. Projections of precipitation are much less certain than for temperature, but the mean projections indicated modest increases of about 10 per cent or so are likely in the winter and spring. Because of more intermittent rainfall and increased evaporation with warmer temperatures, droughts lasting several weeks are more likely to occur during the summer.

Water Resources & Aquatic Environments

Increased winter-spring precipitation would continue to adequately supply reservoirs, but not alleviate current overdrafts of groundwater aquifers. Water supplies in the greater Baltimore area would not be diminished, but the adequacy of summer water supplies in the greater Washington region, which rely on Potomac River flows, is less certain. Any increases in precipitation are unlikely to replace groundwater substantially enough to compensate excessive withdrawals of some aquifers. At the same time, summer droughts may increase groundwater demand for agricultural irrigation.

More intense rainfall resulting from the combined effects of global climate change and localized factors, for example the influence of the urban canopy on rainfall, is likely to increase peak flooding in urban environments. Continued increase in impervious surfaces attendant with development would exacerbate this problem. Aquatic ecosystems will likely be degraded by more flashy runoff and increased temperatures. Intensified rainfall events and warmer surfaces (roads, roofs, etc.) would result in rapid increases in stream temperatures, limiting habitat suitability for native fishes and other organisms. Higher peak flows and degraded streams would also transmit more nutrients and sediments to the Chesapeake Bay and its tidal tributaries, contributing to water quality impairment in the estuaries.

Farms & Forests

Crop production may increase initially, but then decline later in the century if emissions are not reduced. The longer growing season and higher carbon dioxide levels in the atmosphere are likely to increase crop production modestly during the first half of the century, but extreme weather events may limit this. Later in the century, crop production is likely to be reduced due to heat stress and summer drought under the higher emissions scenario. Milk and poultry production would be also reduced by heat stress. These changes will require adaptation by Maryland's agricultural industry, including changes in crop or animal varieties, increased irrigation, and air conditioning for some livestock.

The maple-beech-birch forest of Western Maryland is likely to fade away and pine trees to become more dominant in Maryland's forests. Forest productivity in terms of timber produced is likely to decline late in the century under the higher emissions scenario as a result of heat stress, drought, and climate-related disturbances such as fires and storms. The biodiversity of plants and animals associated with Maryland's forests is likely to decline. Habitat alterations resulting from climate change may force out 34 or more bird species, including the emblematic Baltimore oriole, although southern species may replace them.

Coastal Vulnerability

Sea level in Maryland rose by 1 foot in the 20th century, partially because the land is sinking as a result of slow adjustments of the Earth after the last Ice Age. Maryland coastal regions have been subsiding at about a rate of 6 inches per century and should continue at this rate during this century. Additionally, the average level of the sea in this region rose by about the same amount (6 inches) during the past century, resulting in the observed 1-foot rise in the mean tidal level relative to the land. As a result, Maryland has experienced considerable shoreline erosion and deterioration of coastal wetlands which are a critical component of its bays and estuaries.

Sea-level rise is very likely to accelerate, inundating hundreds of square miles of wetlands and land. Projections that include accelerating the melting of ice would increase the relative sea-level along Maryland's shorelines by more than 1 foot by mid-century and 3 feet by late century if greenhouse gas emissions continue to grow. If sea level rises by 3 feet, most tidal wetlands would be lost—about 200 square miles of land would be inundated. New tidal wetlands developed on newly flooded land would not offset the loss of existing wetlands and significant negative effects on wetland-dependent living resources would result. Moreover, if sea level were to rise by 3 or more feet, this would mean that rapid and probably uncontrollable melting of land-based ice was underway and that sea level would rise at an even greater rate during subsequent centuries.

Rains and winds from hurricanes are likely to increase, but changes in their frequency cannot now be predicted. The destructive potential of Atlantic tropical storms and hurricanes has increased since 1970 in association with warming sea surface temperatures. This trend is likely to continue as ocean waters warm. Whether Maryland will be confronted with more frequent or powerful storms depends on storm tracks that cannot yet be predicted. However, there is a greater likelihood that storms striking Maryland would be more powerful than those experienced during the 20th century and would be accompanied by higher storm surges—made worse because of higher mean sea level—and greater rainfall amounts.

Chesapeake Bay & Coastal Ecosystems

Chesapeake and Coastal Bays restoration goals will likely be more difficult to achieve. Increased winter-spring runoff would wash more nutrients into the Bays and higher temperatures and stronger density stratification in the estuaries would tend to exacerbate water quality impairment, the alleviation of which is the prime restoration objective. Consequently, nutrient loads would have to be reduced beyond current targets to achieve water quality requirements. Very significant changes are also likely to occur that affect sediment delivery and sedimentation in the estuaries, but are difficult to quantitatively predict. These include potential increases in sediment loads from rivers as a result of increased runoff and more erosive extreme discharge events, including those caused by hurricanes, and from shoreline and wetland erosion as a result of accelerated sea-level rise.

Living resources will very likely change in species composition and abundance with warming. A mixture of northern, cool water species and southern, warm water species currently resides in the Chesapeake Bay. Northern species such as soft shell clams and eelgrass are likely to be eliminated later in the century, almost certainly if GHG emissions are not mitigated. Southern species are very likely to increase in abundance because the milder winters would allow or enhance overwintering populations.

As ocean water becomes more acidic, shellfish production could be affected. Increasing atmospheric carbon dioxide concentrations in the atmosphere have already lowered pH in the world's oceans, a trend that is very likely to continue. Recent research indicates that the rate at which oysters and other coastal shellfish build their calcium carbonate shells will likely be affected, but whether this would occur in Maryland has not been evaluated.

Human Health

Health risks due to heat stress are very likely to increase, if emissions are not reduced. Under the higher emissions scenario, heat waves are projected to greatly increase risks of illness and death before the end of the century, with an average of 24 days per summer exceeding 100°F. The poor, the elderly and urban populations are most susceptible. Some, but not all, of these increased risks can be reduced by air conditioning and other adaptation measures.

Respiratory illnesses are likely to increase, unless air pollution is greatly reduced. More ground-level ozone, responsible for multiple respiratory illnesses, is formed under prolonged, high temperatures. Releases of air pollutants (nitrogen oxides and volatile organic compounds) that cause ozone to be formed have been declining, but would have to be reduced much more to avoid a reversal in progress toward achieving air quality standards.

Increased risks of pathogenic diseases may be less likely. The mortality due to vector-borne and non-vector borne diseases in the United States is low because of public health precautions and treatment, which would likely adapt to changes in disease risks. Climate change might affect the exposure of Marylanders to pathogens such as the West Nile virus, but precautions and treatment could manage this risk.

Mitigation & Adaptation

Reduction of GHG emissions has substantial benefits for Maryland. The mitigation of global emissions by mid-century would very likely result in significantly lower sea-level rise, reduced public health risks, fewer extreme weather events, and less decline in agricultural and forest productivity and loss of biodiversity and species important to the Chesapeake Bay. More serious impacts beyond this century, such as sea-level rise of 10 feet or more, would be avoided.

Based on the projections made in the STWG's *Comprehensive Assessment of Climate Change Impacts in Maryland*, adaptation strategies for human health, water resources, and restoration of Maryland's bays should be evaluated and, where necessary, implemented. Adaptation measures to reduce coastal vulnerability should plan for a 1 foot rise in sea level by mid-century and a rise of at least 2 feet by late in the century. Depending on the course of GHG emissions, observations, and modeling, planning for increases in sea level of up to 4 feet by the end of the century may be required. The Commission should evaluate additional adaptation strategies related to human health, water resources, forest management, and restoration of the Chesapeake Bay and Maryland's Coastal Bays. Maryland should marshal and enhance its capacity for monitoring and assessment of climate impacts, as a more extensive, sustained, and coordinated system for monitoring the changing climate and its impacts is required. Because of its national laboratories, strong university programs, knowledge-based economy, and proximity to the nation's capital, Maryland is in a strong position to become a national and international leader in regional-to-global climate change analysis and its application to innovative mitigation and adaptation.

Chapter 3: Climate Change and the Cost of Inaction

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 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. The physical changes that develop will significantly alter the state's coastline, beachfront, agricultural productivity, species biodiversity and weather patterns that are tightly correlated with economic conditions. 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. By becoming a more populated, developed, and economically robust 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.

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. 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.

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 sync with past and current climatic conditions. These costs are likely to increase as climate change accelerates. 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. Benefits from climate change may be fleeting -- for example, climate does not stop changing once a farm benefits from temporarily improved growing conditions. In contrast, costs of inaction are likely to stay and to increase. 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. 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 pales in comparison to the cost of inaction.

Chapter 4: Greenhouse Gas and Carbon Footprint Reduction Strategy

The Commission's Mitigation Working Group (MWG) was charged with developing a *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy*. The Executive Order calls for the *Strategy* to recommend GHG emission reduction goals and short- and long-term strategies to mitigate and offset GHG emissions, and to provide a detailed timetable for each strategy.

Recommended GHG Emission Reduction Goals

The Commission's recommended goals are based on the findings of the Intergovernmental Panel on Climate Change (IPCC) that industrialized nations need to take substantial early actions to stem the growth in GHG emissions and then start to reduce them rapidly, achieving reductions of 25 per cent to 40 per cent below 2000 levels by 2020, and 80 per cent to 95 per cent below 2000 levels by 2050, in order to avoid the most dangerous anthropogenic changes to the earth's climate. Keying on this, the Commission set early, aggressive, consumption-based goals for Maryland, as follows: (1) 25 per cent to 50 per cent below 2006 levels by 2020, 25 per cent being a minimum, regulatory driver and 50 per cent an aspirational goal to reward deeper, market-based cuts; (2) 90 per cent below 2006 levels by 2050, a non-regulatory goal to drive climate-neutral technology innovations; (3) interim targets of 10 per cent reductions by 2012 and 15 per cent by 2015 to spur early actions; and (4) a science-based review of the goals every four years.

Commission's Key Mitigation Messages

The Commission's *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy* has three simple, overarching messages:

Early actions are key.

The science tells us that atmospheric concentrations of GHGs are fast approaching, if they haven't already reached, levels that could tip us into severe and unpredictable changes in the earth's climate. Given this and the long residence times of GHGs in the atmosphere, a program that keeps a ton of GHGs out of the atmosphere today is worth more than the same program started five years from now, because five years of GHG accumulation will be avoided if we start today. Every year we delay (the "business as usual" scenario) increases the amount of reductions we will need to achieve in later years, until we may reach a point where the reduction measures are vastly harder, or impossible, and too expensive, and our 2020 and 2050 goals are not achievable. On the other hand, by implementing early and significant GHG reduction programs now, and phasing in medium- and long-term programs on an aggressive "ramp up" schedule, we will avoid continued rapid GHG accumulations and get on a sustainable glide path to our 2020 and 2050 goals.

Shrinking our GHG footprint will grow Maryland's economy.

Energy efficiency is the fastest and least expensive approach available to reduce GHG emissions. Most of the Commission's policy recommendations for reducing energy demand can be implemented right now. A recent study done for the Maryland Department of Business and Economic Development and the Maryland Energy Administration reached these conclusions about the impact of energy efficiency and clean energy programs on Maryland's economy:

- Energy efficiency can reduce energy costs to homeowners, businesses, institutions and government at a cost 60 per cent to 70 per cent cheaper than building new generating capacity in Maryland.
- Developing clean energy industries in Maryland will create thousands of "green collar" and R&D jobs, will increase wages and salaries for Maryland citizens, and will significantly boost the state's tax revenues and gross state product.
- By lagging behind other states that are already investing in the fast-growing clean energy industry, Maryland is missing out on huge economic development and job growth potential.

What we do in Maryland matters in Maryland.

Despite Maryland's small size, our state is responsible for almost as many GHG emissions as Sweden and Norway combined, and our per capita and statewide emissions are growing faster than the U.S. as a whole. We have a responsibility to adopt mitigation measures commensurate with our carbon footprint. These actions will have many local benefits. In addition to lowering the demand for costly energy and boosting our state's economy, GHG reductions will reduce air and water pollutants in Maryland and, through Smart Growth and transit-oriented development programs, will reduce vehicle miles traveled, traffic congestion and lost productivity, suburban sprawl and attendant infrastructure investments, and loss of agricultural and forested lands.

Recommended GHG Reduction Strategies

The Commission and its MWG were guided by the following principles as they developed and analyzed potential policy options:

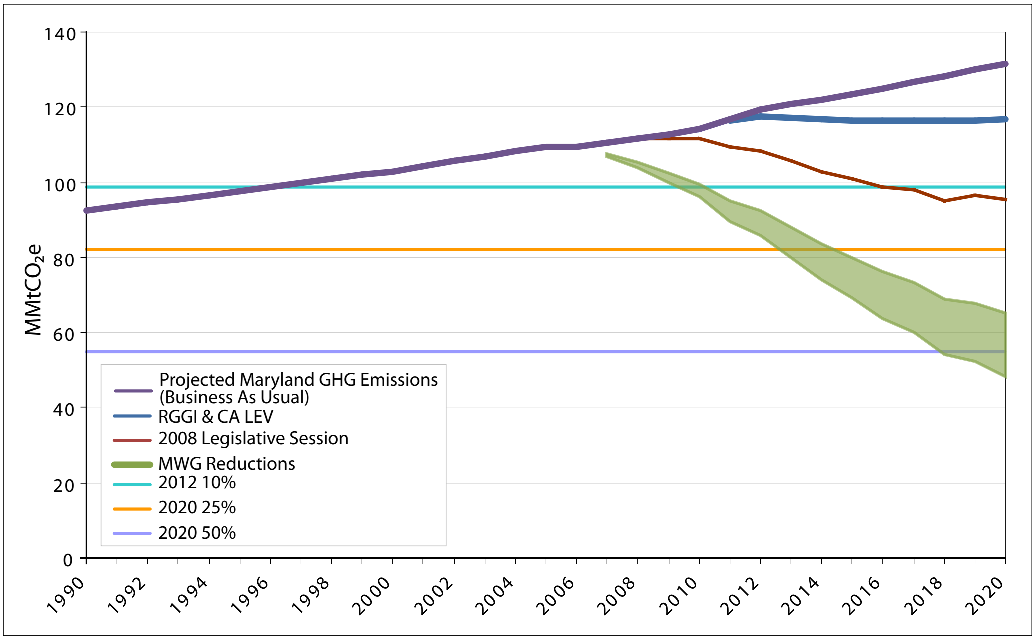
- Achieve significant long- and short-term emission reductions of GHGs in Maryland
- Demonstrate leadership
- Maximize the cost-effectiveness of the *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy*
- Provide savings to Maryland consumers and businesses
- Provide a net economic benefit to the State
- Drive job creation, business growth and economic development in Maryland

Starting from a catalogue of about 300 possible policy options for reducing GHG emissions, the Commission approved for further analysis fifty-four priority policy options. These were identified in the Commission's ***Interim Report***. The MWG and its five Technical Work Groups (TWGs) developed and refined each of these policy options from straw proposals into specific policy options. The process then further narrowed the list of policy options to a final suite of forty-two (several options were eliminated and a few were consolidated). Each policy option includes a description, a design and a goal, and each examines implementation mechanisms, feasibility and barriers, related existing programs, co-benefits, and key assumptions and uncertainties. Where appropriate, the policy's estimated reduction in GHG emissions has been quantified (expressed in million metric tons of CO_2 equivalent, or $MMtCO_2e$) based on the policy's stated goal. The cost or cost savings of achieving the reduction is also calculated for each quantified policy, expressed in dollars per ton. The forty-two policy options approved by the Commission form the core of the ***Climate Action Plan's*** mitigation strategy.

Some of the policy options have well-developed implementation mechanisms. Because of the scope of the Commission's work and its compressed time frame, the details of implementation for some policy options will need to be further analyzed and worked out by State agencies after the ***Plan*** is submitted to the Governor and the General Assembly. Where this is the case, it is so noted. The technical analyses that were performed to estimate reductions, costs or cost savings for each policy option were limited to what could be completed in a six-month time frame. There will be additional technical analysis of many of the policy options over the next several years.

As Figure ES-1, "GHG Reduction Potential from Maryland's Recent and Proposed Actions", shows, Maryland has already made significant progress in enacting programs that will dramatically reduce GHG emissions. The Maryland Clean Cars Program (CA LEV) and the Regional Greenhouse Gas Program (RGGI) (together, the blue line), and the ***EmPOWER Maryland*** and other 2008 legislative actions by the General Assembly aimed at reducing GHGs (the red line) get Maryland about 60 per cent of the way to the lower end of Maryland's 2020 goal (25 per cent reduction from 2006 levels). Adding in the reductions from all forty-two of the Commission's mitigation policy options (the green wedge*), the graph shows Maryland could easily make the lower end of the 2020 goal (25 per cent) and come within the range of the higher end of the goal (50 per cent), if all the policy options were adopted and aggressively implemented.

Figure ES-1 GHG Reduction Potential from Maryland's Recent and Proposed Actions



*The green wedge represents a range of potential emission reductions from the forty-two recommended measures, created due to uncertainty in calculating the benefits.

Figure ES-2, "Projected Emissions by 2020", shows how close recent actions (RGGI, Clean Cars, ***EmPOWER Maryland***, etc.) get Maryland to the 25 per cent goal by 2020.

Figure ES-2 Projected Emissions by 2020

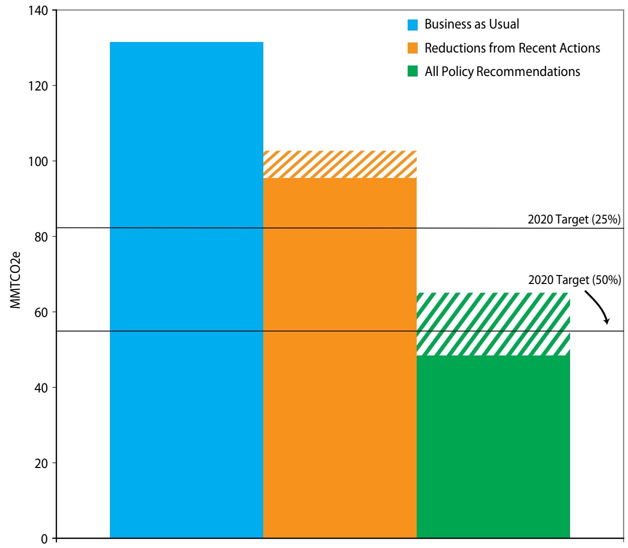


Figure ES-3, "Projected Emissions by 2012", shows that reductions from the forty-two strategies are projected to achieve an approximate 15 per cent to 22 per cent reduction from 2006 levels by 2012. Early actions are expected to achieve about 40 per cent to 50 per cent of the reductions needed to meet the 2012 goal.

Figure ES-3 Projected Emissions by 2012

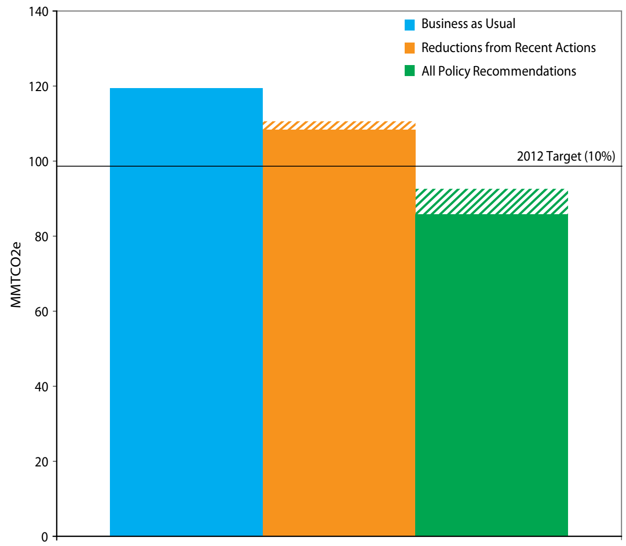


Figure ES-4, "Annual Greenhouse Gas Reduction Potential of Maryland Policy Options in 2020 and 2012", shows the individual reductions from each of the Commission's quantified policy options in 2020 and 2012.

Figure ES-4 Annual Greenhouse Gas Reduction Potential of Maryland Policy Options in 2020 and 2012 (The top bar in each pair represents 2020 emission reduction potential. The bottom bar in each pair represents 2012 emission reduction potential.)

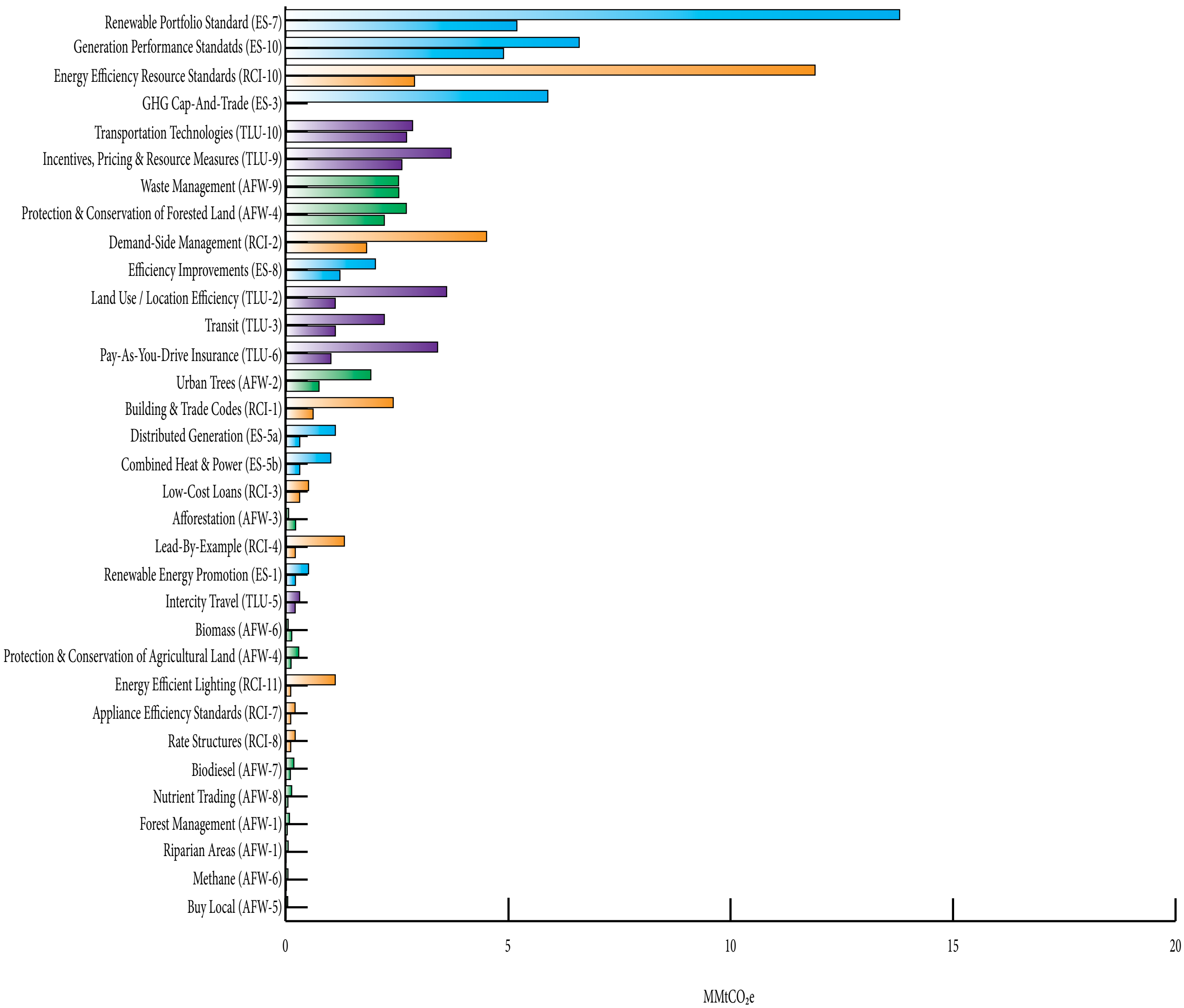
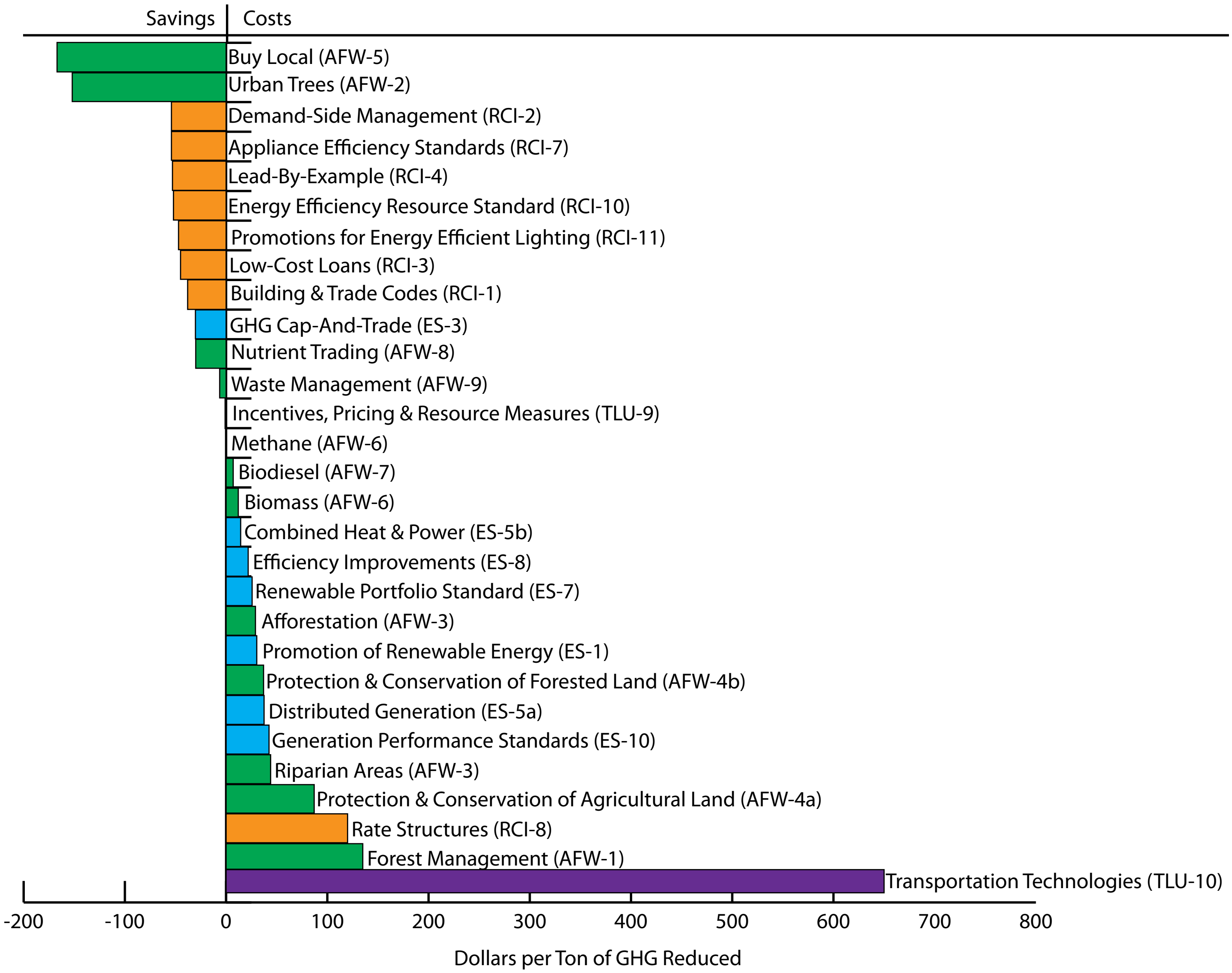


Figure ES-5, "Maryland Policy Options Ranked by Cost / Savings per Ton of GHG Reduced", shows the quantified policy options ranked by their cost-effectiveness. The measures to the left have a benefit to the State economy and the measures to the right have a direct cost to Maryland. In the aggregate, the policies yield a net economic benefit to Maryland, estimated to be approximately 2 billion dollars in 2020.

Figure ES-5 Maryland Policy Options Ranked by Cost / Savings per Ton of GHG Reduced



The charts on this and preceding pages are really illustrative in nature as quantifying emission reductions from GHG policies is a very complicated process. MDE has started to develop the resources necessary for a close review of GHG emission reduction potentials but the numbers generated by this process should be considered to be "based on the best available estimates" – they are in no way perfect.

Commission's Policy Options Bins

With forty-two measures to consider, the Commission decided to place the policies in "bins" based on the following criteria:

Bin 1: Higher Emission Reductions/ Easier to Implement
Bin 2: Lower Emission Reductions/ Easier to Implement
Bin 3: Higher Emission Reductions/ Harder to Implement
Bin 4: Lower Emission Reductions/ Harder to Implement

The actual policy options are described in detail, and the GHG reduction potential and cost-effectiveness of each, is quantified where possible, in Chapter 4 of this ***Plan*** and Appendix D. While too numerous to summarize here, the policies are sorted by name into the four Bin Tables below. The Commission identified a lead agency for each policy option (listed in the right-hand column), which is responsible for implementing the policy. In some cases a co-lead or assisting agency is also named.

The following abbreviations refer to the Technical Work Group (TWG) that developed the policy option:
AFW – Agriculture, Forestry and Waste TWG
ES – Energy Supply TWG
RCI – Residential, Commercial and Industrial TWG
TLU – Transportation and Land Use TWG
CC – Cross Cutting Issues TWG

The Commission's forty-two recommended mitigation strategies have evolved in the course of a rigorous, comprehensive, ten-month long stakeholder process which drew upon the expertise and commitment of MWG and TWG participants representing broad and diverse interests. While the work of these dedicated individuals is complete, the actual work of implementing the ***Climate Action Plan*** and getting Maryland on a sustainable trajectory to the 2020 and 2050 reduction goals just begins now, building on early initiatives such as RGGI, the Clean Cars and ***EmPOWER Maryland*** programs, and Maryland's Renewable Portfolio Standard.

Bin 1: Higher Emission Reduction / Easier Implementation

Policy Number	*Policy Name*	*Lead Agency*
ES-3	GHG Cap-and-Trade	MDE
TLU-10	Transportation Technologies	MDOT (MDE)
RCI-10	Energy Efficiency Resource Standard	MEA
CC-4	State & Local Government Lead by Example	MDE (MEA, MDOT)
RCI-4	Improved Design, Construction, Appliances & Lighting in Government	MDE (MEA, MDOT)
AFW-9	Waste Management / Advanced Recycling	MDE
ES-7	Renewable Portfolio Standard	PSC (MEA)
RCI-2	Demand Side Management & Energy Efficiency	MEA (PSC)
RCI-1	Improved Building & Trade Codes	DHCD (MEA)

Bin 2: Lower Emission Reduction / Easier Implementation

Policy Number	*Policy Name*	*Lead Agency*
CC-1	GHG Emission Inventories & Forecasting	MDE
CC-2	GHG Reporting & Registries	MDE
CC-3	Statewide GHG Reduction Goals	MDE
CC-5	Public Education & Outreach	MDE (MSDE, MEA)
CC-8	Participate in Regional, Multi-State & National Efforts	MDE
CC-7	Review Institutional Capacity	Commission
CC-10	After Peak Oil	MEA (MDE)
CC-11	Public Health Risks	DHMH (MDE)
RCI-11	Promotion & Incentives for Energy Efficient Lighting	MEA
ES-5	Clean Distributed Generation	MEA (PSC)
RCI-3	Low-Cost Loans for Energy Efficiency	MEA
ES-1	Promotion of Renewable Energy	MEA (PSC)
ES-6	Integrated Resource Planning	PSC (MEA)
RCI-7	More Stringent Appliance / Equipment & Efficiency Standards	MEA
CC-9	Promote Economic Development Opportunities	DBED (MEA)
ES-2	Technology Focused Initiatives for Electricity Supply	MEA
AFW-2	Managing Urban Trees & Forests	DNR
AFW-3	Afforestation, Reforestation, & Restoration of Forests & Wetlands	DNR (MDA)
AFW-4	Protection & Conservation of Agricultural Land, Coastal Wetlands & Forested Land	MDA
AFW-1	Forest Management for Enhanced Carbon Sequestration	DNR
AFW-5	Buy Local Programs	MDA (DNR)

Bin 3: Higher Emission Reduction / Harder Implementation

Policy Number	*Policy Name*	*Lead Agency*
ES-8	Energy Improvements & Repowering Existing Plants	MEA (PSC)
ES-10	Generation Performance Standards	MDE (PSC, MEA)
TLU-2	Land Use & Location Efficiency	MDOT (MDP, MDE)
TLU-3	Transit	MDOT (MDP, MDE)
TLU-5	Intercity Travel	MDOT (MDP, MDE)
TLU-6	Pay-As-You-Drive Insurance	MDOT (MDP, MDE)
TLU-8	Bike & Pedestrian Infrastructure	MDOT (MDP, MDE)
TLU-9	Incentives, Pricing & Resource Measures	MDOT (MDP, MDE)
TLU-11	Evaluate GHGs from Major Projects	MDOT (MDP, MDE)

Bin 4: Lower Emission Reduction / Harder Implementation

Policy Number	*Policy Name*	*Lead Agency*
AFW-6	Expanded Use of Forese & Feedstocks for Energy Production	DNR (MDA)
AFW-7b	In-State Liquid Biodiesel Production	MEA (MDA)
AFW-8	Nutrient Trading with Carbon Benefits	MDE (MDA)

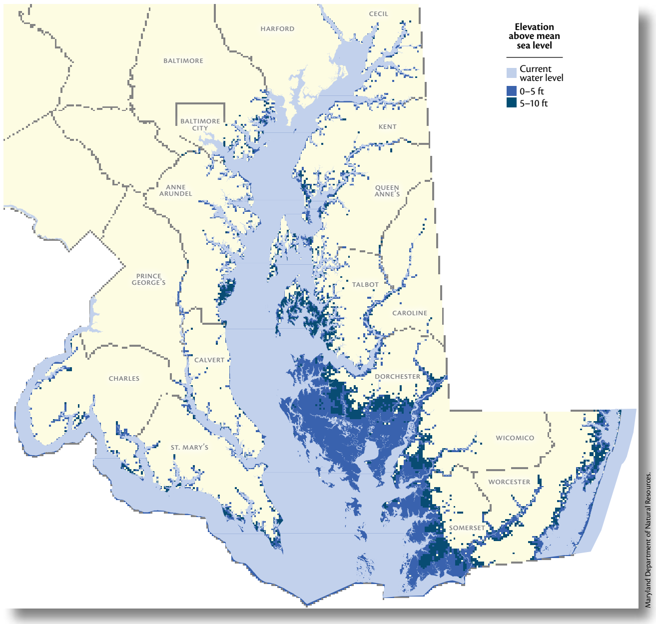
Chapter 5: Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change: Phase 1 Sea Level Rise & Coastal Storms

Introduction - We must take action now to plan for the impacts of climate change

The Commission's Adaptation and Response Working Group (ARWG) was charged with developing a *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change*. The Executive Order calls for the *Strategy* to outline specific policy recommendations for reducing the vulnerability of the State's natural and cultural resources and communities to the impacts of climate change, with an initial focus on sea level rise and coastal hazards.

With over 3,000 miles of coastline, Maryland is poised in a very precarious position when it comes to the impacts of climate change. Maryland's coast is particularly vulnerable to both episodic storm events, such as hurricanes and Nor'easters, as well as chronic problems associated with shore erosion, coastal flooding, storm surge, and inundation. Problems such as these are both driven by and exacerbated by climate change and sea level rise.

Rising sea levels over the last 20,000 years have formed the Chesapeake Bay that we know today. While the rapid rate of sea level rise that occurred over the past 5,000 years has slowed, historic tide-gauge records show that levels are still rising and have increased approximately one-foot within Maryland's coastal waters in the past 100 years. Such a rate of rise is nearly twice that of the global average, over the same time period. In support of this ***Climate Action Plan***, the STWG assessed the 2007 global sea level rise projections of the Intergovernmental Panel on Climate Change (IPCC), along with regional land subsidence variables, and provided a conservative estimate that by the end of this century, Maryland may experience a relative sea level rise of 2.7 feet, under a lower-emission scenario, and as much as 3.4 feet under the higher-emission scenario,



Sea-level rise vulnerability in the coastal areas of Maryland, calculated using LIDAR elevation data. Note: LIDAR elevation data were not available for Baltimore City, Harford County, and Prince George's County. Therefore, vulnerability data do not exist for those areas and cannot be shown on this map.

Due to its geography and geology, the Chesapeake Bay region is ranked the third most vulnerable to sea level rise, behind Louisiana and Southern Florida. In fact, sea level rise impacts are already being detected all along Maryland's coast, as 13 charted Chesapeake Bay islands and large expanses of tidal wetlands have already disappeared. Two to three feet of additional sea level rise will result in a dramatic intensification of coastal flood events; increase shore erosion; cause the intrusion of salt-water into freshwater aquifers; and submerge thousands of acres of tidal wetlands, low-lying lands and the Chesapeake's last inhabited island community, Smith Island.

Sea level rise poses a significant threat to resources and infrastructure in Maryland's coastal zone. As growth and development continues, especially within low-lying Eastern Shore communities, these impacts are likely to escalate. In the short-term, coastal areas already under natural and human-induced stress are most vulnerable. Of these, barrier and bay islands, and Lower Eastern Shore of the Chesapeake Bay are in critical need of protection. However, much larger portions of Maryland's coast will become threatened over time.

Adaptation and response planning is crucial to Maryland's ability to sustainably manage its coastal zone. A "do nothing" approach will lead to unwise decisions and increased risk over time. Planners and legislators must realize that the implementation of measures to mitigate climate change and sea level rise impacts associated with erosion, flooding, and the inundation of low-lying lands is imperative to sustainable management, as well as protection of Maryland's coastal resources and communities.

This *Strategy* lays out the specific priority policy recommendations developed by the ARWG and approved by the Commission to address short- and long-term adaptation and response measures, planning and policy integration, education and outreach, performance measurement, and where necessary, the *Strategy* identifies new legislation and/or modifications to existing laws. Full versions of the priority policy recommendations, which include a detailed discussion of implementation mechanisms, related policies and programs in place, qualitative benefits and cost assessments and feasibility issues, are contained in Appendix E.

Vision/Statement of Intent - Protect Maryland's Future Economic Well-Being, Environmental Heritage, and Public Safety

Climate change, sea level rise and associated coastal storms, are putting Maryland's people, property, natural resources, and public investments at risk. To protect Maryland's future economic well-being, environmental heritage and public safety and to guide the fundamental intent of the *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change*, the Commission recommends that the Governor and the Maryland General Assembly take legislative and policy actions to:

- Promote programs and policies aimed at the avoidance and/or reduction of impact to the existing-built environment, as well as to future growth and development in vulnerable coastal areas;
- Shift to sustainable economies and investments; and, avoid assumption of the financial risk of development and redevelopment in highly hazardous coastal areas;
- Enhance preparedness and planning efforts to protect human health, safety and welfare;
- Protect and restore Maryland's natural shoreline and its resources, including its tidal wetlands and marshes, vegetated buffers, and Bay Islands, that inherently shield Maryland's shoreline and interior.

Reduction of Impact to Existing and Future Growth and Development -Take action now to protect human habitat and infrastructure from future risks

Leadership by Maryland's State and local governments is imperative to reduce Maryland's vulnerability to climate change, sea level rise, and coastal storms. Maryland's State agencies and its local governments must take action now to protect human habitat and infrastructure from future risks. The State can accomplish this by taking steps to effectively reduce the impact to existing-built environments by requiring that public and private structures be elevated and designed to reduce damage; and to avoid future impact, by directing new growth and development away from areas vulnerable coastal areas.

Priority Policy Recommendations

- Integrated Planning: Require the integration of coastal erosion, coastal storm and sea level rise adaptation and response planning strategies into existing state and local policies and programs.
- Adaptation of Vulnerable Coastal Infrastructure: Develop and implement State and local adaptation policies (i.e., protect, retreat, abandon) for vulnerable public and private sector infrastructure.
- Building Code Revisions and Infrastructure Design Standards: Strengthen building codes and construction techniques for new infrastructure and buildings in vulnerable coastal areas.
- Financial and Economic Well-Being – Minimize risks and shift to sustainable economies and investments

Maryland's people, property, natural resources, and public investments are all vulnerable to climate change and sea level rise; and, at some point, the inevitability of climate change will require critical actions to protect them rather than purposeful foresight and preparedness planning. Two to three feet of sea level rise would inundate thousands of properties in of low-lying areas, and expose millions of dollars worth of public infrastructure to the threat of submergence and/or storm surge. Billions of dollars more of public and private investments are at risk. Over time, federal, State, and local government will not be able to afford to assist all in need - the costs will be just too high. Maryland should begin a sweeping shift to develop sustainable economies and investments and at the same time, must work hard to avoid the assumption of the financial risk of development and redevelopment in highly hazardous coastal areas.

Priority Policy Recommendations

- Resource-Based Industry Economic Initiative: Develop and implement long-range plans to minimize the economic impacts of sea level rise to natural resource-based industries.
- Climate Change Insurance Advisory Committee: Establish an independent Blue Ribbon Advisory Committee to advise the State of the risks that climate change poses to the availability and affordability of insurance.
- Disclosure: Develop a Maryland Sea Level Rise Disclosure and Advisory Statement to inform prospective coastal property purchasers of the potential impacts that climate change and sea level rise may pose to a particular piece of property.
- Green Economic Development Initiative: Recruit, foster, and promote market opportunities related to climate change adaptation and response.

Protection of Human Health, Safety and Welfare - Guarantee the safety and well-being of Maryland's citizens in times of foreseen and unforeseen risk

Sea level rise will impact both the coastline and some interior portions of Maryland and will change the way health-related infrastructure and programs are maintained and managed in the future. The general population may take for granted that clean and adequate water supplies are available, waste water is cared for and properly disposed of, and that our population is generally safe from the impact of coastal flood events and vector-borne illnesses. However, with a projected growing population in Maryland, mostly in coastal areas, protecting human health and safety will become an increasing large responsibility for the State and local governments. With that responsibility, new tools and adequate resources will be needed in order to protect Maryland's communities – both large and small.

Priority Policy Recommendations

- Inter-Agency Coordination: Strengthen coordination and management across Agencies responsible for human health and safety.
- Health Impact Assessments: Conduct Health Impact Assessments to evaluate the public health consequences of climate change and sea level rise-related projects and/or policies.
- Vector-borne Surveillance and Control: Develop a coordinated plan to assure adequacy of Vector-borne Surveillance and Control Programs.
- Natural Resource Protection - Retain and expand forests, wetlands and beaches to protect us from coastal flooding

Maryland's natural resource lands provide critical wildlife habitats, have regional significance for migratory birds, sequester large amounts of carbon, provide sediment and nutrient water quality benefits, and generate economic benefits through farming, forestry, fishing, and passive recreation. Natural resources, particularly coastal wetlands and barrier and bay islands, also play a vital role in protecting Maryland's shoreline and interior by absorbing the damaging impact of coastal floods, heavy winds, and strong waves. Identifying undeveloped lands and ecologically and economically important lands will be critical for targeted conservation and coordinated restoration in response to sea level rise and its associated effects. Preserving undeveloped, vulnerable lands also offers a significant opportunity to avoid placing people and property at risk to sea level rise and associated hazards including storm surge, coastal flooding, and erosion in the future.

Priority Policy Recommendations

- Natural Resource Protection Areas: Identify high priority protection areas and strategically and cost-effectively direct protection and restoration actions.
- Forest and Wetland Protection: Develop and implement a package of appropriate regulations, financial incentives, educational, outreach, and enforcement approaches to retain and expand forests and wetlands in areas suitable for long-term survival.
- Shoreline and Buffer Area Management: Promote and support sustainable shoreline and buffer area management practices.

Adaptation and Response Toolbox – Give State and local governments the right tools to anticipate and plan for sea level rise and climate change

To adequately plan and respond to sea level rise, it is imperative that both state and local governments have access to the right tools at the right time. Over the last ten years, the State of Maryland has made significant progress acquiring new technology and data, including the statewide high resolution topographic data and has utilized this data to undertake state-of-the-art sea level rise mapping and research. The State has also proactively been working with select state agencies and coastal counties to provide the necessary funding and technical assistance to build capacity to integrate data and mapping efforts into decision-making processes. Maryland is well on its way to providing the tools, technical resources, and educational programs, however, a continued commitment on the part of both State and local governments is still essential.

Priority Policy Recommendations

- Integrated Observation Systems: Strengthen federal, State, local, and regional observation systems to improve the detection of biological, physical, and chemical responses to climate change and sea level rise.
- GIS Mapping, Modeling and Monitoring: Update and maintain statewide sea level rise mapping, modeling, and monitoring products.
- Public Awareness, Outreach, Training and Capacity Building: Utilize new and existing educational, outreach, training and capacity building programs to disseminate information and resources related to climate change and sea level rise.

Future Steps and Directions – State and local governments must commit resources and time to assure progress

Planning for climate change and sea level rise is extremely complex - there are many potential impacts and there is no single remedy. While climate change and sea level rise are both gradual processes occurring slowly over time, the impacts of both are already being detected. Maryland's State and local governments must take specific action now to plan for the inevitable impacts. The recommendations laid out in this *Strategy* are intended to guide adaptation activities over the next five years and along the way, Maryland's state and local governments must measure and track progress, keeping in mind that many of the implementation strategies must be adaptable to change. Progress will take time, fiscal resources, flexibility, and continual commitment.

Priority Policy Recommendations

- Local Government Planning Guidance: Develop state-wide sea level rise planning guidance to advise adaptation and response planning at the local level.
- Adaptation-Stat: Develop and implement a system of performance measures to track Maryland's success at reducing its vulnerability to climate change and sea level rise.
- Future Adaptation Strategy Development: Pursue the development of adaptation strategies to reduce climate change vulnerability among affected sectors, including agriculture, forestry, water resources, aquatic and terrestrial ecosystems, and human health.

The Commission should continue to evaluate adaptation strategies in addition to sea level rise and coastal vulnerability over the next year and beyond. The sector-based impact and issue assessments provided by the STWG (Chapter 2 of the ***Plan***) will serve as a useful basis for evaluation of adaptation strategies appropriate for Maryland in the areas of human health; water resources; forest management; and the restoration of the Chesapeake and Maryland Coastal Bays. Phase II of the *Comprehensive Strategy to Reduce Maryland's Vulnerability to Climate Change* should be initiated within one-year. Sector-based working groups, comprised of a broad array of stakeholders and issue experts, will be necessary to fulfill this task.

Chapter 6: Building a Federal-State Partnership

Spurred by the growing momentum of state leadership in climate protection, the U.S. Congress is now seriously engaged in shaping a federal climate policy centered around an economy-wide GHG cap-and-trade program. The Administration and Congress should actively engage the states and regional consortiums such as RGGI in building a federal-state partnership in climate regulation. States should have an active role in establishing national science-based mandatory GHG reduction goals, and in deciding how emission allowances will be allocated in a national cap-and-trade program, how auction revenues will be distributed and can be used by the states, and how an offset credit program will work.

For sectors not amenable to a national cap-and-trade, the federal government should limit its sphere of regulation to the things it is uniquely positioned to do: adopt national technical and performance standards for certain sectors; fund research and development for technological advancement and improved energy efficiency; and amend the Clean Air Act and Surface Transportation Authorization Act and provide funding to enable states to use the Transportation Conformity Process to reduce GHG emissions in the transportation sector.

States should retain the autonomy to implement mitigation programs in areas within their traditional purview, such as land use, building codes, transportation, roads, water, sewer and other infrastructure, school curricula, and police powers. Other non-traditional programs better suited to state implementation include renewable portfolio standards tailored to capitalize on the state's natural resources and economy, utilities' demand-side management programs, integrated resource planning by state public service commissions, and removing siting and regulatory obstacles to clean distributed generation. Recognizing this is the fastest and most cost-effective path to energy efficiency and GHG reductions, Congress should *expressly* not preempt state programs and regulations that are at least as stringent as the federal standards, and should provide priority funding and other incentives for "first mover" states that adopt goals and mandatory climate action plans by a specified date and demonstrate adequate progress toward meeting the goals.

In the 110th Congress, Members have introduced numerous bills that would directly or indirectly address climate change. However, only a few of these bills address the issue of adaptation to climate change. Currently, there are no stand-alone adaptation bills; adaptation provisions are contained in broader legislation on climate action or research. Because of earlier GHG emissions, some level of warming will occur regardless of mitigation activity. The nation should strategically focus on preparing communities and natural systems to adapt to the effects of a changing climate. Maryland must prepare now to adapt and respond to existing and future impacts with the support of the next Administration and Congress.

Fundamental to the requirements for effective adaptation is the ability to monitor, assess, and forecast climate changes. This should be provided through enhanced federal programs for integrated observing systems and climate services in partnership with the states. Furthermore, Maryland should develop and implement a strategy, in partnership with the federal laboratories and programs based in the State, to become a national and international center of excellence for climate change science and technology.

Each of the fifty states faces its own unique set of global warming challenges and is in the best position to assess the risks and implement solutions. The Administration and Congress should recognize the primacy of states as "first responders" in protecting the health, safety and welfare of their citizens, economies, natural resources, and built environments, and to leave them the autonomy to continue their leadership and be the "laboratories for innovation" in climate protection.

Chapter 7: Legislative Update and Next Steps

2008 Legislation

Nearly all of the Commission's recommendations for "Early Action" legislation in the ***Interim Report*** were adopted by the General Assembly in its 2008 Session.

Early Action legislative highlights include:

- Adopting an Energy Efficiency Performance Standard
- Establishing a Publicly Administered Energy Investment Fund
- Amending State Building Codes to Improve Energy Efficiency
- Strengthening Maryland's Renewable Portfolio Standard
- Updating Jurisdictional Boundaries of Bays Critical Areas
- Protecting Shorelines

Next Steps

The Commission will prepare an annual update on the ***Climate Action Plan*** for the Governor and General Assembly every November as called for in the Executive Order. With the ***Plan*** complete, the focus will shift to implementing the policy options that are adopted.

The Commission recommends that Maryland's State government build the institutional capacity to address climate change comprehensively and systematically. Recommended options include the following:

- Adopt the ***Plan's*** GHG reduction goals as Maryland's goals.
- Create an Office of Climate Change within the Governor's office to oversee and coordinate ***Plan*** implementation.
- Prepare and update a statewide GHG inventory and forecast and establish reporting requirements and a registry for GHG sources.
- Establish policies and procedures to give emission reduction and offset credits to sources that take early actions to reduce emissions.
- Establish government lead-by-example policies and procedures for State agencies to: (1) demonstrate and implement best GHG reduction practices through the allocation of State fiscal resources and in operations, procurement, programs, high performance buildings, and management of state lands; and (2) implement sound sea level rise adaptation and response measures on State lands and through the allocation of State fiscal resources.
- Require State agencies to perform a Climate Impact Assessment, under approved protocol, prior to undertaking new capital projects.
- Develop and implement a system of performance measures to track Maryland's success at reducing its vulnerability to climate change and sea level rise (Adaptation-Stat).
- Create a statewide Education/Outreach program.
- Establish work groups recommended in the ***Plan*** to operate under the Commission's umbrella.

The Commission recommends that the lead and supporting State agencies identified in the policy options work together to develop policy implementation plans and start implementing policies immediately where possible, and report their progress to the Commission at its Spring 2009 meeting.

The Commission should continue to evaluate adaptation strategies in addition to sea level rise and coastal vulnerability over the next year and beyond. The sector-based impact and issue assessments provided by the STWG (Chapter 2 of the ***Plan***) will serve as a useful basis for evaluation of adaptation strategies appropriate for Maryland in the areas of human health; water resources; forest management; and the restoration of the Chesapeake and Maryland Coastal Bays. Phase II of the *Comprehensive Strategy to Reduce Maryland's Vulnerability to Climate Change* should be initiated within one-year. Sector-based working groups, comprised of a broad array of stakeholders and issue experts, will be necessary to fulfill this task.


Miss Brooke

CHAPTER ONE

Introduction

Introduction

August 2008

COMMISSION PROCESS

In April of 2007, Governor Martin O'Malley established the Maryland Commission on Climate Change (Commission) through Executive Order 01.01.2007.07. The Commission was charged with the task of developing a ***Climate Action Plan*** (***Plan***) that discusses the drivers and consequences of climate change, necessary preparations for its ensuing impacts on the State, and establishes firm benchmarks and timetables for policy implementation. Shari T. Wilson, Secretary of the Maryland Department of the Environment (MDE) has served as chair of the Commission, whose 21 members represent legislative leadership and State agencies.

As the facilitating agency for development of the ***Plan***, MDE was also responsible for producing an ***Interim Report.*** The ***Interim Report***, which was released on January 14, 2008, updated the Governor and General Assembly on the state of the science on climate change, recommended GHG reduction goals for Maryland, and provided a suite of early actions and priority policy options for consideration, including the recommendations for legislative action addressed in Chapter 7. In months that have followed, the Commission supported its subgroups in further refining and analyzing these options for its final ***Plan***. As a result, this final ***Climate Action Plan*** contains policy recommendations that have been thoroughly discussed through a series of meetings, conference calls, and continuous exchanges between State agencies, stakeholders, and the Center for Climate Strategies (CCS), a consultant that facilitated the Commission's process.

Guided by and comprising the Commission were three Working Groups, also established by the Executive Order: the Greenhouse Gas and Carbon Mitigation Working Group (MWG), chaired by George (Tad) Aburn, Director of MDE's Air and Radiation Management Administration, and co-chaired by Malcolm Woolf, Director of the Maryland Energy Administration (MEA); the Adaptation and Response Working Group (ARWG), chaired by John R. Griffin, Secretary of Maryland's Department of Natural Resources (DNR), and co-chaired by Richard Eberhart Hall, Secretary of the Maryland Department of Planning (MDP) and Don Halligan, Assistant Secretary of MDP; and the Scientific and Technical Working Group (STWG), chaired by Donald Boesch, President, University of Maryland Center for Environmental Science (UMCES), and co-chaired by Frank W. Dawson, Assistant Secretary of DNR and Robert M. Summers, Deputy Secretary of MDE. Each Working Group also had its own set of subgroups, which supported and informed their respective Working Groups regarding priorities for further analysis in their respective fields of interest and expertise. For the MWG and ARWG, these processes were focused on developing final policy recommendations for the *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy* (Chapter 4 of this ***Plan***) and the *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change* (Chapter 5 of this ***Plan***), respectively. The STWG developed the *Comprehensive Climate Change Impact Assessment* (Chapter 2 of this ***Plan***). Its group of 21 scientists and engineers used latest scientific findings of the Intergovernmental Panel on Climate Change (IPCC) and other organizations and computer model projections of Maryland's 21st century climate under scenarios of both continued growth of GHG emissions and mitigated reductions in global emissions.

The membership lists for the Commission, its three Working Groups, and their respective technical work groups are attached to this Plan in Appendix B.

Greenhouse Gas and Carbon Mitigation Working Group (MWG)

MDE continued to lead the MWG's five subgroups, or Technical Working Groups (TWGs), in developing priority policy options for the *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy* (*Reduction Strategy*). During creation of the ***Interim Report***, sector-specific policies had been developed by each of the TWGs: Energy Supply; Transportation and Land Use; Agriculture, Forestry and Waste; Residential, Commercial, and Industrial; and Cross-Cutting Issues. Experts and stakeholders within the TWGs formed subgroups to further refine each policy option description (POD) for review and approval by the MWG and eventually the full Commission. At conclusion of the ***Interim Report***, the MWG had developed 55 priority policy options; in the months following, these were further refined into a suite of 42 cost-effective policy recommendations for reducing GHG emissions in Maryland.

For each recommendation amenable to quantification, the amount of foreseeable GHG reductions, in annual and cumulative tonnages avoided by goal years, and the cost or cost savings were calculated. As one of the last steps in its analysis, these quantifications gave the MWG and the Commission the opportunity to remove impractical measures and move forward with an overall cost-effective suite of recommendations.

The Commission developed the *Reduction Strategy* to support state and national climate policy objectives and to take into account state, regional, and national climate change policy opportunities involving energy, transportation, economic development, environmental quality, and civic infrastructure. CCS was able to work with the Commission as an impartial and expert party, providing technical support and planning activities for the Commission. This combined effort culminates in policy recommendations that, if adopted and aggressively implemented, will reduce GHG emissions and enhance energy and economic opportunities in Maryland as early as 2012, and will achieve or exceed Maryland's reduction goals in 2020 and beyond.

Adaptation and Response Working Group (ARWG)

The ARWG followed a similar path to that of the MWG in order to complete the development of Phase One of the *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change*. Working closely with CCS, DNR and MDP coordinated the efforts of the ARWG's thirty-four working members. Following the release of the ***Interim Report***, the ARWG continued to develop and refine specific policy recommendations within its four Technical Working Groups (TWGs): Existing Built Environment & Infrastructure, Future Built Environment & Infrastructure, Human Health, Safety & Welfare, and Resources & Resource-Based Industry. Led by a facilitator from CCS, experts and stakeholders within the TWGs also formed subgroups to further refine each policy option description (POD) for review and approval by the AWRG and full Commission.

Full versions of the priority policy recommendations developed by the ARWG contained in Appendix E of this ***Climate Action Plan***. Each POD write-up includes a detailed discussion of implementation mechanisms, related policies and programs in place, qualitative benefits and cost assessments and an overview of feasibility issues. Following the approval of the priority policy options by the ARWG, independent policy recommendations from respective TWGs were integrated into a framework consistent with the ARWG's vision for protecting Maryland's future economic well-being, environmental heritage and public safety.

Scientific and Technical Working Group (STWG)

Under the leadership of the University System of Maryland, the STWG developed an assessment of the likely consequences of the changing global climate to Maryland's agricultural industry, forestry resources, fishery resources, aquatic and terrestrial ecosystems, and human health. Subgroups addressed (1) observed climate changes and model projections of future climatic conditions in Maryland; (2) water resources and aquatic environments; (3) agriculture, forestry and terrestrial ecosystems; (4) coastal vulnerability from sea-level rise and storms; (5) the Chesapeake Bay and other coastal ecosystems; and (6) human health. All of the subgroups used the common model projections of changes in temperature, precipitation and other variables derived from these projections, such as soil moisture, droughts, intense rainfall events and heat waves. The same climate model runs that were employed in the most recent IPCC assessment were used for higher emissions and lower emissions scenarios.

Based on these analyses and reviews of the latest scientific literature, the STWG prepared an integrated climate impact assessment to inform Maryland citizens and policy makers of the likely consequences of global climate change on the places we live and resources we depend on. The use of higher and lower scenarios allowed an estimation of the consequences of climate change in Maryland that could be avoided by global actions to reduce emissions of GHGs. The assessment is also intended to provide guidance for efforts in Maryland to adapt to our changing climate through this century.

The STWG worked to produce an assessment report that is scientifically sound and documented but understandable to the non-scientific reader. A draft report of the *Comprehensive Climate Change Impact Assessment* underwent peer review and revision before submitting it to the Commission.

CHAPTER TWO

Comprehensive Assessment of Climate Change Impacts in Maryland

REPORT OF THE SCIENTIFIC AND TECHNICAL WORKING GROUP
MARYLAND COMMISSION ON CLIMATE CHANGE

Scientific and Technical Working Group

Donald F. Boesch, Chair, University of Maryland Center for Environmental Science; **Frank W. Dawson**, Co-Chair, Maryland Department of Natural Resources; **Robert M. Summers**, Co-Chair, Maryland Department of the Environment; **William C. Boicourt**, University of Maryland Center for Environmental Science; **Antonio J. Busalacchi**, University of Maryland, College Park; **Donald R. Cahoon**, U.S. Geological Survey; **Frank J. Coale**, University of Maryland, College Park; **Victoria J. Coles**, University of Maryland Center for Environmental Science; **Russell R. Dickerson**, University of Maryland, College Park; **William M. Eichbaum**, World Wildlife Fund; **Brian D. Fath**, Towson University; **Raymond M. Hoff**, University of Maryland, Baltimore County; **David G. Kimmel**, University of Maryland Center for Environmental Science; **Curtis E. Larsen**, Lusby, Maryland (U.S. Geological Survey, retired); **Andrew J. Miller**, University of Maryland, Baltimore County; **Margaret A. Palmer**, University of Maryland Center for Environmental Science; **Louis F. Pitelka**, University of Maryland Center for Environmental Science; **Steven D. Prince**, University of Maryland, College Park; **Brian S. Schwartz**, The Johns Hopkins University; **David H. Secor**, University of Maryland Center for Environmental Science; **Timothy Warman**, National Wildlife Federation; and **Claire Welty**, University of Maryland, Baltimore County.

Members of the Scientific and Technical Working Group reviewing draft materials for the Comprehensive Assessment.

Acknowledgements

The Working Group appreciates the interest and vision of Governor Martin J. O'Malley in establishing the Commission on Climate Change and charging it to develop an objective and science-based assessment of the impacts of climate change on Maryland. It has enjoyed the encouragement and support of the Commission Chair, Secretary of the Environment Shari T. Wilson, and the cooperation of Tad Aburn, Brian Hug, and Elizabeth Entwisle of the Maryland Department of the Environment, and Zoe Johnson, Gwynne Schultz, and Gwen Shaughnessy of the Maryland Department of Natural Resources. Chancellor William E. Kirwan and the presidents of the University System of Maryland encouraged the participation of faculty experts. The preparation of the report was greatly assisted by the generous support of the Town Creek Foundation and the Keith Campbell Foundation for the Environment. Katherine Smith of the University of Maryland Center for Environmental Science (UMCES) assisted in developing the climate change projections from model archives. Jane Thomas and Joanna Woerner of the Integration & Application Network of UMCES assisted with design and report preparation. Special thanks to David L. Evans, Jay Gulledge, Anthony C. Janetos, and Jerry M. Mellillo for their helpful reviews of the report.

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

Integration & Application Network

Cover photos: NASA, Peggy Davis, Jane Thomas, and Andrew Bossi.

CHAPTER TWO

Comprehensive Assessment of Climate Change Impacts in Maryland

REPORT TO THE MARYLAND COMMISSION ON CLIMATE CHANGE
JULY 2008

SCIENTIFIC AND TECHNICAL WORKING GROUP

EDITED BY DONALD F. BOESCH
DESIGNED AND PRODUCED BY JANE M. HAWKEY

Michael Juskelis, Maryland Sierra Club

MDE
UNIVERSITY SYSTEM OF MARYLAND
MARYLAND DEPARTMENT OF NATURAL RESOURCES

Victoria Coles

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EXECUTIVE SUMMARY

Heritage Festival celebration, Cumberland, Maryland.

Wikipedia Commons

THE ASSESSMENT

This is an assessment of the likely consequences of the changing global climate for Maryland's agricultural industry, forestry resources, fisheries resources, freshwater supply, aquatic and terrestrial ecosystems, and human health. It was undertaken by the Scientific and Technical Working Group of the Maryland Commission on Climate Change as part of the Commission's charge to develop a Plan of Action to address the drivers and causes of climate change and prepare for its likely consequences in Maryland.

The Assessment was based on extensive literature review and model projections. In addition to the scientific literature, other international, national, and regional assessments of the impacts of climate change were consulted. The results from supercomputer models of the responses of climate to increased greenhouse gas concentrations were used to project future conditions for Maryland. These were the same models and scenario assumptions that were used in the acclaimed assessment completed in 2007 by the Intergovernmental Panel on Climate Change (IPCC). Model projections were based on averages for multiple climate models, and selected based on how well they replicated both global conditions and those observed in Maryland during the 20th century. Mean projections for 17 selected models produced more reliable results than individual models. Changes in temperature and precipitation were projected through the 21st century.

In order to estimate the degree of climate change in Maryland that could be avoided by actions to reduce emissions of greenhouse gases, two emissions scenarios were employed. The higher emissions scenario assumes continued growth in global emissions throughout the century, while the lower emissions scenario assumes slower growth, a peak at mid-century, and thereafter, a decline to about 40% of present levels by the end of the century.

RECENT & LIKELY CLIMATE CHANGES IN MARYLAND

Maryland's climate warmed after the peak of the last Ice Age 20,000 years ago, but has been relatively stable for the past 6,000 years. Around these long-term average conditions, there have, of course, been variations in temperature and precipitation due to ocean current cycles and solar and volcanic activity. However, atmospheric concentrations of greenhouse gases—gases, such as carbon dioxide, methane, and nitrous oxide, that trap the sun's energy from radiating back into space—have dramatically increased since pre-industrial times. Carbon dioxide concentrations exceed those experienced over at least the last 650,000 year.

Largely as a result of this increase in greenhouse gases, average global temperature and sea level began to increase rapidly during the 20th century. In its 2007 report, the IPCC concluded that the evidence for the warming of the Earth is "unequivocal." The IPCC also concluded that most of the observed temperature increase since the middle of the 20th century is very likely due to the observed increase in greenhouse gases.

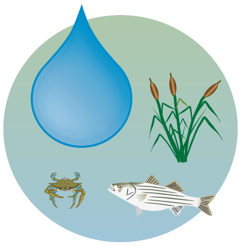
In evaluating the changes in Maryland's climate that we are likely to experience over the 21st century, it should be remembered that climatic regimes will continue to vary across the state. Western Maryland has cooler winters and summers and less precipitation during the winter than the rest of the state. Changes that occur will overlay these regional differences, perhaps with some greater warming during the summer to the west than on the Eastern Shore. Temperature is projected to increase substantially, especially under higher emissions. The increase in average summer temperatures in terms of degrees of warming is greater than that in winter. Annual average temperature is projected to increase by about 3°F by mid-century and is likely unavoidable. The amount of warming later in the century is dependent on the degree of mitigation of greenhouse gas emissions, with summer temperatures projected to increase by as much 9°F and heat waves extending throughout most summers if greenhouse gas emissions continue to grow unchecked.

Victoria Coles

Sailing club event on the Chesapeake Bay.

Precipitation is projected to increase during the winter, but become more episodic, with more falling in extreme events. Projections of precipitation are much less certain than for temperature, but the mean projections indicated modest increases of about 10% or so are likely in the winter and spring. Because of more intermittent rainfall and increased evaporation with warmer temperatures, droughts lasting several weeks are more likely to occur during the summer.

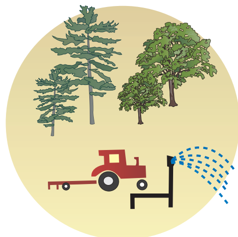
WATER RESOURCES & AQUATIC ENVIRONMENTS



Increased precipitation in the winter and spring would mean that the water supplies in the greater Baltimore area will probably not be diminished, but the adequacy of summer water supplies in the greater Washington region, which rely on Potomac River flows, is less certain. Any increases in precipitation are unlikely to replace groundwater substantially enough to compensate excessive withdrawals of some aquifers. At the same time, summer droughts may increase groundwater demand for agricultural irrigation.

More intense rainfall resulting from the combined effects of global climate change and localized factors, for example, the influence of the urban canopy on rainfall, is likely to increase peak flooding in urban environments. Continued increase in impervious surfaces attendant with development would exacerbate this problem. Aquatic ecosystems will likely be degraded by more flashy runoff and increased temperatures. Intensified rainfall events and warmer surfaces (roads, roofs, etc.) would result in rapid increases in stream temperatures, limiting habitat suitability for native fishes and other organisms. Higher peak flows and degraded streams would also transmit more nutrients and sediments to the Chesapeake Bay and its tidal tributaries, contributing to water quality impairment in the estuaries.

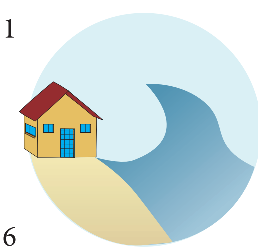
FARMS & FORESTS



Crop production may increase initially, but then decline later in the century if emissions are not reduced. The longer growing season and higher carbon dioxide levels in the atmosphere are likely to increase crop production modestly during the first half of the century. Later in the century, crop production is likely to be reduced due to heat stress and summer drought under the higher emissions scenario. Milk and poultry production would be also reduced by heat stress. These changes will require adaptation by Maryland's agricultural industry, including changes in crop or animal varieties, increased irrigation, and air conditioning for some livestock.

The maple-beech-birch forest of Western Maryland is likely to fade away and pine trees to become more dominant in Maryland's forests. Forest productivity in terms of timber produced is likely to decline late in the century under the higher emissions scenario as a result of heat stress, drought, and climate-related disturbances such as fires and storms. The biodiversity of plants and animals associated with Maryland's forests is likely to decline. Habitat alterations resulting from climate change may force out 34 or more bird species, including the emblamatic Baltimore oriole, although southern species may replace them.

COASTAL VULNERABILITY

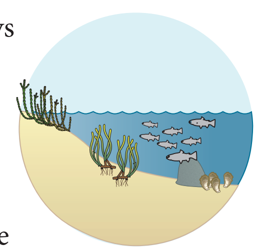


Sea level in Maryland rose by 1 foot in the 20th century, partially because the land is sinking as a result of slow adjustments of the Earth after the last Ice Age. Maryland coastal regions have been subsiding at about a rate of 6 inches per century and should continue at this rate during this century. Additionally, the average level of the sea in this region rose by about the same amount (6 inches) during the past century, resulting in the observed 1 foot of rise of the mean tidal level relative to the land. As a result, Maryland has experienced considerable shoreline erosion and deterioration of coastal wetlands which are a critical component of its bays and estuaries.

Sea-level rise is very likely to accelerate, inundating hundreds of square miles of wetlands and land. Projections that include accelerating the melting of ice would increase the relative sea-level along Maryland's shorelines by more than 1 foot by mid-century and 3 feet by late century if greenhouse gas emissions continue to grow. If sea level rises by 3 feet, most tidal wetlands would be lost—about 200 square miles of land would be inundated. New tidal wetlands developed on newly flooded land would not offset the loss of existing wetlands and significant negative effects on living resources dependent on these wetlands would result. Moreover, if sea level were to rise by 3 or more feet, this would mean that rapid and probably uncontrollable melting of land-based ice was underway and that sea level would rise at an even greater rate during subsequent centuries.

Rains and winds from hurricanes are likely to increase, but changes in their frequency cannot now be predicted. The destructive potential of Atlantic tropical storms and hurricanes has increased since 1970 in association with warming sea surface temperatures. This trend is likely to continue as ocean waters warm. Whether Maryland will be confronted with more frequent or powerful storms depends on storm tracks that cannot yet be predicted. However, there is a greater likelihood that storms striking Maryland would be more powerful than those experienced during the 20th century and would be accompanied by higher storm surges—made worse because of higher mean sea level—and greater rainfall amounts.

CHESAPEAKE BAY & COASTAL ECOSYSTEMS

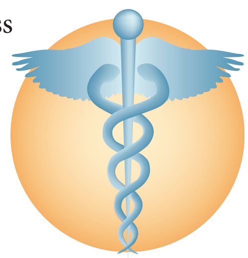


Chesapeake and Coastal Bays restoration goals will likely be more difficult to achieve as the climate in Maryland and the Chesapeake watershed changes. Increased winter-spring runoff would wash more nutrients into the Bays, and higher temperatures and stronger density stratification in the estuaries would tend to exacerbate water quality impairment, the alleviation of which is the prime restoration objective. Consequently, nutrient loads would have to be reduced beyond current targets to achieve water quality requirements. Very significant changes are also likely to occur that affect sediment delivery and sedimentation in the estuaries, but are difficult to quantitatively predict. These include potential increases in sediment loads from rivers as a result of increased runoff and more erosive extreme discharge events, including those caused by hurricanes, and from shoreline and wetland erosion as a result of accelerated sea-level rise.

Living resources will very likely change in species composition and abundance with warming. A mixture of northern, cool water species and southern, warm water species currently resides in the Chesapeake Bay. Northern species such as soft shell clams and eelgrass are likely to be eliminated later in the century, almost certainly if greenhouse gas emissions are not mitigated. Southern species are very likely to increase in abundance because the milder winters would allow or enhance overwintering populations.

As ocean water becomes more acidic, shellfish production could be affected. Increased atmospheric carbon dioxide concentrations in the atmosphere have already lowered pH in the world's oceans, a trend that is very likely to continue. Recent research indicates that the rate at which oysters and other coastal shellfish build their calcium carbonate shells will likely be affected, but whether this would occur in Maryland waters has not been evaluated.

HUMAN HEALTH



Health risks due to heat stress are very likely to increase, if emissions are not reduced. Under the higher emissions scenario, heat waves are projected to greatly increase risks of illness and death before the end of the century, with an average of 24 days per summer exceeding 100°F. The poor, the elderly, and urban populations are most susceptible. Some, but not all, of these increased risks can be reduced by air conditioning and other adaptation measures.

Respiratory illnesses are likely to increase, unless air pollution is greatly reduced. More ground-level ozone, responsible for multiple respiratory illnesses, is formed under prolonged, high temperatures. Releases of air pollutants (nitrogen oxides and volatile organic compounds) that cause ozone to be formed have been declining, but would have to be reduced much more in a warmer climate to avoid a reversal in progress toward achieving air quality standards.

Increased risks of pathogenic diseases may be less likely. The mortality due to vector-borne and non-vector borne diseases in the United States is low because of public health precautions and treatment, which would likely adapt to changes in disease risks. Climate change might affect the exposure of Marylanders to pathogens such as the West Nile virus, but precautions and treatment could manage this greater risk.

MITIGATION & ADAPTATION

The reduction of greenhouse gas emissions has substantial benefits for Maryland. The mitigation of global emissions by mid-century would very likely result in significantly lower sea-level rise, reduced public health risks, fewer extreme weather events, and less decline in agricultural and forest productivity and loss of biodiversity and species important to the Chesapeake Bay. More serious impacts beyond this century, such as sea-level rise of 10 feet or more, would be avoided.

Based on the projections made in this report, adaptation strategies for human health, water resources, and restoration of Maryland's bays should be evaluated and, where necessary, implemented. Adaptation measures to reduce coastal vulnerability should plan for a 1 foot rise in sea level by mid-century and a rise of at least 2 feet by late in the century. Depending on the course of greenhouse gas emissions, observations, and modeling, planning for increases in sea level of up to 4 feet by the end of the century may be required. The Commission on Climate Change should evaluate additional adaptation strategies related to human health, water resources, forest management, and restoration of the Chesapeake Bay and Maryland's Coastal Bays. The projections of impacts provided in this assessment provide a frame of reference for these evaluations.

Maryland should marshal and enhance its capacity for monitoring and assessment of climate impacts, as a more extensive, sustained, and coordinated system for monitoring the changing climate and its impacts is required. Because of its national laboratories, strong university programs, knowledge-based economy, and proximity to the nation's capital, Maryland is in a strong position to become a national and international leader in regional-to-global climate change analysis and its application to innovative mitigation and adaptation.

Section 1

PURPOSE OF THE ASSESSMENT

US Fish & Wildlife Service

Sunset over Maryland marshlands.

Recognizing the scientific consensus about climate change, the contribution of human activities, and the vulnerability of Maryland's people, property, natural resources and public investments, Governor Martin O'Malley issued an Executive Order on April 20, 2007, that established Maryland's Commission on Climate Change in order to address the need to reduce greenhouse gas emissions and prepare the State for likely consequences of climate change. The Commission was given the task of developing a Plan of Action to address the drivers and causes of climate change, prepare for the likely consequences and impacts of climate change to Maryland, and establish firm benchmarks and timetable for implementing the Plan.

The Plan of Action includes three components:

1. a Comprehensive Climate Change Impact Assessment,
2. a Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy, and
3. a Comprehensive Strategy for Reducing Maryland's Climate Change Vulnerability.

This report constitutes the climate change impact assessment and thus a key part of the Commission's Action Plan. It was prepared by a Scientific and Technical Working Group comprised of Maryland-based scientists, engineers and other experts, who worked over ten months to produce this report. Specifically, the Working Group was charged to investigate climate change dynamics, including current and future climate models and forecasts and evaluate the likely consequences of climate change to Maryland's agricultural industry, forestry resources, fisheries resources, freshwater supply, aquatic and terrestrial ecosystems, and human health. In addition, the Working Group was called

Governor Martin O'Malley signs the Executive Order creating the Maryland Commission on Climate Change, joined by Cabinet members and General Assembly leaders.

on to advise the Commission and its other working groups as their work proceeded. In particular, the Scientific and Technical Working Group provided information and analysis for the development of the goals for reducing greenhouse gas emissions and for adaptation strategies for reducing coastal vulnerability.

This Comprehensive Assessment of Climate Change Impacts in Maryland is intended to serve a number of purposes. First, it is one of the three legs of the stool for the Commission's Plan of Action, providing regional context for the importance of reducing Maryland's greenhouse gas emissions and projections of future climate change for which we should be prepared to adapt. For this reason, projections for climate change and its impacts present two scenarios, one assuming continued growth in greenhouse gas emissions and the other assuming global action to reduce these emissions. The second scenario helps to identify the changes that may be inevitable and for which Maryland must be prepared to adapt. In this manner, it seeks to provide a basis for the development of prudent and effective public policy by the Governor and General Assembly.

Secondly, this Assessment is presented so as to be accessible and comprehensible to the citizens of Maryland as they develop their understanding of this unprecedented challenge to humankind and make personal choices and decisions regarding policy options at local, state, and national levels.

Finally, this Assessment is just the first installment of what must be continuous reassessment of Maryland's changing climate, the impacts of this change, and what science and engineering can do to understand, predict, and manage these impacts.

Victoria Coles

Forested mountains and grass meadows of western Maryland.

Section 2

WHY IS THE WORLD'S CLIMATE CHANGING?

KEY POINTS

- **Maryland's climate has been variable but stable for several thousand years.**
  Maryland's climate warmed after the peak of the last Ice Age and has been relatively stable for the past 6,000 years. Around these long-term average conditions there have, of course, been variations in temperature and precipitation due to ocean current cycles, solar activity, and volcanic activity.

- **Atmospheric concentrations of greenhouse gases have dramatically increased.**
  Certain gases that trap the sun's energy from radiating back into space have increased since pre-industrial times. Carbon dioxide concentrations exceed those experienced over at least the last 650,000 years. Average global temperature and sea level began to increase rapidly during the 20th century.

- **Global warming is unequivocal.**
  The Intergovernmental Panel on Climate Change found the evidence for the warming of the Earth to be "unequivocal." The IPCC concluded that most of the observed temperature increase since the middle of the 20th century is very likely due to the observed increase in greenhouse gases.

CLIMATE VARIABILITY & CHANGE

Maryland's climate has changed over millennia as the major planetary forces affecting the Earth's climate caused glaciers to spread and recede. However, after the peak of the last Ice Age about 20,000 years ago, the climate warmed, most of the glaciers melted, and sea level rose, reaching approximately the present conditions about 6,000 or more years ago. The slow, continued rise in local water levels was mainly the result of the slow sinking of the Earth's crust beneath us—this itself is a delayed effect of melting glaciers. The first Native Americans came to Maryland as its climate was becoming more moderate and habitable. For most of the time they have been here and all of the time of occupancy by Europeans, Africans and other subsequent migrants, our climate has been relatively stable. Our society, economy, and quality of life has developed under and adapted to this climatic regime.

Of course, our weather (see Section 4 for a discussion of the differences between weather and climate) still varies from year to year—some years are warmer or wetter than others—and even over cycles that extend over several years to a decade or more. This variability is caused by shifts in large-scale processes in the ocean and atmosphere such as the El Niño cycles in the Pacific Ocean, variations in solar activity, and even volcanic eruptions halfway around the world. But, over the past few thousand years, this has caused climate to fluctuate around a rather consistent average.

During the 20th century, however, scientists have concluded that the Earth's climate was warming and is very likely to warm much more dramatically as a result of human activities that have increased the amount of certain gases in the atmosphere. These gases, most notably carbon dioxide, but also methane and nitrous oxide, trap some of the sun's energy radiating back out into space, much as the glass panes of a garden greenhouse. The presence of these gases warms the atmosphere sufficiently for life to flourish—without these greenhouse gases the average surface temperature of Earth would be 0°F rather than 57°F.[1] But, as these heat-trapping gases continue to increase, the temperature of Earth's atmosphere and oceans will also continue to increase—this is what is meant by global warming.

MAJOR CHANGES DOCUMENTED

There is no doubt that greenhouse gases in the atmosphere have been increasing. Since pre-industrial times (1750) carbon dioxide concentration has increased by 38 percent, methane by nearly

170 percent, and nitrous oxide by 17 percent.[2] The increase in carbon dioxide has been caused primarily by burning of fossil fuels (coal, oil, and natural gas) and the clearing of forests which held reservoirs of carbon in wood and soils and removed carbon dioxide from the atmosphere through photosynthesis. The increase in the other two major greenhouse gases is mostly due to agricultural activities: methane through growing rice and raising cattle, and nitrous oxide from the application of industrial fertilizers to crops, as well as a result of the high-temperature combustion of fossil fuels.

Carbon dioxide concentration in the atmosphere has increased from a pre-industrial value of about 280 parts per million (ppm) to 384 ppm by 2007 (Figure 2.1), exceeding by far the natural range over at least the last 650,000 years as determined from analyses of air bubbles trapped in glacial ice.

The global mean surface temperature, based on both air and ocean temperatures, has increased by more than 1°F (0.6°C) since 1930 (Figure 2.2), with most of this due to a steady and rapid increase since 1980. Twelve of the last thirteen years rank among the warmest years since 1850, when thermometer measurements became widely recorded. In the Northern Hemisphere, where there are numerous data on temperature proxies such as tree ring thickness and ratios of stable isotopes, neither the recent high global mean temperature nor the rapid rate of temperature increase have been experienced during the last 2000 years.[2]

Global warming affects not only air and ocean temperatures but also precipitation and sea level—ocean waters expand as they warm and as melting glaciers and polar ice sheets further contribute to the ocean's volume. Warmer conditions cause

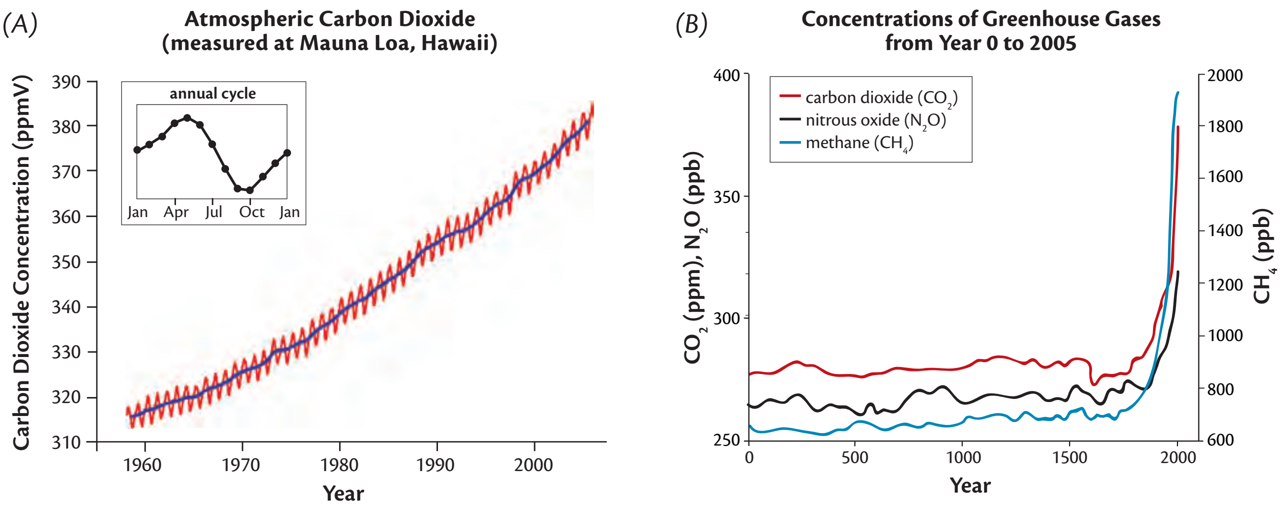


Figure 2.1. (A) Concentrations of carbon dioxide measured at Mauna Loa, Hawaii have shown a continuous increase since measurements began in 1958. Annual fluctuations represent seasonal biological cycles of photosynthesis and respiration. (B) Concentrations of the greenhouse gases carbon dioxide, methane, and nitrous oxide dramatically increased during the 20th century, exceeding by far concentrations that occurred over the last 2,000 years.[2]

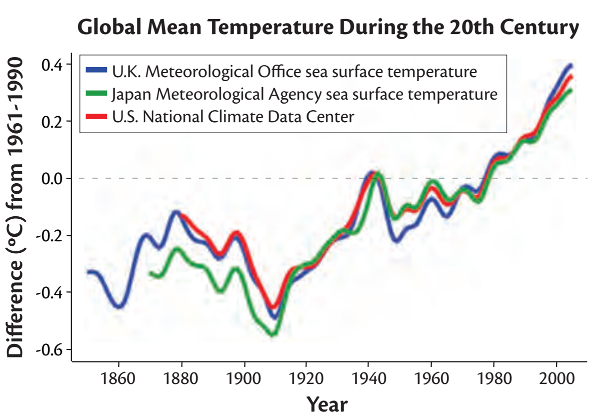


Figure 2.2. Global mean temperature has increased approximately 1.4°F (0.8°C) during the 20th century as reflected in three separate meteorological databases.[2]

NASA Jet Propulsion Lab, CIT

AIRS, a new spaceborne instrument, is designed specifically to measure the amounts of water vapor and greenhouse gases.

more moisture to go into the atmosphere through evaporation and plant transpiration, and this water vapor must come down in the form of precipitation. However, the effect is not uniform, with increased precipitation documented over the middle and high latitudes of the Northern Hemisphere and over tropical land areas, while precipitation declined in the already dry, lower latitude lands.

WARMING IS UNEQUIVOCAL

The conclusion that the warming of the climate system is unequivocal and the preceding observations come from the most recent assessment of the Intergovernmental Panel on Climate Change, an international scientific body established by the World Meteorological Organization and by the United Nations Environment Programme. The IPCC was awarded, along with Vice-President Al Gore, the Nobel Peace Prize for its Fourth Assessment Report[3], released in 2007. The findings of the Panel are careful and deliberate and enjoy the wide acceptance of the climate science community—in fact, scientific criticism that the IPCC was too cautious and reticent[4] is more common than criticism for overstating the case.

Global warming is unequivocal and could cause irreversible damage to the planet

The IPCC concluded that most of the observed increase in globally averaged temperatures since the middle of the 20th century is very likely due to the observed increase in greenhouse gas concentrations resulting from human activities. The Panel also found decreases in snow cover and sea ice extent and the retreat of mountain glaciers during this period. Global average sea level rose with increasing ocean water temperatures. Heavy rains increased in frequency in some regions of the world.

Extensive physical and ecological changes resulting from the changing climate are also described in the IPCC assessment, including thawing of permafrost, lengthening of the growing season in middle and high latitudes, shifts in the ranges of animals and plants toward the poles and up mountain elevation gradients, declines in some plant and animal species, and earlier seasonal flowering of trees, emergence of insects, and egg-laying in birds.[5]

The same detailed appraisal of the relationship of the changes in Maryland's climate and the increase in greenhouse gas concentrations has not been undertaken, and indeed is not practical because of the global scale of the climate system. However, the trends of increased temperature, precipitation, and sea level rise and many of the biological changes that have been observed are very consistent with the assessment of the IPCC for North America.[2,5]

U.S. Geological Survey

Comparison photos of McCarty Glacier in Kenai Fjords National Park, Alaska. McCarty glacier retreated ~12 miles between the period these two photos were taken and is not visible in the 2004 photo.

NPS

The lakes, ponds, and streams of Maryland are a favorite habitat for the twelve-spotted dragonfly.

Section 3

APPROACH TO ASSESSING RECENT & FUTURE CLIMATE CHANGE

KEY POINTS

- **The Assessment was based on extensive literature and model projections.**
  In addition to the scientific literature, other international, national and regional assessments of the impacts of climate change were consulted. The results from supercomputer models of the responses of climate to increased greenhouse gas concentrations were used to project future conditions in Maryland.

- **Model projections were based on averages for multiple climate models.**
  Models were selected based on how well they replicated both global conditions and those observed in Maryland during the 20th century. Mean projections for 17 models produced more reliable results than individual models. Changes in temperature and precipitation were projected through the 21st century.

- **Higher and lower emissions scenarios were employed.**
  In order to estimate the degree of climate change in Maryland that could be avoided by actions to reduce emissions or greenhouse gases, two emissions scenarios were employed. The higher emissions scenario assumes continued growth in emissions throughout the century, while the lower emissions scenario assumes a slower growth peak at mid-century and declines thereafter to about 40% of present emissions levels by the end of the century.

THE PROCESS

The Scientific and Technical Working Group (STWG) developed this assessment using published scientific information on Maryland's climate and environments, the recent IPCC reports, even more recent scientific literature, and several new assessments of specific issues or region impacts. Particularly important among these assessments were various Synthesis and Assessment Products being produced by the U.S. Climate Change Science Program (some drafts still in preparation or review)[6] and regional assessments, especially the Northeast Climate Impacts Assessment (NECIA). The NECIA, led by the Union of Concerned Scientists, produced two very readable reports[7] on climate change, its impacts and solutions in the northeastern United States, defined as the nine-state region including Pennsylvania and New Jersey northward. Because of its proximity, the findings of the NECIA are highly relevant and have been reflected in the Maryland assessment.

The STWG did not have the time or resources to collect or analyze extensive data or to develop new models of Maryland's climate, relying instead on the primary or summary literature as described above. It did, however, use the results of the extensive general circulation models that were run on a global scale for the IPCC assessment. Such models are run on supercomputers using common assumptions about future emissions of greenhouse gases and have become increasingly skillful in reproducing the climatic conditions experienced during the 20th century looking backward in hindcast mode. This gives some level of confidence in their ability to project conditions with future increases in greenhouse gases for at least the near future. The models were used by the IPCC in demonstrating that the warming observed over the past 100 years is unlikely to be due to natural causes, such as the sun and volcanoes, alone. Model results that take into account greenhouse gas emissions and the cooling effects of sulfate aerosols, also emitted by burning fossil fuels, are able to reproduce the observed 20th century warming, while those that only account for the natural climate forces do not (Figure 3.1).

While our understanding of the forces that affect the Earth's climate will improve, the scientific community believes that the current generation of models produces reasonable projections of future climatic conditions. They cannot, of course, predict the weather on a specific place or day, but can represent best estimates of future climatic conditions within a broad region averaged over a decade.

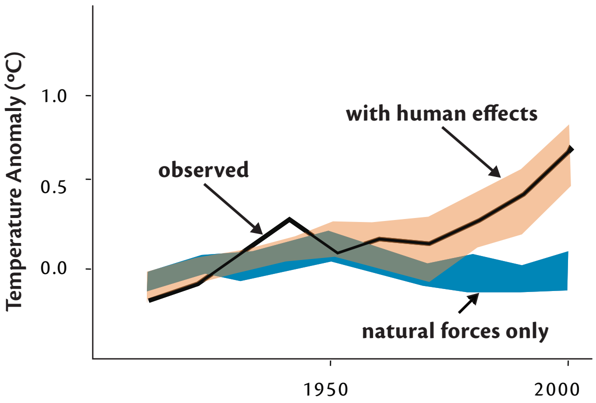


Figure 3.1. Climate models run with just natural forces due to solar activity and volcanoes (blue band) suggest slight declines in global mean temperature during the latter 20th century, while the same models including greenhouse gases and aerosol sulfates from human activities (pink band) show warming very consistent with what was actually observed (solid black line).[2]

OBSERVATIONS

The focus of this assessment is the impacts of future climate change, rather than how much of past climate variability is due to human effects, so the emphasis is on model projections. However, data from stations from the United States Historical Climate Network, corrected for the warming effects of urbanization and the local effects of topography, were used to determine how well models reproduce recent climate in Maryland. These individual weather station records also yield information on the trends in temperature and precipitation that have been experienced.

Beyond temperature and precipitation, sufficiently long records of other climate-sensitive variables are scarce, thus attribution of past changes to climate is difficult. One example of the value of such secondary indicators is the recorded trend toward earlier start of honey production in the Piedmont region.[8] Honey production requires both temperatures high enough to maintain larval bees and an ample source of nectar from flowering trees, thus integrating two measures of climate change. Other examples of observed changes in forestry and agriculture, Chesapeake Bay processes, sea level, and hydrology are highlighted later in the report.

PROJECTIONS

In forecasting the storm tracks of active or developing hurricanes, for example, an ensemble of models is used rather than just relying on one. This allows for a 'best estimate' prediction within a range of plausible tracks. A similar approach was used in the IPCC Fourth Assessment by employing a group of satisfactorily performing general circulation models all run with the same assumptions for greenhouse gas emissions. The archived files of output from these supercomputer model runs were accessed for this assessment.[9] The average of the model outputs yields a better representation of present climate than any single model[10] or the small number of models used in the Northeast Assessment.[7] This ensemble mean gives the best projections because some model inaccuracies are unrelated to the shortcomings of other models, so they cancel out on average.

This assessment used a similar strategy, beginning with the 24 models used for the IPCC Fourth Assessment model intercomparison. The 17 best performing models were selected based on how well the models reproduce the climate in Maryland over the past century.[11] Net error scores were computed for temperature and precipitation based on means, trends over the century, seasonal and ten-year filtered correlations, the standard deviation, and the skill with which the models represent global climate. The subset of better performing models was then averaged over the state of Maryland to estimate changes in future climate in this region.

Projections of the 17 best performing models were averaged

Because the global models require so many hours of supercomputer time to run, they cannot represent regions as small as Maryland with more than a few grid points (Figure 3.2). Thus, the projected changes over the state need to be considered in the context of the large differences in local state climate. For example, one would expect the climate in high elevation regions of western Maryland to remain cooler than the climate on the coastal plain despite similar temperature increases in both regions (see Table 4.1 in the next chapter). The average seasonal cycle for 1979-1999 is removed from each model output prior to determining future changes. This reduces the effect of individual model biases on the projection of future changes and projects future climate relative to the average conditions around 1990.

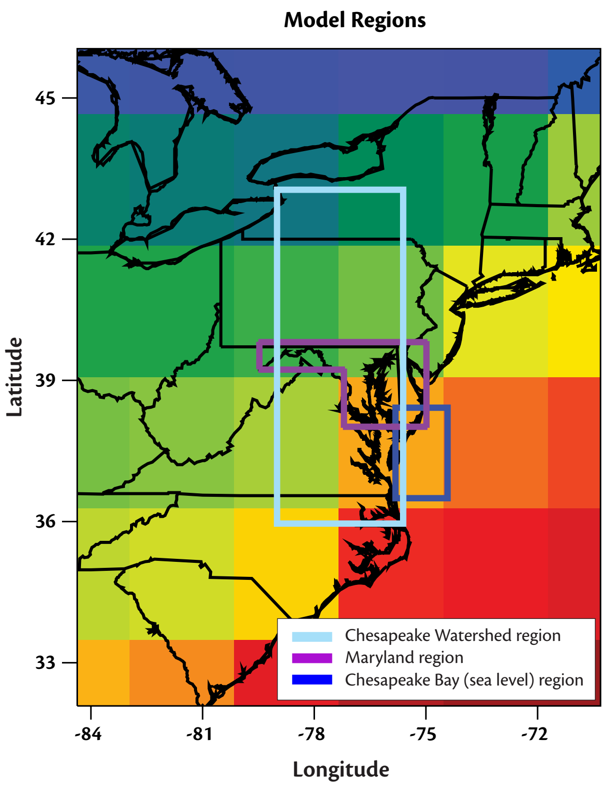


Figure 3.2. Surface air temperature for one of the climate models, showing the number of grid cells covering Maryland, and also the averaging regions employed for this assessment.

EMISSION SCENARIOS

A critical objective of this assessment was to compare future climate impacts under the situation in which greenhouse gas emissions continue to grow throughout the 21st century with the situation that might be realized if global action was taken to reduce greenhouse gas emissions. A similar approach was used in the Northeast Assessment. Two plausible global emissions scenarios were selected from among those used by the IPCC assessments. The higher emissions (A2) scenario assumes a heterogeneous world, with locally self-reliant response to climate change, regional technological and economic development, and faster growing population. The even higher emission, A1Fi, scenario used in the Northeast Assessment was not used because of the limited archived output available for this scenario. The lower emissions (B1) scenario assumes slower population growth, clean technologies are developed and implemented globally, and there is a general emphasis on global solutions to economic and environmental issues.

These scenarios can be viewed representing the 'business as usual' response to climate change versus sustained emissions reduction strategy, although the lower emissions scenario was not developed with that specific assumption in mind. However, the scenarios should not be seen as either a floor or ceiling of possible outcomes. Recent growth in carbon dioxide emissions exceed the higher emissions scenario.[12] On the other hand, the emission reduction goals being actively discussed internationally, i.e. reductions of 60-80% by 2050, would, if implemented, reduce emissions more and result in less warming than the lower emissions scenario. Although the IPCC intends to use several specific emissions mitigation scenarios in its next assessment, projections do not yet exist for such scenarios.

While carbon dioxide emissions for the two scenarios begin to diverge significantly around 2025 and decline in the low emissions scenario after 2050 (Figure 3.3), the cumulative emissions begin to diverge only after 2040. Because carbon dioxide is retained in the atmosphere for a long time, the full effects of this divergence are not fully manifest until late in the century. Thus, in the model projections,

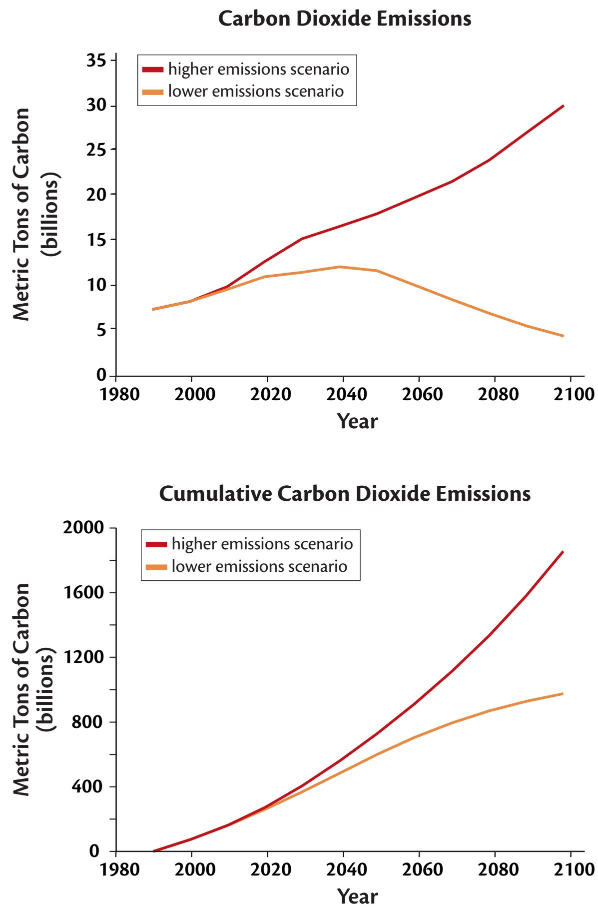


Figure 3.3. Top: Carbon dioxide annual emissions for the low and high emissions trajectories. Bottom: Total carbon dioxide emissions summed from 1990 to 2100.

Smog hangs over a Baltimore highway clogged with traffic.

there is often little difference between the higher and lower emissions scenarios until after 2050 and the differences increase thereafter.

CONFIDENCE

The spread in model predictions is one indication of how well the underlying physics and feedbacks of climate processes are represented. The hydrological cycle, for example, is less well represented than temperature in all of the climate models because coarse spatial resolution of models precludes a good representation of the physics involved in evaporating, transporting, and precipitating water. As a result, we have high confidence in temperature projections for which the physical processes represented in the model are better understood, moderate confidence in trends in temperature extremes, moderate confidence in directional changes in precipitation and other hydrological variables, and relatively low confidence in model projections of precipitation extremes at this scale.

The spread of model projections for a given parameter is used to assess the likelihood of the projected outcome. Throughout this report, the characterization of likelihood of both trends in observations and certainty of projections has followed with the IPCC assessments, except without the discrete probabilities assigned by the IPCC (Figure 3.4). Similar to the assessment of weather and climate extremes by the U.S. Climate Change Science Program[13], this approach allows the communication of the level of certainty that is consistent throughout the report.

Terms Used to Express Judgement of Likelihood

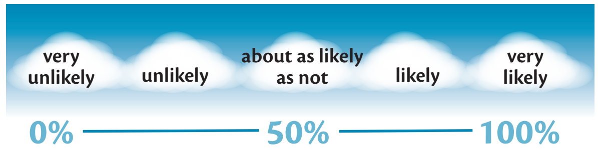


Figure 3.4. Terms used in this assessment to communicate judgment of likelihood.

ABRUPT CLIMATE CHANGE

Finally, a word of caution is offered about the use of climate model projections in planning for future climate conditions. There is greater confidence regarding some variables (such as global and regional temperature) than others (such as regional precipitation). Some variables (such as soil moisture or stream flow) result from the complex interplay of temperature, water, carbon dioxide concentrations, and living organisms, making them difficult to model with great reliability. Still others will be influenced by processes that may dramatically change and thus are inherently challenging for scientists to predict (such as the contribution of future polar ice sheet melting to sea-level rise).

Because of the way they are constructed, climate models can be used to assess gradual trends averaged over decades. They are, at this point in their development, less reliable as a signal of more abrupt climate changes. Various records of past climate changes, including deep sea sediments, ice cores, tree rings, and other natural recorders, indicate that they have often taken place within a fairly short period of time, within a century or even a decade. Scientists are actively conducting research on the causes and consequences of such abrupt climate changes, but few attempts have been made to model them under future global warming conditions. For the purpose of this assessment, it is simply important to keep in mind that the changes that will take place during this century may be more 'jerky' than continuous, with trends reversing for some years and advancing more dramatically over the period of just a decade. This places a challenge both for our observations of trends and for our ability to adapt quickly.

Section 4

RECENT & LIKELY CLIMATE CHANGES IN MARYLAND

KEY POINTS

- **Climatic regimes will continue to vary across Maryland.**
  Western Maryland has cooler winters and summers and less precipitation during the winter than the rest of the state. Changes will occur on top of these regional differences, perhaps with some greater warming during the summer to the west than on the Eastern Shore.

- **Temperature is projected to increase substantially, especially under higher emissions.**
  Average temperature is projected to increase by about 3°F by mid-century and is likely unavoidable. The amount of warming later in the century is dependent on the mitigation of greenhouse gas emissions, with summer temperatures projected to increase by as much 9°F, and heat waves extending throughout most summers.

- **Precipitation is projected to increase during the winter, but become more episodic.**
  Projections of precipitation are much less certain than for temperature, but modest increases are more likely in the winter and spring. Because of more intermittent rainfall and increased evaporation with warmer temperatures, droughts lasting several weeks are projected to be more likely during the summer.

THE CONTEXT

The state of Maryland, although comprising only 12,303 square miles, spans diverse geographic and climatic zones, from the flat Coastal Plain, westward to the Piedmont foothills, and the Appalachian Plateau. Well-defined seasons divide the cool, northwesterly wind-dominated, dormant season for plant growth from the warm summers with southwesterly winds and high humidity in the coastal regions. Spring and fall are highly variable with weather changing almost daily as warm and cool fronts push through mainly from the west. Although Maryland lies south of the main winter cyclone track, the influence of these storms can affect winter climate. Storms originating in the south or coastal regions (Nor'easters) also play a role in destructive winter weather, as they are accompanied by large amounts of rainfall and high tides. Hurricanes and tropical storms, although infrequent with only eight storms affecting Maryland since 1954, also can have a destructive influence on Maryland Coastal Plain regions in particular, primarily through flooding and storm surge.

Figure 4.1 illustrates the seasonal range of temperature across Maryland. While the higher elevations to the west remain cooler in both winter and summer, the rate of temperature increase from 1977 to 1999, is similar across the state, with an increase in the mean annual temperature of 2°F. No weather stations show a temperature decrease. This is significantly more warming than the global average.[2] The rainfall differences across the state are much smaller, with Maryland having little seasonality in rainfall; consequentially, most agriculture relies on precipitation rather than irrigation (see Section 6). Precipitation is highly variable from year to year, and no clear trend emerges from the stations in Maryland, although significant increases in precipitation have been documented to the north.

Adrian Jones

Winter wheat is sometimes planted in a mix with cool-season clovers or field peas to suppress weeds and prevent soil erosion.

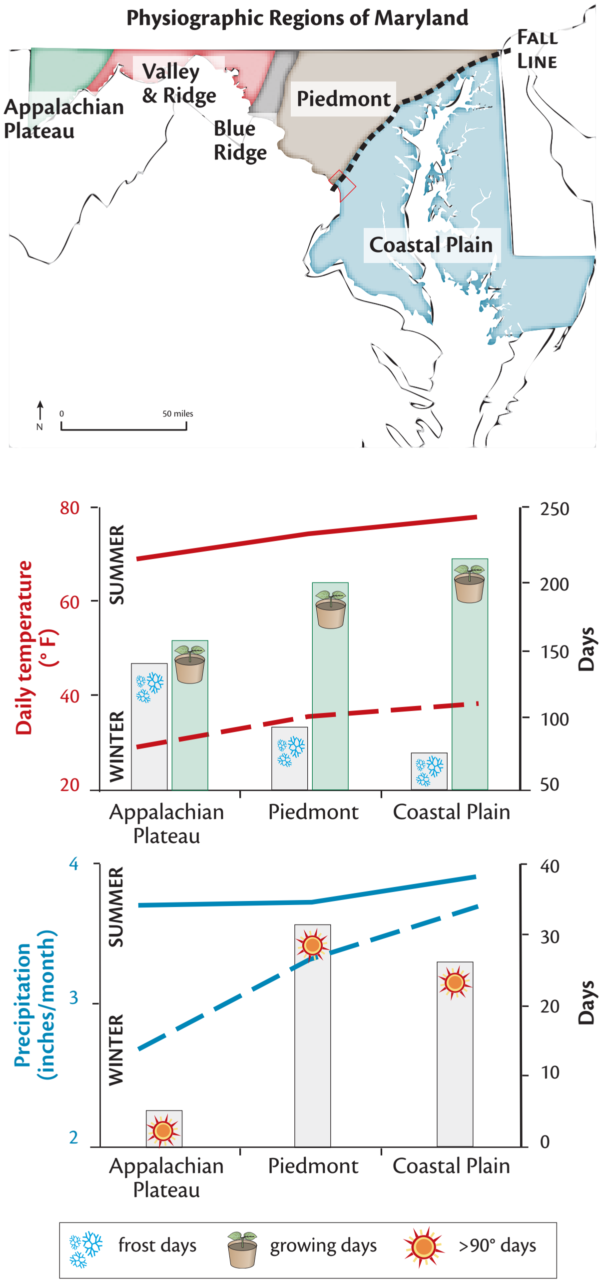


Figure 4.1. Top: The five physiogeographic regions of Maryland. Middle: Temperatures range seasonally across Maryland, with the elevated, inland regions to the west remaining cooler in both winter and summer and experiencing a shorter growing season. Bottom: The precipitation differences across the state are modest, except in winter, when it is lower on the Appalachian Plateau. The average number of days with temperatures greater than 90°F is much lower in the Appalachian Plateau.[13]

TEMPERATURE

Human-induced climate change is most directly linked to global temperature rise. However, atmospheric circulation, interactions of climate with land surfaces and oceans, and other factors drive patterns of heating and cooling that affect the projected temperature increases. On a global scale, temperature increases are generally expected to be greater in the Northern Hemisphere, particularly toward the Arctic regions.[2] Maryland, therefore, will not warm by as many degrees as the New England states.[7] Nonetheless, Maryland will experience significant warming in the coming decades and century (Figure 4.2).

The climate model mean projects an additional 2°F of warming by 2025, regardless of which emissions scenario is followed. By 2050, the policy decisions applying to which emissions path is followed begin to have an effect, and a difference in winter versus summer warming also emerges. The lower emissions scenario warms slightly less by 2050, with summertime temperature increases of nearly 3°F. Temperature under the higher emissions scenario begins to increase sharply after mid-century, with summertime seeing somewhat greater warming than winter.

By the end of the century, the difference between the higher and lower emissions scenario is marked. The low emissions path has held temperature increase to 4.8°F in summer, and 4°F in winter, while the higher emissions scenario leads to warming of nearly 9°F in summer and 7°F in winter in Maryland. One would expect these increases to be above the current mean temperatures for the three regions of the state as shown in Figure 4.1. Summertime average (over both night and day) temperatures in the Coastal Plain would increase from 77°F to 86°F by the end of the century under the higher emissions scenario. However, an ongoing national assessment has produced statistically

Under higher emissions, summers are projected to be nearly 9°F hotter by end of century

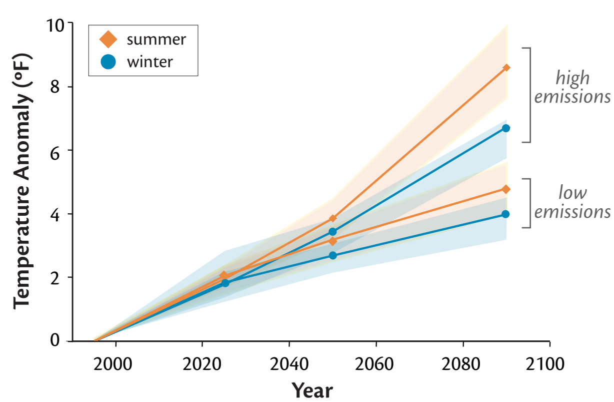


Figure 4.2. Temperature increase (°F) for Maryland from 1990 to the year 2100. The shaded regions depict the 25th-75th percentile spread between all the models.

downscaled maps based on the averages of a similar array of outputs that suggest summertime warming would be greater in Western Maryland and less on the lower Eastern Shore because of the moderating influence of the ocean (Figure 4.3)

These projections have relatively little spread between model projections for a given scenario, thus it is very likely that there will be more warming in summer than winter, and that the higher emissions scenario will result in substantially greater warming than the lower emissions scenario. Confidence in how well models represent the underlying physics of human caused warming is also high. While the likelihood of warming is high, the exact magnitude of the amount of increase is less so. However, none of the models project less than 4°F of warming in summer by 2100.

This is not to say that as the century progresses each year will be warmer than the preceding year. There will likely be months and even years that are on average cooler than the current seasonal norms. This is due to variations in the weather, not changes in climate. This assessment focuses on the average temperature over longer periods, and this continues to increase in all emission scenarios. Thus, any given warm or cold weather episode cannot be unambiguously attributed to climate; rather it is the accumulation of weather over time that gives rise to changes in climate.

HEAT WAVES

These projections for summer and winter are based on temperatures averaged over a three-month season. However, it is not the average temperature that affects our comfort or health, but rather the daily extremes. A 4°F average warming could be derived from an endless succession of slightly warm days or from average summer days interspersed with intense heat waves (operationally defined here as three or more consecutive days with temperatures exceeding 90°F). Figure 4.4 depicts increases in the number of days with maximum daily temperatures above 90°F and 100°F. In the late 20th century, there was an average of 30 days per year with maximum temperatures in excess of 90°F. Of course, this number would be higher in urban areas, and lower at higher elevation or near the ocean (see Figure 4.1). On the average, temperatures reached 100°F on only about two days per year. Recent trends suggest a moderation in the number of high maximum temperature days in the Mid-Atlantic region[14], however the monthly average maximum

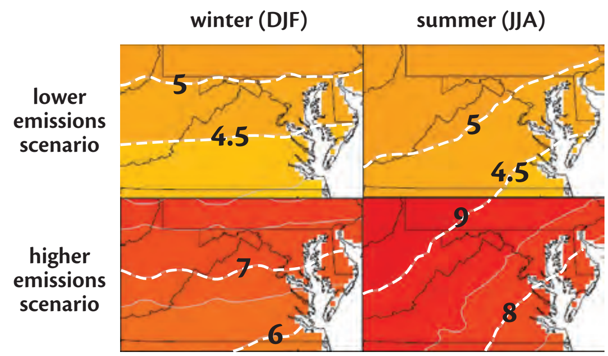


Figure 4.3. National maps of downscaled model projections of mean temperature increases for the period 2080-2099 show results very similar to this assessment. Note the east to west trend in the warming during the summer. Courtesy of Katherine Hayhoe, Texas Tech University.

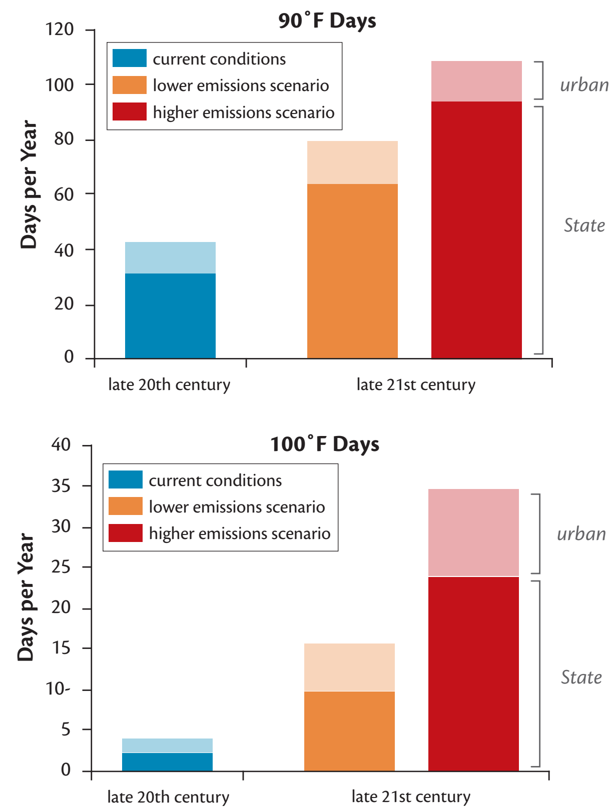


Figure 4.4. Number of days with high temperatures reaching or exceeding 90°F and 100°F in the late 20th century and projected for the late 21st century under higher and lower emission scenarios. Extension of the bars show the number days exceeding these levels in urban settings.

temperature at Maryland weather stations has been increasing faster than the average temperature, suggesting that maximum daily temperature will ultimately follow suit.

The number of days with temperatures exceeding 90°F is projected to double by the end of the century even under the low emissions scenario and triple under the higher emissions scenario in which virtually all summer days would exceed 90°F during an average summer (Figure 4.4). Under the higher emissions scenario, the number of days with temperatures in excess of 100°F is projected to increase by a factor of five, with most summer days exceeding this threshold. While at present, heat waves tend to have a limited duration with only a 13% chance per year of a heat wave lasting longer than 20 days, extended heat waves are likely to be much more frequent and longer lasting, especially under the higher emissions scenario (Figure 4.5). In the low emissions scenario, it remains most likely that any heat wave experienced will be of less than 20 days duration; however, the chance of a longer heat wave increases greatly. Under the higher emissions scenario, any given year is more likely to have a heat wave persisting for 140 days or more than it is to not have a heat wave exceeding 20 days. The predictions for increasing heat waves and temperature extremes are likely, with moderate confidence.

CHESAPEAKE BAY TEMPERATURES

Climate models currently do not resolve at the scale of estuaries, even for an estuary as large as the Chesapeake Bay (see Figure 3.2). However, observations of Chesapeake water temperatures extend back into the 1940s (Figure 4.6). These observations show a trend of increasing water temperature of 0.4°F per decade, with much of that increase over the past 30 years, consistent with increasing air temperatures. This amounts to a warming of 2.8°F over much of the Bay since 1940.

A statistical model was used to quantify the relationship between air temperature, over the preceding month, and Chesapeake Bay surface water temperature based on these observations.

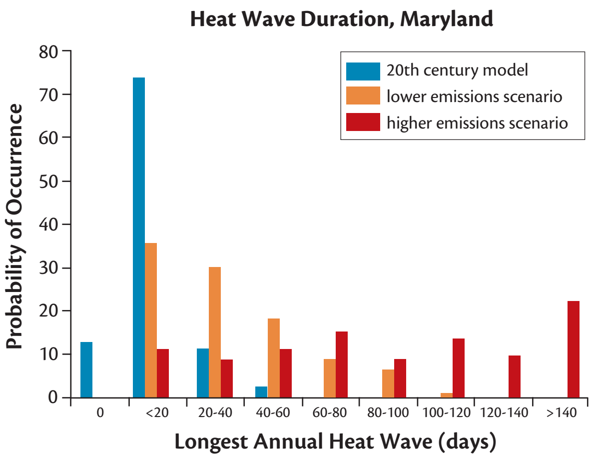


Figure 4-5. The chance that any given year will experience a heat wave of the indicated duration for present day and for the end of the century under low emissions and high emissions scenarios.

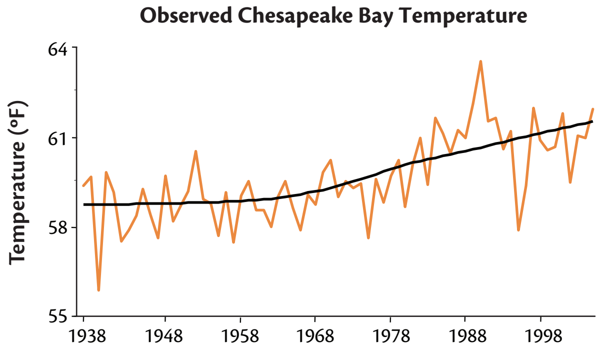


Figure 4.6: Bay temperature at Chesapeake Biological Laboratory at Solomons, MD, annual temperature, and a smoothed line illustrating the trend through 2006.

This relationship was then applied to project Bay temperatures as a function of climate-model projections of air temperature.

Temperatures in the Chesapeake Bay have already warmed by more than 2°F

Because the Chesapeake Bay is shallow in most places, surface water temperature is not only closely related to the air temperature, but also reflects temperatures in the shallows where many benthic organisms such as seagrasses, oysters, or blue crabs live. The temperature increases projected by the model average for Chesapeake Bay closely follow the air temperature increase shown in Figure 4.2, suggesting increases of 4°F by 2050 in the higher emissions scenario and 2.5°F for the low emissions path. This additional warming is of a similar magnitude to that observed in the Bay since 1940 (Figure 4.6). By 2100, the model projections suggest warming of 9°F and 5°F for the higher and lower emissions scenarios, respectively.

Another way to express how these temperature changes might affect the ecology of the future Bay, including what plants and animals might live there, is to compare these future conditions with those currently experienced elsewhere along the Atlantic coast where current conditions resemble those projected for the Bay (Figure 4.7). Summertime water temperatures are likely to be similar to those of the North Carolina sounds by 2050. Under the higher emissions scenario, summertime water temperatures in the Bay might approximate conditions in South Florida. The effects of temperature increase and other climate changes on the Chesapeake Bay ecosystem are discussed further in Section 8.

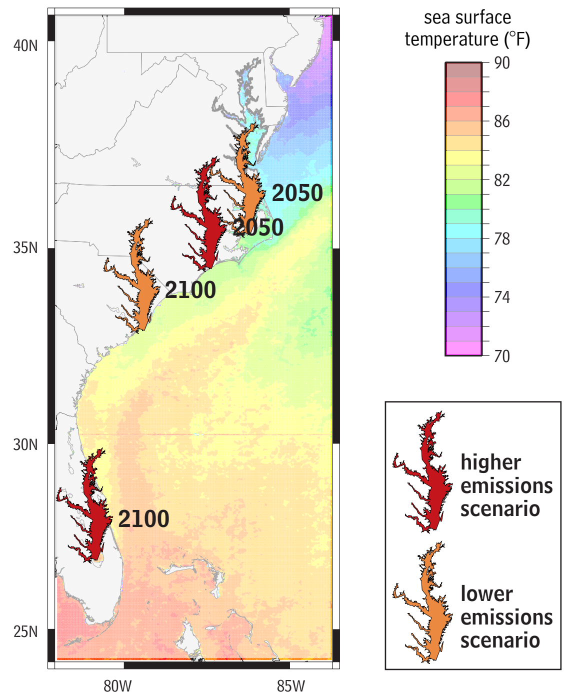


Figure 4.7. Summertime surface water temperatures in the Chesapeake Bay are projected to approximate those of estuaries well down the Atlantic Coast by 2050 and 2100.

PRECIPITATION

There has not been a statistically significant trend in precipitation in Maryland in recent years and this is consistent with the relatively modest changes projected by the climate model ensemble mean (Figure 4.8). Projections of winter rainfall show the greatest change, with increases of 5% by 2025

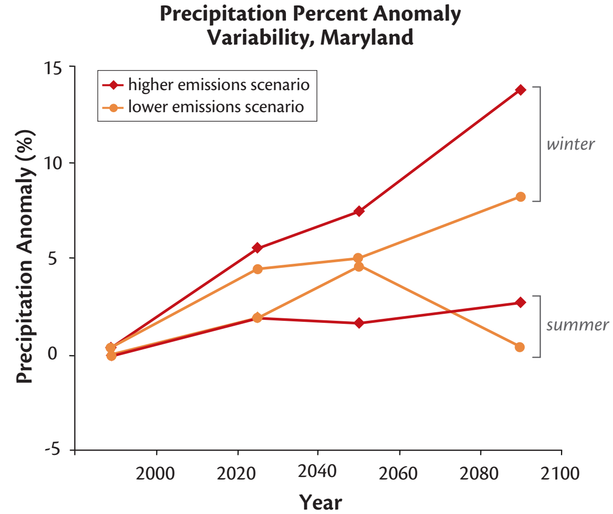
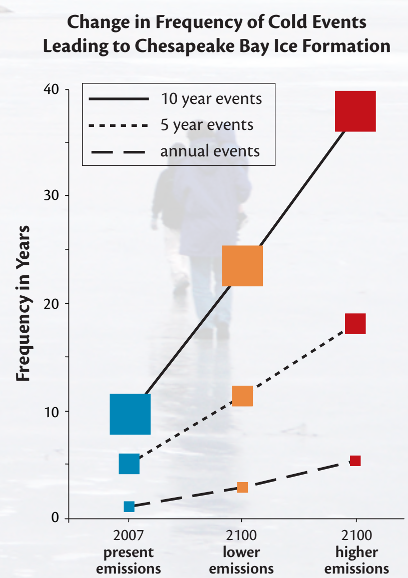


Figure 4.8. Winter and summer percent change in precipitation.

BOX 4.1 CHESAPEAKE FREEZE IS LESS FREQUENT

An ice-covered Chesapeake Bay is an iconic symbol of winter for many Maryland residents. Thin ice presently forms in sheltered embayments in most years. However, at roughly ten-year intervals, the Bay freezes over from shore to shore at the Chesapeake Bay Bridge. While these infrequent ice cover events may have little effect on the ecology of the Chesapeake Bay, they represent an obstacle to shipping, and ice cover reports are routinely issued for Chesapeake Bay by the U.S. Coast Guard. The climate model average predicts that these once every ten year ice cover events are likely to occur much less frequently in the future: every 25 years for the year 2100 low emissions scenario and as infrequently as once every 40 years under the higher emissions scenario (Box Figure 4.1). Ice cover that occurs every year at present may become less common in the future, with ice in the nearshore environment occurring only every 2-5 years by the end of the century under both the lower and higher emissions scenarios. This may have beneficial implications for nearshore oyster communities (see Section 8).



Box Figure 4.1 Time between ice cover events at the end of the century that occur every 1, 5, and 10 years at present.

Victoria Coles

projected for both scenarios, a 6.6 to 6.8% increase by 2050, and increases of 10.4 to 12.6% by 2090 under the lower and higher emissions scenarios respectively. However, there is a very wide band of uncertainty around these mean tendencies and increases of that scale do not approach the level of present year-to-year variability in winter precipitation. No season is projected to experience a substantial decrease in mean precipitation; however, some models project small declines in summer or fall precipitation and larger increases of up to 40% in winter precipitation by the end of the century. At the same time, large decreases are projected in winter snow volume (25% less in 2025 to 50% less in 2100 regardless of emission scenario). While Maryland does not receive large amounts of snowfall compared with states to the north[7], these reductions are large enough to reduce the spring river discharge associated with melting snow. Also, snow accumulation is very likely to be less common in western Maryland, thus affecting winter recreational activities.

When precipitation (P) is compared with the loss of water due to evaporation and plant transpiration (ET) that accompany increased temperatures, the water remaining (P-ET) shows little difference between the higher and lower emissions scenarios. However, the mean P-ET difference, reflecting the water available for runoff or groundwater recharge, is projected to decrease by 2 to 7 mm per month during the summer and increase by 6 to 7 mm (or only about one quarter of an inch) per month during the winter by end of the century; spring and fall projections show more modest changes.

Precipitation is likely to increase, but become more variable

Perhaps more relevant than the average rainfall, is how that rainfall is delivered. There is little change projected for the precipitation in the one-quarter of months that are driest. However, the range of precipitation from 25 to 75 percent of the time suggests a trend to increasing precipitation in the wet winter and summer months. The widening

NOAA

Summer rain drenches the landscape.

of this range in the projections illustrates that the month-to-month precipitation variability is projected to increase.

One measure of this variability is the amount of rainfall delivered in each rainy day. Climate models typically underestimate this at present, having too many days with weak precipitation.[15] However, even with this shortcoming, the mean of model ensemble projects increases in the amount of rain in any given day. The models also predict a increase in the maximum amount of rainfall occurring in any 5-day period, with the likelihood of getting more than 5 inches of rainfall in a storm event increasing from 5% at present, to 8% for the lower emissions scenario, and to 15% for the higher emissions scenario. These projections, coming as they do from models that are not able to spatially resolve many aspects of the hydrological cycle, are only moderately likely; however, they are broadly consistent with observed trends.[16] More accurate model predictions of precipitation will require development of regional climate models with finer spatial resolution.

The Northeast Climate Impacts Assessment (NECIA) report also projected increases in precipitation over the region to the immediate north of Maryland of up to 10% by the end of the century, with larger increases in winter and little change in summer. Indices of precipitation intensity, number of days with precipitation greater than two inches, and maximum five-day precipitation all showed comparable trends with the higher emission scenario used in that assessment yielding greater effects. The NECIA also found that increased evapotranspiration and frequency of short-term droughts were likely, particularly under higher emissions. This is consistent with this Maryland assessment. The NECIA projected less snow accumulation and earlier snowmelt, higher winter stream flows, and longer summer low-flow periods than at present, and these trends are also reproduced here.

SOIL MOISTURE

The effect of changes in temperature and precipitation and their implications for evaporation from water or soil and from plants are integrated in the projections of the changes in soil moisture. In spite of moderate increases in precipitation, increases in temperature in the models lead to decreases in soil moisture throughout the year. This is consistent with recent studies showing a change in the trend in North American soil moisture toward drying over the past 30 years.[17]

Changes represent 10% more drying in summer and fall by 2100 for both emissions scenarios in comparison to present normal summer conditions. Curiously, there is little difference between the lower and higher emissions scenarios, despite the much warmer temperatures projected under the higher emission scenario. This may be due to the very high relative humidity likely to occur, which will limit the rate of evapotranspiration. In years with lower than average rainfall, soil moisture reductions in spring and fall may be important to the local ecosystem and agricultural production. While soil moisture is dependent on the hydrological cycle and thus we have moderate confidence in the underlying physics, there is high agreement among models that summertime soil moisture will decrease, which makes this prediction likely.

GROWING SEASON

The length of the growing season is also important to terrestrial ecosystems in Maryland. The climate models project decreases in the number of frost days, where temperatures dip below freezing, and increases in the length of the frost-free growing season (Figure 4.9). Increases in growing season have been observed over the past fifty years.[18] While an increase in growing season may be a boon for gardeners, the increased active growth time coupled

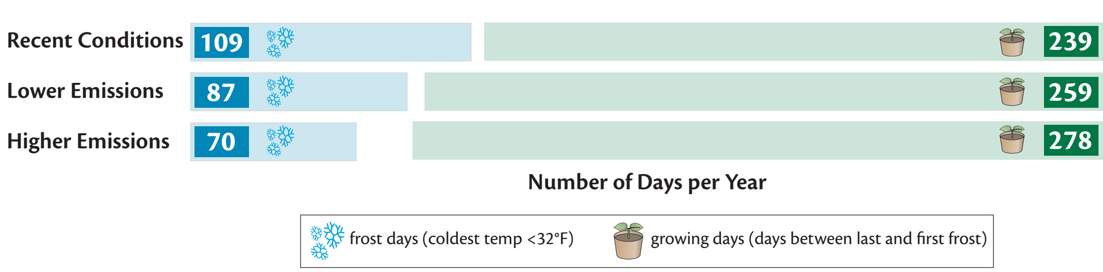


Figure 4.9. The number of frost days and growing season length projected before the end of the 21st century under the lower and higher emissions scenarios compared to recent conditions (end of the 20th century). These represent averages for the state and will vary depending on regional differences (Figure 4.1).

with reductions in soil moisture will likely cause some regions of the state to experience increased water demand for crop and landscape irrigation.

Frost days and growing season length are related to model representation of temperature, and so there is moderate confidence in our understanding of the underlying mechanisms driving changes, although the range of the model predictions leads to only moderate likelihood. Nonetheless, all the models predict reductions in frost days and increases in growing season length.

DROUGHT AND FLOODS

Global climate models do not capture present day extremes in drought or flood very well. Projections for droughts are probably more reliable than for flood conditions, because droughts reflect the influence of weather patterns that develop over large parts of the United States during periods of weeks to months. Floods, on the other hand, are associated with short-term phenomena and more intense weather events of a smaller spatial and temporal scale than resolved in global climate models. Yet, because these extreme events have such devastating effects on humans, the economy, and the environment, it is critical to estimate how the occurrence of flood events may change in the future to ensure adequate time for developing response strategies.

The models project an increase in the duration of annual dry spells, from about 15 days on average at present, to 17 days for the higher emissions scenario, and a smaller increase under the lower emissions scenario. Most of this increase is projected to occur during the latter part of the century. Based on these projections, it is likely that summer-fall droughts of modest duration will increase, especially after the middle of the century and that under the higher emissions scenario, there will be longer periods without rain. This has greater significance for soil moisture and attendant agricultural drought than for water supply. However, it is not the average that affects agricultural drought, but rather the more extreme or unusual events. The models suggest that, at present, a month-long drought can be expected to occur every 40 years, but this might increase to occurring every 8 years in 2100 under the higher emissions scenario, and there would be no appreciable change for the lower emissions path.

Even for drought conditions, it is important to point out that model projections of the two emission scenarios are based on averaging the output of different models, each of which was run for a continuous period extending from 1980 through 2100. Because each model simulation is the result of a single model run rather than multiple runs from which probabilities can be assigned, the modeling results cannot accurately predict rare events with low probability of occurrence (e.g., such as a 100-year or longer recurrence interval). Thus the projections reported here provide guidance on the likelihood of moderate drought conditions, but cannot represent the probability of an extreme multi-year drought such as the drought of the mid-1960s. Water-supply drought is more heavily affected by periods of low precipitation extending over multiple months, and is most strongly correlated with dry periods persisting through winter and spring when soil moisture, water tables, and reservoir levels would normally experience recharge.

Long-term or water-supply droughts, where rainfall deficits of more than 14 inches persist over a period of two years or more occur slightly less than 4% of the time at present in both observations and the models (Figure 4.10). While this number increases slightly to 5% under the higher emissions scenario, the models do not predict a likely increase in incidence of long-term drought. In contrast, the models suggest that two-year precipitation excesses of more than 14 inches, which are almost never observed but occur 4% of the time in the models, will occur much more frequently in the future. The higher and lower emissions scenarios have 14 inch excesses in precipitation occurring 28% and 14% of the time respectively. Thus, the models predict that while some moderate increase in short-term droughts may occur, increases in extreme precipitation events are more likely in the long-

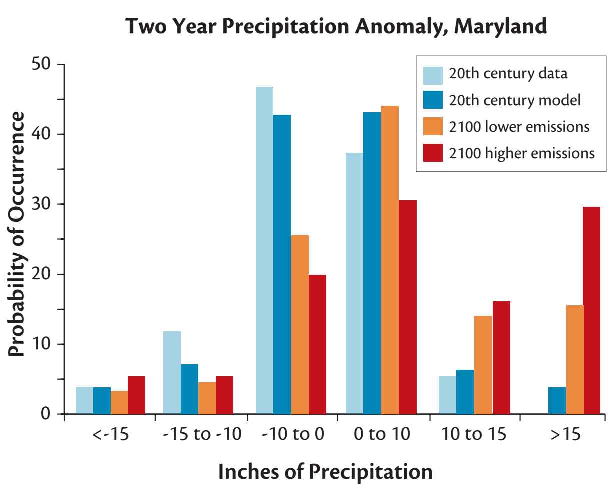


Figure 4.10. Long-term (two-year) drought and flood probability in the present day observations and models, and for the low and high emissions futures at the end of the century.

term. Further efforts to simulate extreme events at a regional scale are needed to reduce uncertainty.

Changes in precipitation extremes in the United States are already apparent in weather records. A report to be published later this year for the U.S. Climate Change Science Program (CCSP) concludes that extreme precipitation episodes (heavy downpours) have become more frequent and more intense in recent decades over most of North America and now account for a larger percentage of total precipitation.[13] Intense precipitation (the heaviest 1% of daily totals) in the continental U.S. increased by 20% over the past century while total precipitation increased by 7%. The CCSP report further concludes that the increase was consistent with increases in atmospheric water vapor, which have been associated with warming resulting from the increase in greenhouse gases, and that precipitation is likely to become less frequent and more intense. Under a medium emissions scenario, daily precipitation so heavy that it now occurs only once every 20 years is projected to occur approximately every eight years by the end of this century over much of eastern North America.

Heavy downpours have become more frequent and intense in the U.S.

For Maryland, the observed increase in frequency of extreme precipitation has to this point only been 3%, which is not a statistically significant increase. However, significant increases in intense precipitation of as much as 41% have been documented for West Virginia, Delaware, and Pennsylvania.[19] As was mentioned in Section 2, as the world warms increases in precipitation are expected to be greater at higher latitudes than lower latitudes. Maryland sits at the transition between the northeastern region where increases in precipitation are very likely in winter and spring, and the southeast region where projections of changes in precipitation cannot be confidently made.

At present, a watershed in Maryland might experience more than 8 inches of rain in a single day only once every 100 years. The climate models, however, consider 2.5 inches of rain in a single day to be a 100-year event. This is partly because the 2.5 inches of rain is spread evenly over more than 15,000 square miles in the model and because it does not provide high resolution at smaller scales (see Figure 3.2).

The percent of total rainfall coming in extreme events is projected to increase modestly but steadily during the century, with a slightly larger increase under the higher emissions scenario. However, this does not necessarily mean that less rain will fall the rest of the time. The model averages project only small changes in the number of days with more than 10 mm (about four tenths of an inch) of precipitation, with a slight increase under the lower emissions scenario and a slight decrease under the higher emissions scenario, by the end of the century. Five-day maximum precipitation is projected to increase more consistently from approximately 88 mm presently to 95-97 mm (i.e., from 3.4 to 3.8 inches), with little difference between higher and lower emissions scenarios. The maximum one-day precipitation over a year, a decade, and a century is projected to increase more, particularly under

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Finally ... some rain hits region

But flood warnings follow drought in Va.

By JANE W. GRAHAM
AFP Correspondent

BLACKSBURG, Va. — Rain finally came to Delmarva last week.

However, it brought the possibility of flooding where drought conditions have existed for months.

"We've gone from drought to flood warnings," Peter Corrigan of the National Weather Bureau in Blacksburg, Va., said on Friday morning.

"The welcome rain that finally arrived in Virginia in late October is a first step toward recovery for farmers across the state who have been experiencing significant drought conditions for months," wrote Todd P. Haymore, the commissioner of the Virginia Department of Agriculture and Consumer Services in an e-mail on Friday morning.

"However," Haymore continued, "when drought is as severe as it has been in some areas, it will take much more than a few inches of rain

Farmers got much-needed rain across most of the region last week. Here, rain filled up some low spots in a field near Easton, Md., where a few ears of corn were left behind.

Sean Clougherty

Maryland newspaper headlines failing corn crop due to lack of rain in 2007.

Frieda Squires

Heavy rain causes flooding and hazardous conditions for roadways.

the higher emissions scenario near the end of the century (Figure 4.11). The projected increases are greater for longer recurrence intervals, consistent with increasing climate volatility. But, again, it's important to remember that the global climate models have limited ability to project extreme rainfall events and tend to underestimate extreme precipitation events.

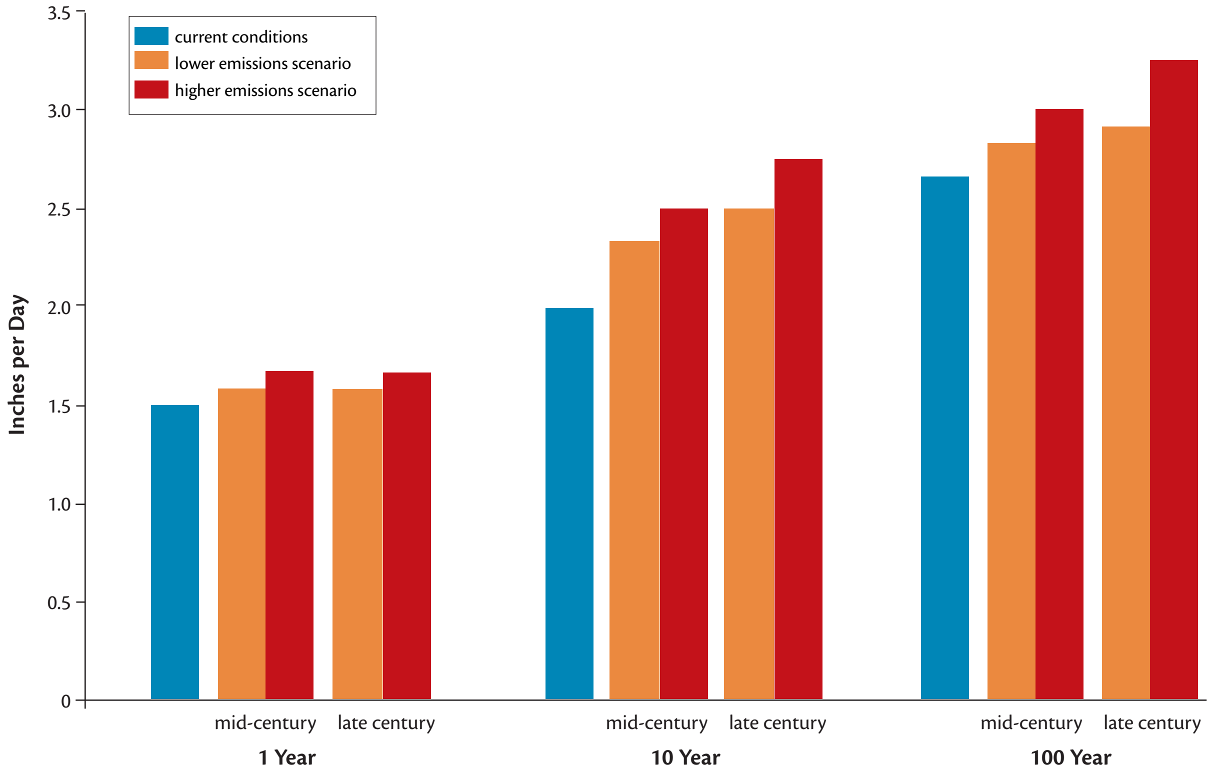


Figure 4.11. Projected one-day maximum precipitation for 1, 10, and 100 year return frequencies. Models tend to under-estimate extreme precipitation amounts, so the relative comparisons rather than the actual amounts are relevant.

Section 5

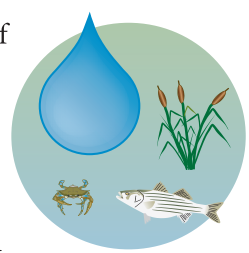
WATER RESOURCES & AQUATIC ECOSYSTEMS

KEY POINTS

- **Increased precipitation would supply reservoirs but not alleviate overdraft of aquifers.**
  Water supplies in the greater Baltimore area should not be diminished, but the adequacy of summer water supplies in the greater Washington region is less certain. Any increases in precipitation are unlikely to alleviate the present over-withdrawal of groundwater and summer droughts may increase groundwater demand for irrigation.

- **Urban flooding will likely worsen because of intensification of rainfall events.**
  More intense rainfall resulting from large-scale and localized (e.g., urban canopy) climate effects are likely to increase peak flooding in urban environments. Continued increase in impervious surfaces attendant with development would exacerbate this problem.

- **Aquatic ecosystems will likely be degraded by increased temperatures and flashy runoff.**
  Intensified rainfall events and warmer surfaces (roads, roofs, etc.) would result in rapid increases in stream temperatures, limiting habitat suitability for native fishes and other organisms. Degraded streams would transmit more nutrients and sediments to the Chesapeake Bay and its tidal tributaries.



The natural waters of Maryland provide essential habitat for aquatic life and support the fundamental needs of every economic sector of society. The water cycle and the physical and chemical character of natural waters are both strongly dependent on climate patterns and trends, including average and extreme weather conditions, such as floods and droughts, that although infrequent are very important. Although this assessment is intended primarily to address predictions associated with climate change, it is important to recognize that such changes will occur in the context of continuing population growth and economic development. Past experience strongly suggests that the combined impacts of climate change and development on water resources and aquatic ecosystems will be far greater than those of climate change alone. Therefore, reasonable predictions about Maryland's future must consider both factors.

This assessment addresses: (1) reliability of freshwater supply, including both surface water and groundwater; (2) changes in flood hazards; (3) effects of changes in runoff and water temperature on aquatic habitats and populations; (4) impacts on water quality with implications for management and regulation of sediments and nutrients; and (5) potential salt contamination of aquifers and freshwater intakes as the boundary between fresh and brackish water shifts with rising sea level. These impacts are examined with reference to climate projections based on the higher and lower emissions scenarios (see Section 3). The projections (Table 5.1) are broadly consistent with previous assessments conducted for the Mid-Atlantic region[20] and to a large extent with the Northeast Climate Impacts Assessment.[7]

Maryland Sierra Club

Burnt Mills Dam, Maryland.

Table 5.1. Summary of general projections of climate models related to water resources.

Property	21st Century Projection
Precipitation	Winter precipitation is likely to increase with smaller changes in other seasons.
Runoff	Wintertime runoff is likely to increase and summer runoff is likely to decrease, but with more frequent and larger summer floods.
Soil moisture	Soil moisture is likely to decrease during the summer and fall toward the end of the century.
Snow volume	Snow volume is very likely to decline substantially during the mid-late century.
Heavy precipitation events	Heavy precipitation events are likely to increase.
Drought	Consecutive dry days and summer-fall (but not multi-year) droughts are likely to increase under the higher emissions scenario.

FRESHWATER SUPPLY

Water stress—the imbalance between water demand and available supply—is anticipated to increase in many areas of the world over the coming decades. This is partly a result of increases in demand and partly a result of decreasing availability in some areas. Water availability must be examined not only in terms of average conditions, but also with respect to the amounts available during droughts that are expected to recur periodically. From a global perspective, the region including Maryland is considered as relatively low stress with regard to the projected ratio of water withdrawals to availability under the higher emissions (A2) scenario for 2050.[21] As the Advisory Committee on the Management and Protection of the State's Water Resources noted in 2004: "Nature provides Marylanders with abundant water, which, if well managed, could meet present and future needs." [22]

On the other hand, this same report identifies potential threats to water quantity and water quality resulting from population growth and land development. And, as recent difficulties in the southeastern U.S. demonstrate, the eastern seaboard is certainly not immune to drought.[23] Within the last six years in Maryland, we have witnessed two of the driest years on record as well as the wettest year on record, and there have been impacts on water supplies during the dry years that required public response. These short-term variations are larger than the range of variation in mean precipitation or moisture availability during this century predicted using global climate models. Sensitivity of water supply to wet and dry cycles is in large measure a function of the nature of the water-supply system, together with the array of management options that are available to be used during times of shortage.

Recent evidence suggests that summer drought may be correlated with patterns of sea-surface temperature—a consequence of multi-year cycles in the Atlantic (Atlantic Multidecadal Oscillation) or Pacific (El Niño-Southern Oscillation and the Pacific Decadal Oscillation) oceans—and that these correlations might be used in drought forecasting over time periods of one or two decades.[24] It has been suggested that superimposing these cycles on longer term trends projected by global climate models could improve forecasting of drought probabilities and provide a tool for water-supply management for the greater Washington area in adaptation for global warming.[25]

Within six years, Maryland experienced some of the driest and the wettest years on record

The Advisory Committee pointed out that total water use in Maryland has not increased even with the increase in population (Figure 5.1).[26] This reflects a complex set of changes in water used by different economic sectors, with declining industrial and commercial use and increasing domestic use, public supply, and irrigation. Demand is anticipated to rise over the next 30 years, coinciding with increased suburban land development, affecting

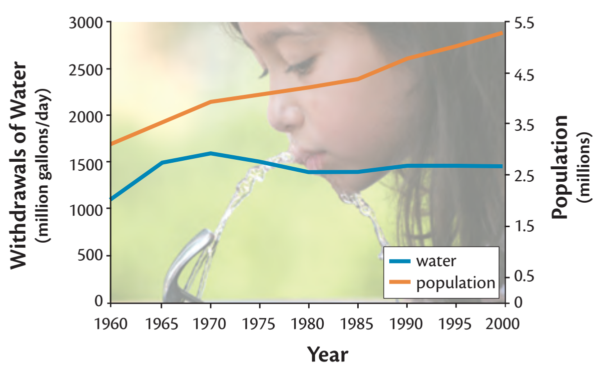


Figure 5.1. Trends in Maryland's water consumption and population.[26]

areas that might otherwise be available for recharge of groundwater, and with increased irrigation needs on agricultural land during summer droughts anticipated with the warmer climate. Summer water demand will increase as temperatures increase and water availability during the summer becomes less reliable. Options for demand reduction do exist but have not been fully explored by utilities and public agencies.

Marylanders rely both on surface water, derived from free-flowing streams and from storage in water-supply reservoirs, and on groundwater retrieved from wells in both shallow and deeper confined aquifers. The relative importance of these sources varies both as a function of urban versus rural location and physiographic province (Figure 5.2). Surface water is the primary source in and around major metropolitan areas with about 3.2 million of the state's population of 5.4 million (based on 2004 estimates; present population is at least 5.7 million) served by public water supply in the Baltimore and Washington, D.C. metropolitan areas.[26] Public and community water-supply systems elsewhere, using a mix of surface water and groundwater, served a cumulative population of 1.3 million. Groundwater is the primary source of supply in rural areas where public water is not available and in most of the Coastal Plain, with 900,000 people relying on private wells. Surface water withdrawals increased by 6% between 1985 and 2000, whereas groundwater withdrawals increased by 21%.

Groundwater withdrawals increased by 21% between 1985 and 2000

Although agriculture accounts for only 3 to 5% of state water use at the present time, agricultural needs of 285 million gallons per day (mgd) statewide are anticipated by 2030—more than currently used by the Baltimore metropolitan area. Much of this increased demand will be associated with irrigated agriculture on the Eastern Shore.[26] Furthermore, over half of the new households anticipated by 2030 will likely be located in the rapidly growing counties of Howard, Harford, Frederick, Carroll, Charles, Calvert, and St. Mary's. Many of these counties are already experiencing water stress because of rapid exploitation of local supplies, resulting in building moratoria in parts of Carroll County[27] and rapid declines in well levels in confined aquifers of southern Maryland.[28]

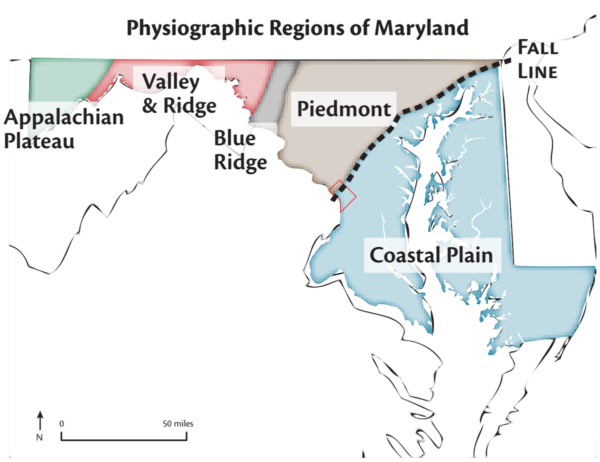


Figure 5.2. Maryland's five physiographic regions.

Surface water

The major metropolitan water-supply systems in Maryland rely on a mix of impoundments and direct withdrawal from major rivers. Baltimore City supplies water to Baltimore County as well as a portion of the public water-supply needs of Anne Arundel, Howard, Harford, and Carroll counties. The City has three major water-supply reservoirs with cumulative storage of 86.7 billion gallons, as well as a pipeline that can be used to augment the reservoir supply with water from the Susquehanna River during times of extreme drought.[29] Cumulative safe yield of the reservoirs is nearly 240 mgd and the intake on the Susquehanna River currently has a capacity of 250 mgd with ultimate capacity of 500 mgd. There are additional pumping stations on Deer Creek that can expand capacity further if necessary.

The climate change scenarios described in Section 3 suggest an increased frequency of short-term drought despite a net increase in average annual flow. Baltimore has managed to weather two severe droughts since 2000 without serious negative impacts, although it was necessary to pump water from the Susquehanna and this involved increased treatment costs. It is likely that Baltimore City's water-supply system should be sufficient to meet demands under the projected climate change. Greater winter-spring precipitation will increase the likelihood that reservoirs will be full heading into the drier summer periods, resulting in protection from water-supply shortages for areas served by the reservoirs.[30]

The Washington Metropolitan Area's water supply situation is somewhat more precarious. Average annual water use (including Maryland, D.C., and Virginia users) currently is about 488 mgd and projections call for an increase to 572 mgd by 2025.[31] About 75% of the water supply is derived from the Potomac River, the flow of which is largely unregulated. A total storage volume of about 17 billion gallons is available in reservoirs to augment the supply of the Potomac River during dry periods, and additional storage of about 18 billion gallons is available in other suburban reservoirs that do not connect directly to the Potomac supply. A Water Supply Coordination Agreement and a Low Flow Allocation Agreement among the various water suppliers are intended to coordinate the operation of all the water utilities in the region and to allocate shortfalls when water is insufficient to meet all demands.

The Interstate Commission on the Potomac River Basin (ICPRB) has estimated that the existing system is adequate to meet 2025 demand, and even 2045 demand, under a repeat of the worst historical drought conditions.[31] The ICPRB concluded that, even accounting for uncertainties associated with climate change, contingencies in place to restrict demand could be used to avert a water-supply crisis. However, Maryland's Advisory Committee on the Management and Protection of the State's Water Resources observed that planning has been complicated by the outcome of a 2003 Supreme Court case that gave Virginia the right to remove water from the Potomac River without following Maryland's permit regulations.[22] Furthermore, even if this issue can be resolved by mutual agreement, other measures, including development of additional supplies and water reuse, may be necessary to meet local needs.

Groundwater

Groundwater in the Piedmont and Appalachian Plateau regions occurs principally in fractured bedrock and the overlying layer of weathered material that can be as much as 100 feet thick (Figure 5.3).[32] The volume of storage available in these shallow aquifers is typically quite limited and there are strong connections between groundwater and local surface water, such that a reduction in groundwater storage is likely to be reflected in reduced base flow to local streams. Because of the complex flowpaths and connectivity of the fracture network, the spatial pattern of groundwater availability is unpredictable and is therefore unsuitable for large-scale water-supply development. Groundwater availability is sensitive to short-term climate fluctuations and to alteration of the land surface by development. These factors, plus the growing demand, led to the building moratoria near Westminster in Carroll County that were mentioned previously.[27]

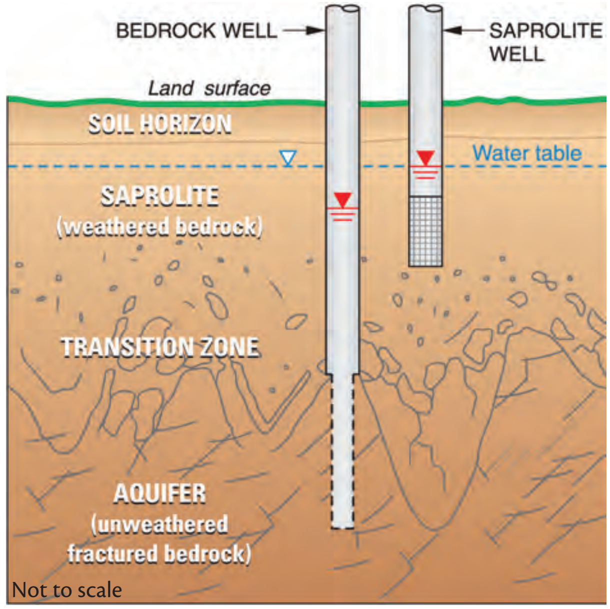


Figure 5.3. In the Piedmont, shallow wells draw from unconfined weathered bedrock and deep wells from bedrock aquifers.[32]

Although climate models generally project changes in water availability under average conditions, the likelihood of more frequent short-term drought poses a challenge to the reliability of water supply dependent on shallow groundwater during the late summer and fall in rural areas. Even with significant increases in winter and spring precipitation, it is not clear how much of the increase will contribute to recharge of groundwater in the Piedmont and Appalachian provinces if significant amounts are instead diverted to increased runoff.

The situation in the Coastal Plain of Maryland is quite different. Most groundwater is stored in deep, confined aquifers (Figure 5.4) that are not in direct contact with the surface or with overlying streams. Because the water that recharges these

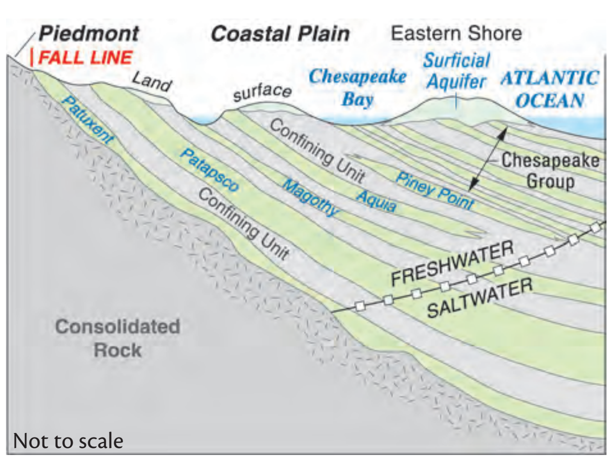


Figure 5.4. Schematic cross-section of the Coastal Plain aquifer system.[33]

aquifers may travel over long distances, these aquifers are not sensitive to short-term weather fluctuations. They are more likely to experience changes in storage and in well levels that are tied to long-term trends in the balance between recharge and water withdrawal. Thus, climate change projections in which precipitation increases more than evapotranspiration are less likely to pose a serious problem for aquifer storage, even if there are short-term droughts superimposed on the long-term trends.

A serious challenge does arise, however, as a result of pumping trends associated with rapid urban and suburban development in the Coastal Plain counties. Long-term trends showing declining well levels have accelerated sharply since the 1980s (Figure 5.5).[33] In many cases, the rate of decline exceeds 2 ft/yr and in the areas of most active pumping it can be substantially higher.[32] The Maryland Department of Environment uses an 80% rule to regulate groundwater extraction from confined aquifers—pumping is not supposed to lower well levels more than 80% of the distance between the pre-pumping water level and the top of the confined aquifer. At present, however, farmers are not required to report the amount of water pumped for irrigation and there are no significant ongoing monitoring studies to document head losses associated with irrigation. While the declines in well levels currently observed are mainly a result of urban and suburban uses, this lack of reporting and monitoring could pose a problem if demand for crop irrigation substantially increased.

Well levels have declined as much as 2' per year in Maryland's Coastal Plain

If the regional declines in confined aquifers continues or accelerates, regional land subsidence over the affected areas may exacerbate local relative sea-level rise as discussed in Section 7. Changes in freshwater storage and in relative sea level may also cause the freshwater/saltwater boundary illustrated in Figure 5.4 to move landward and to reach shallower depths. This may pose a particular problem for withdrawals from shallow aquifers on the Eastern Shore.

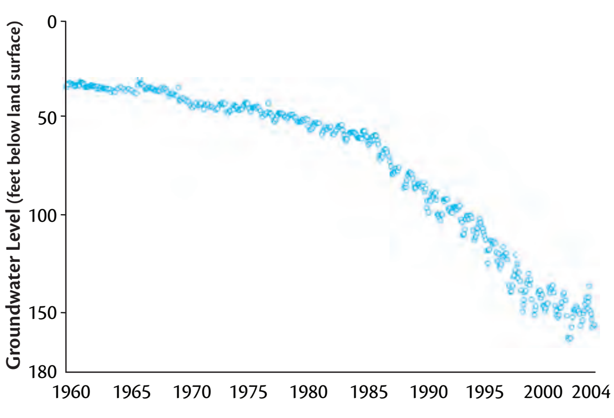


Figure 5.5. Water level decline in a well in the Aquia aquifer in Calvert County, Maryland.[33]

FLOOD HAZARDS

Because floods represent the extreme end of the frequency distribution of streamflows, prediction of flood probabilities is subject to uncertainty even under the best of circumstances. Estimation of the probability or return period of a flood of a given size typically is accomplished using historical records, and standard estimation techniques assume that flood occurrence is essentially a random process and that the underlying probabilities are not changing over time. Therefore, climate change presents a challenge to standard approaches in flood-frequency estimation because the future will no longer resemble the past.

Trends toward increased river runoff are already apparent beginning about 1970 in portions of the eastern United States, including the Mid-Atlantic region.[34] Annual runoff has further been projected to increase in the eastern United States by the middle of this century[35], consistent with increases in atmospheric water vapor and precipitation intensity.[36] The probability of occurrence of a great flood (defined as having a 100-yr return period) in a number of large river basins had increased substantially during the 20th century[37], prompting a group of leading hydrologists to write recently that climate change has undermined a basic assumption about the relevance of past observations for management of future water supplies, demands, and risks.[38] The authors suggest that new modeling approaches are needed to improve our ability to estimate flood hazards under alternative future scenarios. Although intense rainfall is the most important contributor to flood hazards, there are other aspects of land-surface conditions that determine how efficiently intense rainfall is converted into flood flow. These cannot be predicted on a statewide basis for all watersheds with information that is currently available; therefore, this report focuses on the probability of intense precipitation as the primary indicator of flood probability.

Susquehanna River Basin Flood Forecasting and Warning System

The Susquehanna River Basin is one of the most flood-prone watersheds in the nation. The main stem and its tributaries drain 27,510 square miles of New York, Pennsylvania, and Maryland.

As discussed earlier, probabilities of flood inducing rainfall are not well represented in global climate models that predict average conditions over large grid cells. A possible exception would be large-scale events such as powerful extratropical storms occurring in winter, particularly where rain on snow is a key element. These may generate large floods over very large drainage areas comparable to the model grid cells. Such events occur infrequently in Maryland, but can be important in the Susquehanna River Basin, which lies mostly in Pennsylvania and New York and supplies about one-half of the freshwater inflow to the Chesapeake Bay. The January 1996 flood in the Susquehanna River basin is an example of such an event. The magnitude of the flood was in part a result of the large volume of moisture already stored on the landscape in the form of snow, which was released very rapidly as it melted during the precipitation event. Although climate models project higher precipitation totals and greater intensity of rainfall during the winter season, the reduction in volume of snow stored on the landscape may well cause a reduction in the likelihood of this type of extreme flood even as moderate floods become more likely in winter and early spring.

Another major cause of flood hazards in the region is the occurrence of hurricanes and tropical cyclones. The flood of record for many locations in Maryland (including the Susquehanna River at Conowingo Dam) is still Hurricane Agnes, which struck the region in June 1972.[39] By the time it reached Maryland, Agnes was not a major cause of storm surge, wind damage or coastal flooding; its primary impact was as a rainfall-runoff event. Hurricane Floyd, in September 1999, dropped as much as 12.6 inches of rain on Maryland's Eastern Shore and generated floods in some Eastern Shore rivers with estimated return periods of 100-500 years.[40] As discussed in greater depth in Section 7, the current scientific consensus is that tropical cyclones are projected to increase in rainfall intensity even though their frequency may decline.

Precipitation intensities in small watersheds are underestimated in climate models

For small watersheds, the likelihood of flooding depends not only on total amount of precipitation but also on its intensity at smaller spatial and temporal scales. While climate models may be useful for projecting maximum one-day precipitation averaged over a large area (Figure 5.2), they cannot predict the actual rainfall over short periods or areas at a scale comparable to a storm cell. Point and small-area rainfall intensities associated with flood generation will be much higher. This is illustrated by comparing the predicted probabilities of intense precipitation from the model projections with precipitation frequencies based on regional observations for points within the Baltimore-Washington metropolitan area (Table 5.2).[41] Observed rainfall amounts associated with recurrence intervals of 1 to 100 years are already 170 to 300 percent greater than the one-day rainfall amounts projected from the climate models near the end of this century.

If flood magnitudes change in a manner commensurate with the trends in maximum rainfall predictions (Figure 4.11), then one might indeed

Table 5.2. Maximum rainfall amounts for four recurrence intervals based on observations in the Baltimore-Washington area, as summarized in NOAA Atlas 14 and projected for 2090 under higher and lower emissions scenarios.

Recurrence Interval (yr)	Observed[41]	One-day Rainfall Amounts (inches) Higher Emissions	Lower Emissions
1	2.6	1.7	1.6
5	4.1	2.4	2.0
10	4.9	2.6	2.3
100	8.5	3.2	2.7

expect to see larger, more extreme floods in smaller watersheds as the century proceeds. The magnitude of such an increase is necessarily speculative; the point values of extreme rainfall under the present climate are already so much higher than those predicted by these GCM scenarios that only the general trends are relevant, and they are not based on simulation of the actual physical processes associated with extreme precipitation. Nevertheless, if one accepts the comparisons in maximum one-day rainfall as representative of likely changes in flood magnitude, then we might anticipate a 20% increase in the magnitude of the 100-year flood under the higher emissions scenario and a 10% increase under the lower emissions scenario. Comparable increases for the 10-year recurrence interval would be approximately 29% and 16%, respectively, with the increase in peak flood flows under higher emissions approximately double the increase under lower emissions.

These increases are consistent with the trends identified by the IPCC Fourth Assessment, the Northeast Climate Impacts Assessment, and the U.S. Climate Change Science Program concerning the increased likelihood of intense, flood-generating precipitation. However, it is important to remember that land development has had and will continue to have a major effect on increasing flood probabilities in smaller drainage areas. As the area of impervious surface and storm drain networks increase, runoff is accelerated.[42] Also, as was demonstrated with a 2004 event in Baltimore, the urban 'canopy' effect can play an important role in determining the conditions favoring intense thunderstorms.[43] Because of both these effects—surface properties affecting runoff response and atmospheric interactions affecting rainfall intensity—flood peak magnitudes in small urban watersheds may be several times larger than for comparable rural watersheds. This can be illustrated by plotting flood peak discharge as a function of drainage area for thunderstorms in Baltimore compared to some record floods in the Mid-Atlantic region (Figure 5.6). The straight lines are thresholds defining the upper range of extreme flood peaks that may attain values between 1000 and 2000 cfs/mi². The urban floods were, with one exception, events with recurrence intervals of the order of 5 to 10 years; yet these events, represented by blue dots on the plot, were comparable in magnitude to Mid-Atlantic floods that occur much less frequently.

Land development and urban microclimates intensify floods

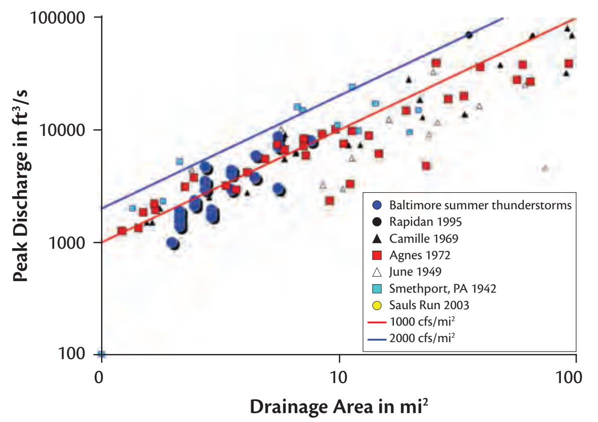


Figure 5.6. Relationship between peak discharges and watershed drainage area for urban floods in Baltimore and historic floods in the Mid-Atlantic region.

The increased frequency and magnitude of floods in urban watersheds has implications not only for flood protection and water allocation, but also for the design of treatment plants, dams, and even bridges. Prediction of future estimates will require the development of new modeling approaches that can incorporate the effects of changing climate superimposed on trends in urban development. Using such an approach, a recent study projected that the number of days with extreme rainfall in the New York metropolitan area is likely to increase from 1-2 days to 3-4 days by the end of the summer under the higher emissions (A2) scenario.[44] Building on efforts like this one, smaller scale atmospheric models linked with global climate models could more accurately project precipitation and those predictions could be used to drive hydrologic models to predict flood probabilities associated with combined climate change and urbanization scenarios.

WATER QUALITY & AQUATIC BIOTA

Freshwater ecosystems provide multiple goods and services (Table 5.3) valued highly by people and inextricably linked to water flows and the interaction of flow with the landscape. The ability of aquatic ecosystems to provide these benefits depends on how 'healthy' they are—that is, the degree to which physical and biological processes that maintain normal ecological functioning are working properly. Climate changes may modify these critical processes and thus diminish the health of the ecosystem.

Of particular concern are climate-induced changes that exacerbate human-caused stresses,

Table 5.3. Freshwater ecosystems (wetlands, rivers, streams, lakes, etc.) provide a number of goods and services that are critical to their health and provide benefits to society. The major services are outlined along with the ecological processes that support the function, how it is measured, and why it is important.[45]

Ecosystem Service	Consequences of Losing the Service	Supporting Ecological Process	Ecosystem/ Habitat
Water Purification a) nutrient processing	Excess nutrients (eutrophication) can build up in the water making it unsuitable for drinking or supporting life; Algal blooms resulting from excess nutrients can lead to anoxic conditions and death of biota	Retention, storage, and transformation of excess nitrogen and phosphorus; Decomposition of organic matter	Floodplain, river and streambeds, wetlands, lake littoral zones
b) processing of contaminants	Toxic contaminants kill biota; Excess sediments smother invertebrates, foul the gills of fish, etc; Water not potable	Biological removal by plants and microbes of materials such as excess sediments, heavy metals, contaminants, etc.	Floodplain and wetland soils and plants; Bottom sediments of rivers, lakes, and wetlands
Water Supply	Loss of clean water supply for residential, commercial, and urban use; Irrigation supply for agriculture	Transport of clean water throughout watersheds	Lakes, rivers, streams
Flood Control	Without the benefits of floodplains, healthy stream corridors, and watershed vegetation, increased flood frequency and flood magnitude	Slowing of water flow from land to freshwater body so flood frequency and magnitude reduced; Intact floodplains and stream-side vegetation buffer increases in discharge	Floodplains, wetlands, stream-side zones
Infiltration	Lost groundwater storage for private and public use; Vegetation and soil biota suffer; Increased flooding in streams	Intact floodplain, stream-side, wetland vegetation increase infiltration of rain water and increase aquifer recharge	Wetlands, streams, floodplains
Carbon Sequestration a) primary production	Water and atmospheric levels of CO_2 build up, contributing to global warming	Aquatic plants and algae remove CO_2 from the water and atmosphere, convert this into biomass thereby storing carbon	Freshwater ecosystems with sunlight, but particularly shallow water habitats such as wetlands or mid-order streams
b) secondary production	Water and atmospheric levels of CO_2 would build up contributing to global warming	Production of biomass by microbes and metazoans stores carbon until their death	All freshwater ecosystems but particularly the bottom sediments for microbes
Nitrogen Sequestration primary and secondary production	Secondary production supports fish and wildlife	Creation of plant or animal tissue over time	All freshwater ecosystems and habitats
Food Production a) primary production	Reduction in food and food products derived from aquatic plants such as algae, rice, watercress, etc.; Decreased production (secondary) by those consumers who rely on primary production as a food source	Production of new plant tissue	All freshwater ecosystems and habitats with sunlight but particularly shallow water habitats such as wetlands

Table 5.3. Continued.

Ecosystem Service	Consequences of Losing the Service	Supporting Ecological Process	Ecosystem/ Habitat
Food Production b) secondary production	Reduction in fisheries including finfish, crustaceans, shellfish, and other invertebrates	Production of new animal tissue or microbial biomass	All freshwater ecosystems and habitats, but particularly the water column and surficial sediments
Biodiversity	Loss of aesthetic features, impacts aquarium trade, potential destabilization of food web, loss of keystone species can impact water quality	Diverse freshwater habitats, watersheds in native vegetation, complex ecological communities support multiple trophic levels	All ecosystem and habitat types, but particularly wetlands for plants and rivers for fish
Temperature Regulation	If infiltration or shading are reduced (due to clearing of vegetation along stream), stream water heats up beyond what biota are capable of tolerating	Water temperature is 'buffered' if there is sufficient soil infiltration in the watershed; Shading vegetation keeps the water cool; Water has a high heat capacity which stores excess heat	Shallow water habitats, especially wetlands
Erosion/Sediment Control	Aquatic habitat burial impacts fisheries, decreases biodiversity, increases in contaminant transport, reduces downstream lake or reservoir storage volume	Intact stream-side vegetation and minimization of overland flow	Wetlands, streams, and rivers
Recreation/ Tourism/Cultural, Religious, or Inspirational Values	Lost opportunities for people to relax, spend time with family; Economic losses to various industries, particularly tourist oriented ones	Clean water, particularly water bodies with pleasant natural surroundings such as forests, natural wildlife refuges, or natural wonders	Lakes, rivers, and streams

Victoria Coles

A beautiful day is enjoyed on a family hike in western Maryland.

such as depletion of water flows and urbanization, both of which are already affecting streams and rivers over much of the State. As is the case with flood probabilities, the influence of urban development signal is likely to be at least as strong through the remainder of this century as the climate signal, and these two signals combined will tend to reinforce trends pointing in the same direction, i.e., more highly variable flows. Global warming will also directly change the temperature regimes, causing shifts in the species inhabiting the ecosystems.

Anticipating the future condition of a river in the face of climate change requires explicit consideration not only of the current climatic, hydrologic, and ecological conditions but also of how it is currently managed and how human behavior will affect the ecosystems. Thus, consideration of how climate change is likely to impact Maryland's freshwater ecosystems rests not only on the assumptions underlying climate models and scenarios, but also on future decisions regarding water use and watershed management. Options also exist for adapting these practices to reduce the impacts of climate change on freshwater ecosystems.[46]

Except for deep reservoirs, fresh waters are generally well mixed and respond to changes in atmospheric conditions fairly readily. Thus, they would become warmer as air temperatures increase.[47] As the water warms, individual growth and reproductive rates of biota are expected to increase so long as thermal tolerances are not exceeded.[48] Faster growth rates and time to maturation typically result in smaller adult size, and, because size is closely related to reproductive output in many aquatic organisms, population sizes may decline over time. The spawning time of native fish may also shift earlier if waters begin to warm earlier in the spring, and species that require prolonged periods of low temperatures may not survive.

For fish, amphibians, and water-dispersed plants, habitat fragmentation due to small dams (which are surprisingly common in Maryland's streams) or the isolation of wetlands and tributaries due to drought conditions may also result in elimination of their local populations. Because higher temperatures result in lower concentrations of dissolved oxygen in all but swift flowing waters, this may present an additional stress on organisms.[49]

Aquatic ecosystems in watersheds with significant urban development are expected to experience not only the greatest changes in temperature, but also greater temperature spikes during and immediately following rain storms that could result in the local loss of species. Such temperature spikes of 6 to 12°F occur in urban streams near Washington, D.C., and are strongly related to the amount of warm impervious surfaces (Figure 5.7).[50]A recent modeling study demonstrated how the combined effects of urbanization and climate change on suburban Washington streams would be greater than either alone. Under a moderate emissions (B2) scenario, warming produced an increase in stream temperatures of 6°F late in the century, while urbanization produced an increase of 7°F (Figure 5.8). However, when both urbanization and climate change were imposed, an increase of over 12°F resulted. The urbanization effects alone would stress 8 of the 39 fish species, but with additional effects of climate change as many as 29 species would be stressed. Almost every recreationally important species (trout, bass, yellow perch, and bluegill) would experience decline in the growth and reproduction ranging from 40% to 90%.

Changes in flow regime toward greater frequency

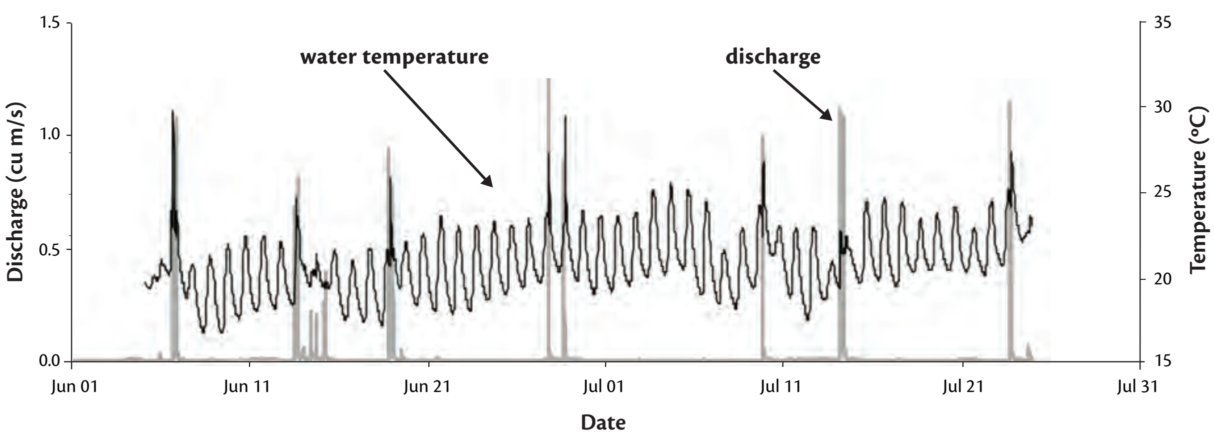


Figure 5.7. Temperature record for an urban stream north of Washington, D.C. Grey spikes represent episodes of warm runoff immediately following rain. Spikes such as these are largely dampened in watersheds with low levels of impervious cover.[50]

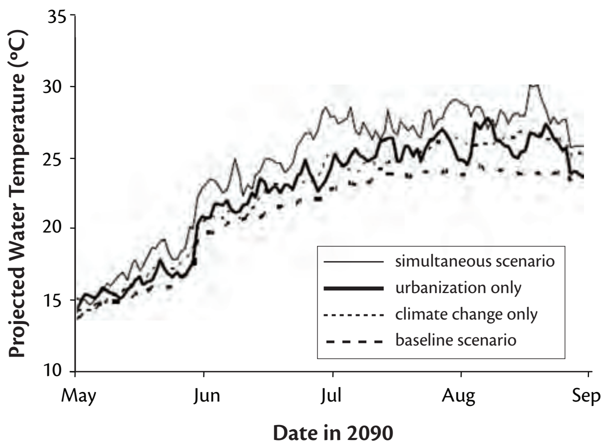


Figure 5.8. Model projections of water temperatures in a central Maryland stream under a moderate emissions (B2) scenario, the influence of urbanization and both simultaneously.[49]

of both wetter and drier conditions are projected under both the higher and lower emissions scenarios. While these changes are anticipated to be incremental, similar but much stronger effects are observed in urbanizing environments. Storm runoff occurs more rapidly and generates higher velocities and larger flood peaks, with serious consequences for the aquatic biota.[51] Higher peak flows associated with urbanization result in well-documented decreases in native biodiversity.[52] Higher flows increase suspended sediment and bedload transport, which interferes with animal feeding, while subsequent sediment deposition reduces the habitat availability for insects and spawning areas for fish.[53] Where flows increase sufficiently to prevent sediment deposition, eroded sediment will ultimately be deposited downstream or in the estuaries fed by the rivers and streams. The higher flows and increased inputs of sediment typically degrade stream habitat quality even when there is no net sediment deposition.

Higher runoff peaks degrade stream beds and transport more pollutants to the Bay

Increased flashiness and higher runoff peaks are likely to mobilize chemicals associated with sediment particles. Changes in the transport and processing of nutrients and organic matter are likely, but difficult to predict under changing climatic conditions. There is a considerable uncertainty about how rates of ecological processes affecting nutrients in wetlands and streams—an important factor in affecting the amount of nutrients reaching the already over-enriched Chesapeake Bay—will be influenced by climate change. Dissolved inorganic nitrogen (as nitrate) levels may decrease if rates of denitrification are increased by higher temperatures and associated lower dissolved oxygen levels. On the other hand, if discharge and sediment transport increase, then the downstream movement of nitrogen (as ammonium or organic nitrogen) and phosphorus (as phosphate) may increase. Concentrations of toxic contaminants in the form of petroleum hydrocarbons and combustion byproducts, metals, pesticides, and other organic compounds are typically much greater in urban settings and are related in part to the density of roads and efficiency of storm sewers in conveying materials from impervious surfaces directly into the drainage network.[54] Additional sources of trace contaminants may be derived from leaking sanitary sewers and include oxygen-demanding organic matter, pathogens, and a whole class of emerging contaminants including pharmaceutical compounds and trace constituents from personal care products.[55]

Drier conditions during summer months are likely to result in the loss of small wetlands and intermittent or ephemeral streams, potentially resulting in negative impacts on the water quality downstream. This impact will be particularly exacerbated in urbanized regions. With increased impervious area and less infiltration, there is less groundwater storage and lower baseflows in urban streams than in more natural streams. However, baseflow during dry periods could also be augmented by some combination of leaking infrastructure and lawn irrigation. A tendency toward reduced infiltration and baseflow would tend to exacerbate the lower summer stream flows projected by the climate models, while any baseflow augmentation would reduce the impacts of summer dry periods. Wetlands and streams experiencing reductions in water levels or baseflow often have stressed biota and stream-side vegetation, reduced dissolved oxygen levels, and loss of habitat for species that depend on currents.[56] Physiological stress and increased predation resulting from crowding, combined with habitat fragmentation (isolated stream pools and wetlands), may dramatically reduce survival and constrain dispersal.

Jane Hawkey

Herbicides are applied to a farm field.

Adrian Jones

Crop production is likely to be reduced under the higher emissions scenario.

Section 6

FARMS & FORESTS

KEY POINTS

- **Crop production may increase initially, but then decline if emissions are not reduced.**
  Longer growing season and higher CO_2 levels are likely to increase crop production modestly during the first half of the century. Later in the century, crop production is likely to be reduced due to heat stress and summer drought under the higher emissions scenario. Milk and poultry production would be also reduced by heat stress.

- **Northern hardwoods will likely disappear and pines become more abundant.**
  The maple-beech-birch forest of Western Maryland is likely to fade away and pine trees to become more dominant in Maryland forests. Forest productivity is likely to decline late in the century under the higher emissions scenario as a result of heat stress, drought, and climate-related disturbances.

- **Biodiversity of plants and animals associated with Maryland forests is likely to decline.**
  Habitat alterations resulting from climate change may force out 34 or more bird species, including the Baltimore oriole.

Maryland's landscapes, from the high mountains of the Appalachian Plateau to the barrier islands of the Eastern Shore, provide diversity and enjoyment to its people and visitors as well economic wealth from the productivity of its farms and forests. This section addresses the potential impacts of climate change on the land, including the living resources that are exploited economically and other natural resources that provide indirect services to us, not the least of which provide recreation and aesthetic satisfaction.

Prediction of the future of Maryland's natural resources is subject not only in the projections of climate model, but also because of the complexity of the responses of both living organisms and human decisions when faced with changing climate. The response of one species can affect others, for example warmer winters could allow some insect pests to survive in greater numbers, possibly increasing forest defoliation—and consequently, a loss of birds and other animal species—and runoff of materials from the watershed. Furthermore, the changes in vegetation may affect the regional climate itself, for example, through changes in the evapotranspiration, albedo (how an object reflects sunlight), and surface roughness of vegetation. Moreover, organisms influence the concentrations of greenhouse gases in the atmosphere by taking up or releasing carbon dioxide, methane, and nitrous oxide. Partially as a result of this complexity, knowledge of the impacts of climate change on terrestrial resources is less developed and predictions more difficult than for other sectors of the climate impact assessment for Maryland.

Climate change is not new for Maryland's terrestrial ecosystems. During the warming after the last Ice Age, very large changes in the biota occurred, but this was a slow warming that allowed migration and adaptation of plants and animals, unlike the rate of climate change projected over the 21st century. As discussed previously, the mean temperature of the Earth's atmosphere has been relatively stable until warming commenced about 50 years ago. After some basic considerations related to terrestrial ecosystems, in general, this section evaluates the likely impacts of projected climate change on Maryland's agriculture and forests.

SOME BASIC CONSIDERATIONS

Before getting to the specifics of the assessment of climate change impacts on Maryland's terrestrial ecosystems, it is useful to consider the complexity of likely responses to climate change, the other human activities that influence these responses, the means of observing changes, and the particular geographic conditions that may influence outcomes.

Responses are complex

Shifts in distribution of terrestrial vegetation of hundreds of miles in eastern North America occurred in association with the 3.6°F increase in global average temperature following the last Ice Age.[57] For example, one tree species, Jack Pine, moved about 800 miles north from the southern U.S. to Canada, passing through Maryland at an average of a quarter of a mile per year.[58] Numerous studies documenting more recent geographical shifts of the distribution of species toward the poles (in Maryland northwards) and toward higher elevation due to climate warming were summarized in the IPCC Fourth Assessment[5] and a recent CCSP synthesis report.[59] A small state such as Maryland can expect a greater proportion of its species to be lost to the north and gained from the south than in a larger state. These changes could be beneficial or deleterious. Not all species can adjust successfully. Biomes (broad geographic zones having distinct climates and species) that shift in a quickly warming world are likely to lose a portion of their species complement.[59] This loss could also disrupt important ecosystem functions if one or more ecologically important species is lost.

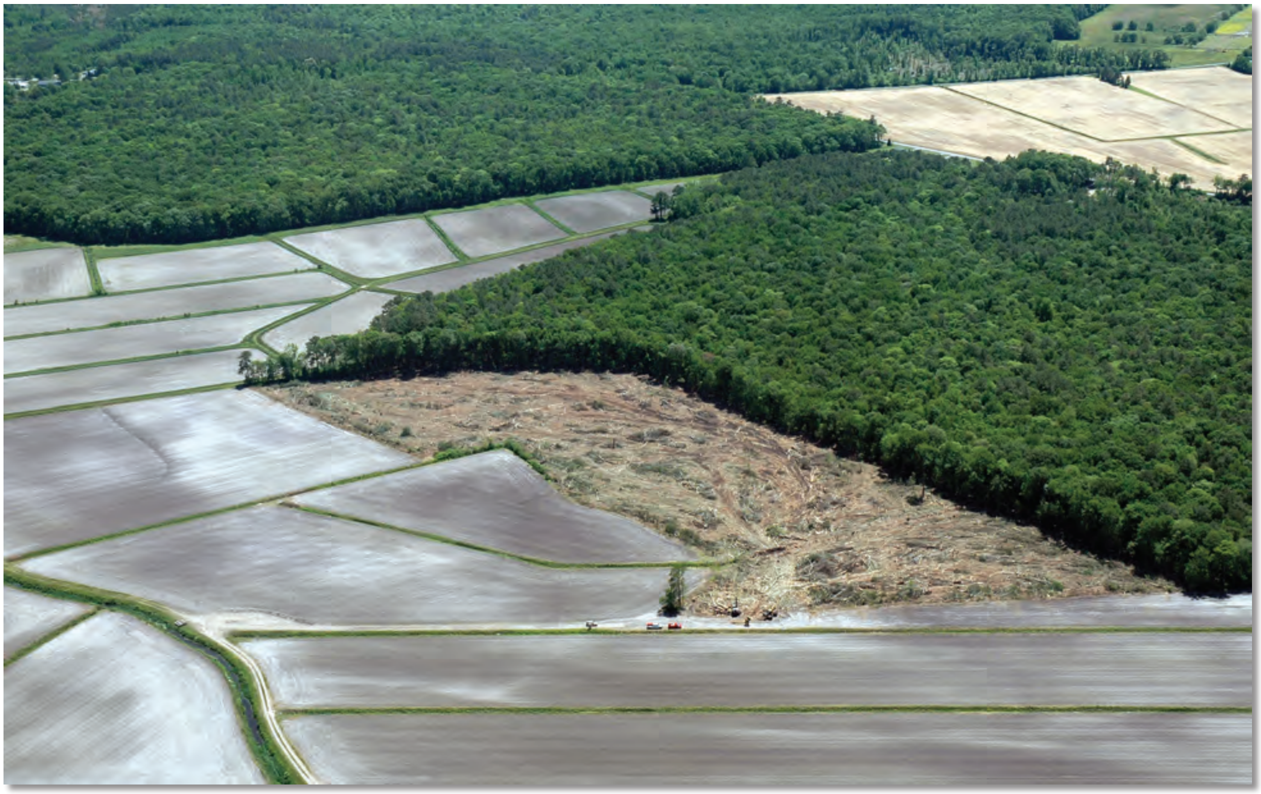
In agriculture and commercial forestry, human skill and knowledge can allow for some adaptation to climate change; for example, by changing crop and plantation tree species, and controlling new pest and diseases artificially. If all else fails, products that can no longer be produced in Maryland economically could be imported from elsewhere. And, other commodities will be produced that are not produced under today's climate. Some impacts on agriculture and forestry may be seen as beneficial and others would require adaptation but at an increased cost.

A significant and already apparent effect of warming on plants is to hasten the beginning of the growing season and prolong it in the fall. But while a shorter winter and earlier arrival of cherry blossoms may be welcomed, overwintering of plant pests that currently are killed by winter cold could also occur. Heat waves and drought can cause mortality directly through increased stress and reduced growth. Forests which grow more rapidly because of the CO_2 fertilization effect—plants require carbon dioxide for photosynthesis and an increase in atmospheric carbon dioxide can increase growth—may become increasingly fire-prone or subject to insect outbreaks. Animals, both livestock and wildlife, are affected directly by climate and indirectly through changes in the frequency and extent of pest outbreaks, spread of invasive species, animal and plant diseases, extreme weather events, and wildfire.

As ecosystems respond to climate changes, there will be not only changes in species found in

Ben Fertig

Wicomico County, Maryland, marshlands and forest share waterway with agriculture and development.



Jane Thomas

Forest cleared for agriculture in one watershed of Maryland's Coastal Bays.

Maryland and in biodiversity, in general, but also in the ecosystem services they provide. Ecosystem services are the benefits to humans that arise from the functioning of ecosystems, but without deliberate action by humans. These include purification of air and water by plants, decomposition of wastes by microbes, soil renewal, pollination of crops, groundwater recharge by wetlands, maintenance of potentially-useful genetic races, removal of greenhouse gases from the atmosphere by carbon sequestration, and provision for recreation in aesthetically pleasing landscapes.

Land use will affect responses

Climate change is taking place in the context of other rapid changes affecting terrestrial ecosystems, agriculture, and forestry. These include continued exurban development, conversion of natural vegetation to farms and pastures, and changes in air and water quality. Many of these factors affect more than one ecosystem or resource simultaneously and interact with each other, often compounding their individual effects.

An important factor in the response of living organisms to current and future warming that did not exist during the post-glacial warming is the extensive fragmentation of natural landscapes by cities, suburbs, farms, highways, and other features. Some species will be slowed in their northward migration by their requirement for specific habitats of suitable size—habitats that, for these species, are now broken into fragments within an impassable matrix of the human landscape. This will favor species capable of "jump dispersal," in which a few individuals can reach new, suitable habitats by occasional transport over long distances by wind and water or hitching a ride on vehicles or birds. Some species, such as weedy plants, are more likely to move by jump dispersal; others such as amphibians are very unlikely to do so. Species with very specific habitat requirements and limited dispersal capability, including many plants, may fail to move and could become, at least locally, extinct.

Observing changes is challenging

Our current capacity to observe meteorological and ecological changes is insufficient to provide early indicators and assess the effects of climate change on Maryland's agriculture, forestry, and terrestrial ecosystems. Meteorological sites on the ground are few in number and limited in the range of measurements they make. The role of these sites in weather forecasting has not been diminished by the development of satellite measurements and computer models; in fact, higher quality observations are required by the models.

Furthermore, ground meteorological stations are irreplaceable for documenting climate variability and change. Studies in other regions have documented changes in the distributions of various plants and animals that are likely the result of recent climate change.[60] Earth resource satellite observations offer a different approach. Satellite data can provide a record of changes in vegetation types and extent, carbon fixation, land cover and human habitation—all essential components of a climate change monitoring and adaptive management system. While satellite measurements have been made over Maryland for over 30 years, the data have not been systematically acquired and archived. The existing record of crop yields by the National Agricultural Statistics Service (from 1961), the Forest Inventory and Analysis program (from 1953), the Maryland Biological Stream Survey (from 2000), the Breeding Bird Survey (from 1966), and Christmas Bird Count (from 1900) all contribute key information in a period of rapid climate change, but they are alone.

A slice of the regional landscape

Maryland is a cross-section of the Mid-Atlantic, from the eastern Atlantic Coastal Plain to the Appalachian Plateau. Altitude varies from sea level to 3,306 ft. There are substantial differences in climate across the state and within microclimates, such as the rain shadows of western mountains and local effects of ocean breezes. Although the global climate models used in this assessment are too coarse in spatial resolution to reveal all of the patterns of change that may be realized, it should not be forgotten that these changes are superimposed on the substantial cross-state and local differences that already exist.

At Hancock, Maryland, the State narrows to less than two miles from its northern boundary with Pennsylvania to its southern boundary with West Virginia and, even at its widest, Maryland is a relatively narrow slice of the eastern United States. The modest area of the State belies the fact that it crosses the full range of physiographic and climatic regimes of the Mid-Atlantic region and is therefore exceptionally diverse with respect to its area. Its small area also means that the species that may take the places of those unable to compete in a changed climate, including pest species, depend on the conditions in bordering states. Thus, Maryland cannot be separated from its context in a continuum of physiography, climate, geology, soils, and biota extending from Maine to Georgia.

AGRICULTURE

Maryland's agricultural commodities account for less than one percent of the value of all U.S. commodities, yet agriculture plays an important role in the economy, social fabric, and landscape diversity of the State. Despite the decline in agricultural lands as a result of urbanization, fully one-third of Maryland's land remains in agricultural land uses. The production of poultry (broilers, turkeys, and eggs) accounts for 36% of the the $1.6 billion 2006 value of agricultural commodities, and the corn and soybeans largely grown to feed these birds represents another 17% (Figure 6.1).[61] Horticulture (greenhouse/nursery) accounts for 22% of the value of Maryland's agricultural output, reflecting the State's high population density and demand for landscaping and plants.

Greenhouses and nurseries are second only to broilers in agricultural value

Crop production

Crop species differ in their critical temperature range for growth and development. Growth and development of a particular crop requires temperatures at some minimum temperature, are fastest at some optimal temperature, and slows down and finally ceases at a temperature maximum. Vegetative development usually has a higher optimum temperature than reproductive development. At elevated temperatures, the life cycle of a grain crop will progress more rapidly but may reduce yield owing to the shorter time available to fill the grain. High temperatures can also result in failure in pollination and grain setting. Yield responses to temperature vary among species based

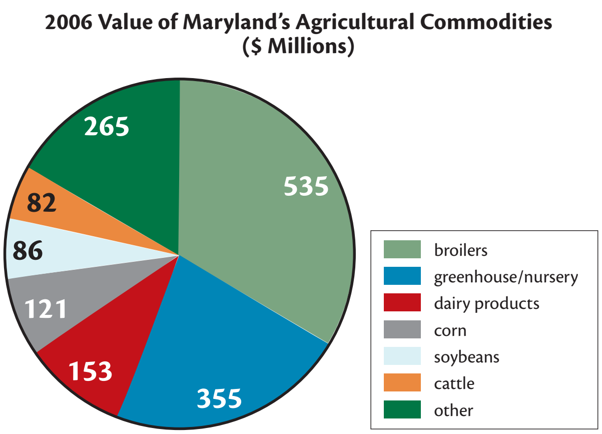


Figure 6.1. The value of Maryland's agricultural commodities in 2006.[61]

A Maryland farm surrounded by forest.

on the crop's temperature requirements. Plants that have an optimum range at cooler temperatures will exhibit significant decreases in yield as the temperature increases above this range. On its own, the projected increase in mean temperature of 2 to 3°F by 2040-2050 could decrease corn and wheat yields by 8-14% [62], but may have little effect on soybean yield.[63] Under the higher emission scenario, toward the end of the century, summer heat stress is likely to be a significant limiting factor in crop production unless there is a transition to new crops or varieties, which may be an expensive proposition for farmers.

Heat stress likely to limit crops under higher emissions scenario

Crop development and yield are also affected by the amount of water available in the soil, which is itself affected by elevated temperature. Furthermore, because evapotranspiration increases with temperature, maintaining soil moisture sufficient for germination, growth and grain setting will be a significant factor in determining the response of crop production to climate change. Despite the mean projection of increased annual precipitation by the climate models, moderate declines in soil moisture are likely to be experienced in summer and fall during the second half of the century under both lower and higher emissions scenarios. Furthermore, rain is likely to be delivered in more intense events, separated by weeks to months with less rain. One has only to recall 2007, a year with relatively high winter and early spring precipitation and a disastrous, weeks-long summer drought as an example of what might occur more frequently. Under these conditions, farmers are likely to increase the use of irrigation—currently, just over 5% of Maryland's crop lands are irrigated—compounding the aquifer drawdown already taking place in some parts of the state (Section 5).

Plant growth is also dependent on the availability of the carbon dioxide required for photosynthesis. Plants respond differently to elevated carbon dioxide concentrations. Cold-season and broad-leaved weeds and cold-season grain crops, including wheat and barley, respond most dramatically to increased carbon dioxide. An increase of carbon dioxide concentrations to 550 ppm could increase the yield of these plants by 10-20%[5], mainly through increased grain production rather than grain size. Corn and many summer weed grasses respond less dramatically to carbon dioxide enrichment, with corn yields increasing less than 10% given the same increase in carbon dioxide.[64] However, high temperature stress during reproductive stages can negate the overall carbon dioxide effects on yield even though total plant biomass may increase and attaining even these modest productivity increases requires more fertilizer, unrestricted root growth, and effective control of weeds, insects and disease.[7]

Under the higher and lower emissions scenarios, atmospheric carbon dioxide concentrations would increase late in the century to 940 ppm and 550 ppm, respectively. By mid-century a modest (5 to 9%) increase in crop yield, except for corn, might be experienced as a result of fertilization.[65] However, under the higher emissions scenario this effect would diminish as concentrations exceed 600-800 ppm. Deficiencies in soil moisture could further limit yield and require increased irrigation.

While carbon dioxide enrichment can stimulate the production of leafy vegetables such as lettuce, spinach or radish, their greater leaf area increases their water requirement during the warmest and driest part of the growing season. Some moderation of this effect may be caused by a decrease in plant evapotranspiration as the stomata on the leaves constrict under higher carbon dioxide concentrations, leading to a reduction in water loss and increase in crop yield. This effect, however, is very likely to be small in comparison to the effects of temperature and carbon dioxide fertilization.

Wheat and barley grain and potato tubers contain 10 to 15% less protein when grown under carbon dioxide concentrations of 540 to 958 ppm, diminishing their nutritional value and performance in food processing, for example, producing sufficient gluten for making bread).[66] This effect can be counteracted by providing the plants more nitrogen, but in Maryland that would require more fertilizer, compounding the nutrient pollution problem in the Chesapeake Bay (see Section 8).

Ground level ozone is created on warm days by the reaction of sunlight with nitrogen oxides (NOx) and volatile organic carbon (VOC) compounds, present because of air pollution. Despite efforts to reduce this pollution, Maryland experiences some of the highest ozone in the country. As discussed in more depth in Section 8, warmer temperatures from global warming threatens to increase the concentrations of ground-level ozone and the frequency of high-ozone events. In addition to its effects on human health, ozone is toxic to many plants and particularly to crops such as soybean and wheat. Even mild chronic exposure (40-60 ppb) decreases yield in soybean.[67] However, these effects may be moderated by the reduction in the apertures of plant stomata under elevated carbon dioxide. While the net effects on crop production may be relatively small during the first half of this century, if the pollutant loads of NOx and VOC are not substantially reduced, the added stress of ozone together with heat stress and desiccation are likely to lead to declines in crop production during the second half of the century.

Crop production is affected by competition with weeds. Because the geographic range of many weed species is determined by temperature, climate warming is very likely to lead to a northern shift in the distribution of some economically significant weed species.[68] These include witchweed, cogongrass, and itchgrass that at present are found south of Maryland and the proliferation of invasive kudzu that is already here.[7] On the other hand, some current weed species may become less of a problem. On-going studies in Maryland are showing that weeds grow much faster under higher temperatures and carbon dioxide concentrations likely to be experienced in the next 30 to 50 years—these conditions simulated by experiments conducted in Baltimore.[69] The growth of many weed species is stimulated more by carbon dioxide enrichment than are the cash crops they invade, presenting an additional challenge for weed control.[69]

Weeds thrive under high temperature and CO_2

Beneficial and harmful insects, microbes, and other organisms present in agricultural ecosystems will also respond to climate change. Numerous studies have shown changes in spring arrival, over-wintering, and/or geographic range of several insect and animal species due to climate change.[5] Diseases caused by leaf and root pathogens may increase in Maryland if increases in humidity and frequency of heavy rainfall events occur, but will decrease if more frequent droughts occur.

Animal production

For optimum production, livestock require temperatures that do not significantly alter their behavioral or physiological functions needed to

Baltimore Sun

An increase in droughts may reduce reservoir water levels.

maintain a relatively constant body temperature. As their core body temperatures move outside normal boundaries, animals must begin to conserve or dissipate heat. This reduces the energy available for growth or the production of products such as milk, and ultimately affects reproduction. The onset of heat stress often results in declines in physical activity and eating or grazing. Hormonal changes, triggered by environmental stress, result in changes in cardiac output, blood flow to extremities, and digestion rates.[70] Adverse environmental stress can elicit a panting or shivering response, which increases the baseline energy requirements of the animal and contributes to decreases in productivity. The temperature thresholds of these responses depend on the species in question and the animal's genetics, temperment, and health.

Heat stress could affect milk production late in the century

The most important forms of animal production in Maryland are poultry (broilers), comprising 36% of all agricultural cash receipts, and dairy production, comprising over 11% (Figure 6.1). There are no quantitative assessments of the impacts of climate change on poultry production in this State, however housing large numbers of birds with a high metabolism in close quarters already makes them susceptible to heat stress during hot summers, when large numbers of birds can die. To reduce the chance of death requires costly insulation and ventilation of growing sheds. The temperature projections after mid-century, particularly under the higher emissions scenario, will pose a much more serious problem of heat stress on confined poultry production.

The Northeast Climate Impacts Assessment projected little increase in heat stress on dairy cattle and no significant heat-related reductions in milk production for the next several decades. However, under a higher emissions scenario generally similar to the one used here, by mid-century New Jersey and southern Pennsylvania were projected to experience moderate heat stress in July and declines of milk production of up to 12%. By late century, the declines are projected to be 10% under the lower emissions scenario and 15-20% under the higher emissions scenario. Similar or greater declines in dairy production are likely in Maryland.

To maintain levels of production under climate change, livestock producers will select breeds that are genetically adapted to the new, warmer climate. However, breeds that are more heat tolerant are generally less productive.

Climate change is also likely to affect the parasites, pathogens, and disease vectors that affect domesticated animals. Similar effects on pest migration and over-wintering as discussed for cropping systems are likely to be observed for some livestock parasites and pathogens. Also, accelerated development of pathogens and parasites due to the earlier spring and warmer winters is likely.

Warming and associated variation in weather patterns will likely result in more livestock being managed in climate-controlled facilities, even in a more energy-constrained world. Furthermore, agriculture, in general, and the animal production industry, in particular, will surely be under pressure to reduce its greenhouse gas emissions, particularly of methane and nitrous oxide.[71] This could incur additional costs to production, thereby affecting profitability and hence the nature of the agricultural industry in Maryland.

Summary of impacts on agriculture

In summary, agriculture in mid-latitude regions

Tom Hollyman

Increased temperatures can cause heat stress in chickens.

www.cornucopia.org

Heat stress can cause a decline in milk production.

such as Maryland may experience moderate warming benefits in the form of crop and pasture yields under moderate increases in temperature (2-5°F) and increases in atmospheric carbon dioxide and rainfall. However, increased risks of drought in summer and early fall and unknown changes in weed and pest damages will generate uncertainty among farmers and animal producers regarding adaptation to climate change. The warming in the lower emissions scenario during the latter part of this century is projected to have increasingly negative impacts as it approaches or passes the upper end of optimum ranges of different crop and animal species if the higher emissions scenario proves more accurate (Figure 4.3). Therefore, without mitigation of greenhouse gas emissions, the changing climate is likely to pose serious problems for Maryland agriculture resulting from heat stress and summer-fall drought that might increase groundwater demand for crop irrigation.

FORESTS

Although Maryland accounts for only 0.3% of the nation's softwood production and 1.6% of its hardwood production, the forest products industry is economically important in parts of the State, resulting in product output worth $262 million. Paper products account for 60% of that total. Forest products industries employed 9,326 in 2006 and generated $0.4 million in State tax receipts.

Climate change and forest productivity

Forest productivity in the United States has generally been increasing slightly since the middle of the 20th century[72], although there is no assessment specifically for Maryland forests. Forested area has increased dramatically from a minimum at the beginning of the 20th century as areas of the eastern U.S. that had been cleared for agriculture and other purposes have been reclaimed by forests. The potential causes of the increase in productivity include increases in temperature, atmospheric carbon dioxide and nitrogen deposition, but these are difficult to isolate. Temperature, water, and solar radiation are the primary climatic factors that affect forest productivity. Increased precipitation, higher temperature, and a longer growing season will increase productivity where those factors are currently limiting. Consequently, a modest increase in forest yields and regrowth is likely. During the latter part of the century under the higher emissions scenario, however, heat stress and the greater likelihood of summer-fall drought could obviate gains in forest productivity due to global warming earlier in the century. If forest species, such as loblolly pine, currently found farther south, migrate into Maryland or are planted and replace existing species, this could at least partially compensate for some of the lost productivity

Large departures from typical conditions and extreme events, such as late frosts, drought, and wind storms, can damage or kill trees. The occurrence and severity of such extreme events associated with climate change are projected to increase. These indirect effects of climate on factors such as wildfires and insect outbreaks are likely to contribute to reduction of forest production. The interaction of climate change and these factors could create unprecedented conditions, the effects of which are very difficult to predict. Forests can take decades to re-establish after disturbances are caused by fire, insect outbreaks, and wind and ice storms. These effects are likely to become more important than the direct effects of climate itself in shaping future forest ecosystem structure and functioning. All of these changes will be influenced by the legacy of the logging in the 19th and 20th centuries and the more recent period of fire suppression that has led to dominance by an even-aged community of trees now reaching old age.

Modest increase in forest yields likely early in the century

Carbon dioxide fertilization

As discussed under agriculture, the projected increases in atmospheric carbon dioxide concentration are likely to increase forest growth due to a fertilization effect, but this will depend greatly on the type of forest and its environmental

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Fall colors illuminate a mountain forest.

conditions. The response of tree growth to elevated CO_2 also depends on the age of the trees; younger trees respond more strongly than older ones.[5] Maryland forests will likely absorb more CO_2 and retain more carbon in wood and soils as atmospheric CO_2 increases, but this will depend on the specifics of how climate changes and on such factors as the age of the forest and the degree of fertilization by nitrogen deposition. These factors are highly relevant when devising strategies to increase forest carbon sequestration for mitigation plans.

Atmospheric pollution

Forest growth and dynamics are affected by air pollution in two important ways: the toxic effects of ozone created by emissions of NOx and VOCs from power plants and vehicles, and the stimulatory effects of nitrogen deposited as a result of these NOx emissions. Nitrogen deposition in the eastern U.S. can exceed 10 kg of nitrogen per hectare (or 9 lbs per acre) per year and has increased 10 to 20 times above pre-industrial levels.[73] Although nitrogen deposition has declined recently in Maryland as result of air pollution controls[74], future emissions are uncertain. Forests are generally limited by nitrogen availability and increased deposition will enhance forest growth. However, if it increases too much, it can have negative effects on forests and on aquatic ecosystems that receive runoff from the forests. The interactions of elevated CO_2, temperature, precipitation, ozone pollution, and nitrogen deposition are likely to be important in determining forest growth and species composition, but the net result of these factors and their interactions is poorly understood. Continued nitrogen deposition on forests can have the result of stimulating the degradation of organic matter in soils by microbes, thus reducing any carbon sequestration resulting from faster growth in a CO_2-enriched world.

Combined effects of temperature, ozone, CO_2, and nitrogen deposition are difficult to predict

Insect outbreaks

Outbreaks of forest insects and diseases affect forest composition and production, leading to altered cycles of matter and energy, and changes in biodiversity and ecosystem services. Damage to Maryland forests caused by outbreaks of defoliating insects and other pests cost several million dollars per year.[75] Weather plays an important role in influencing outbreaks of serious forest insect pests, including the gypsy moth, southern pine beetle, hemlock woolly adelgid, spruce budworm, and western spruce budworm. Temperature affects the rate of insect life-cycle development rates, the synchronization of mass attacks that overcome tree defenses, and insect winter mortality rates. Climate also affects the insects indirectly through effects on the host trees. Drought stress, resulting from decreased precipitation and warming, reduces the trees' ability to resist insect attack.

Outbreaks and expansion of some non-native insect species, such as the hemlock woolly adelgid (Box 6.1), are known to be influenced by climate. The introduced gypsy moth has defoliated millions of acres of Maryland forests. Projections indicate that Maryland's changing climate is likely to increase the frequency and severity of gypsy moth outbreaks in the future.[76] Longer growing seasons and higher carbon dioxide concentrations might allow forests to recover more quickly after such disturbances. But defoliation disturbances affect carbon uptake, nutrient cycling, and stream hydrology, resulting in the loss of nitrogen from the forest where it is needed, to the Chesapeake Bay where it is harmful.[77]


Joanna Woerner

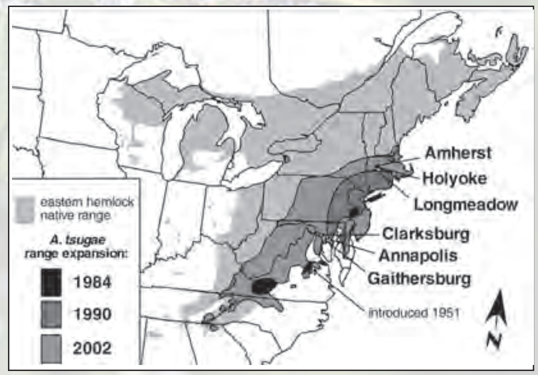
Industrial emissions.


NPS

Hemlock forest, ravaged by insect pests.

BOX 6.1 THE EASTERN HEMLOCK & WOOLLY ADELGID

The hemlock woolly adelgid, an aphid-like insect native to Asia, was first recorded in 1951 in Virginia, and has since spread, causing a severe decline in vitality and survival of eastern hemlock in North American forests (Box Figure 6.1). Once it arrives at a site, complete hemlock mortality is just a matter of time and damaged hemlock stands are replaced by black birch, black oaks, and other hardwoods. While plant biodiversity increases in the canopy and understory, several bird species, including the blue-headed vireo and Blackburnian warbler, have a high affinity for hemlock forests and are at risk as a result of adelgid expansion. Also, changes in the forest canopy affect hydrology and nutrient cycling, resulting in longer periods of dry streams, which, in turn, reduce the abundance of brook trout, brown trout and other fish. Low winter temperatures presently check the spread of the hemlock woolly adelgid, but increasing temperatures and the capacity of the adelgid to develop greater resistance to cold shock indicates that more hemlock forests will succumb in future years.



Box Figure 6.1. Expansion of the range of the hemlock woolly adelgid (*Adelges tsuagae*) with regard to the range of the eastern hemlock.[59]

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Species composition

As the changing climate after the last Ice Age resulted in the northward shift in the distribution of tree species in eastern North America, 21st century warming will very likely result in the northward sift in the range of trees and forest types currently that exists in Maryland. Trees that need cold winter conditions (for example, sugar maples) or are susceptible to diseases or pests under warmer conditions will retreat northward, possibly replaced by species currently found south of Maryland. Plant hardiness zones for horticultural plants have recently been revised to take account of the changes in the potential ranges of garden plants that have already taken place (Figure 6.2).

By relating the preferred environmental conditions of various forest types to current temperature and precipitation, it has been possible

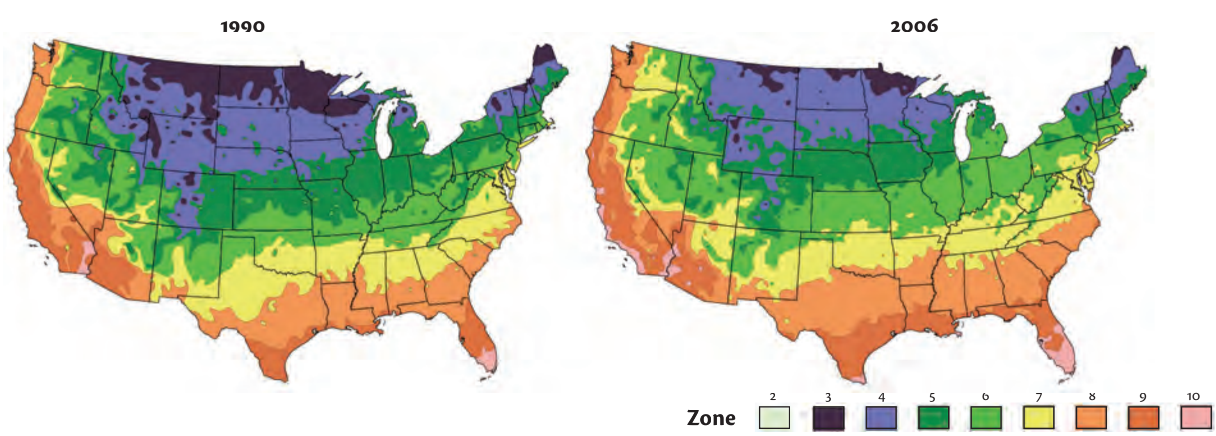

Figure 6.2. U.S. Department of Agriculture plant hardiness zones for 1990 compared to those delimited by the National Arbor Day Foundation's for 2006.

to estimate future ranges as climate changes in eastern North America.[55] Under a doubling of CO_2 concentrations—likely to be experienced in the latter half of the century under the low-emissions scenario—the maple-beech-birch forests of Allegany and Garrett counties are likely to disappear, replaced by oak-hickory forests. The oak-hickory forest type that presently characterizes most of the Piedmont and Coastal Plain west of the Chesapeake is likely to transition to an oak-pine forest.

The NECIA concluded that the region's species would shift northward by as much as 350 miles by the late-century under the lower emissions scenario, and as much as 500 miles under its higher emissions scenario. The NECIA projected that the maple-beech-birch forests that presently characterize most of Pennsylvania would move to northern Pennsylvania, and thus out of Western Maryland, under the lower emissions scenario and retreat to Upstate New York under its higher emissions scenario. In general, then, one would expect that by late-century, Maryland forests would look much like those in eastern Virginia and North Carolina do today, with many more pines.

Maple-beech-birch forests are likely to be eliminated from Western Maryland

Forest ecosystems

Forests provide many other benefits beyond the lumber and fiber. These ecosystem services, including watershed protection, water quality, flow regulation, wildlife habitat and diversity, climate regulation, carbon storage, air quality, recreational opportunities, and aesthetic fulfillment, are important for the well-being of Marylanders. The market values of few of these ecosystem services have been quantified, but they are nonetheless essential and irreplaceable. All of these services are subject to the direct and indirect effects of climate change as forest productivity and composition changes and disturbance by heat stress, seasonal drought, severe storms, fire, disease, and pest outbreaks increase.

The biodiversity of forest plants, animals, and microbes is also likely to be affected in ways that are difficult to predict let alone quantify.[78] Biodiversity is already being affected at the landscape, species, and genetic levels by a variety of human activities, including habitat loss and fragmentation, invasive species, and air pollution.[79] Climate change poses yet another stress that is likely to reduce biodiversity.[80]

Climate changes have been shown to affect the timing of critical processes of growth and reproduction (for example, flowering and fruiting) in thousands of plant and animal species around the world.[5,81] These changes can disrupt previously synchronized relationships among species (for example, pollination, prey availability for predators, and food sources for migrant birds). The reduction in population sizes caused by these adverse effects sets the stage for local or global extinctions of species.[82] The American Bird Conservancy estimated that habitat alterations due to climate change may force out 34 or more bird species from Maryland.

The most emblematic of birds that may no longer breed in Maryland because of the unsuitability of habitats is the state bird, the Baltimore oriole. The NECIA also projected that various migratory bird species with northerly or high altitude distributions, including the American goldfinch, purple finch, rose-breasted grosbeak, and black-capped chickadee would experience declines in abundance in the Northeast, while the tufted titmouse, northern cardinal, and indigo bunting have the potential to increase in both range and incidence.[7]

Summary of impacts on forests

Maryland forests are likely to experience a modest increase in productivity over the first half of the century as a result of longer growing seasons and elevated atmospheric carbon dioxide concentrations. Later in the century, the composition of Maryland forests is likely to undergo pronounced changes as the maple-beech-birch forests of Western Maryland begin to disappear and pine trees become more prominent in oak-hickory forests of central Maryland. Also, later in the century, heat stress, seasonal droughts, and outbreaks of pests and diseases are likely to diminish forest productivity,

University of Texas

Maryland's state bird, the Baltimore oriole.

particularly under the higher-emissions scenario. This could result in impairment of important ecosystem services that forests provide, including carbon sequestration, control of the water cycle, and maintenance of biodiversity. The extent to which and rate at which other tree species from the south would replace the current species and the services the present forests provide cannot be readily predicted.

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Maryland forests provide many resources as well as recreational opportunities.

Section 7

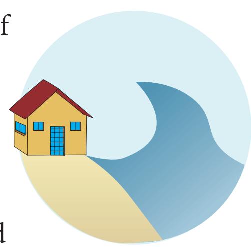
COASTAL VULNERABILITY FROM SEA-LEVEL RISE & STORMS

KEY POINTS

- **Sea level in Maryland rose by 1 foot in the 20th century, partially because the land is sinking.**
  Coastal regions of Maryland have been sinking at about a rate of 6 inches per century and this should continue. Additionally, the average level of the sea in this region rose by about the same amount. As a result, Maryland has experienced considerable shoreline erosion and deterioration of coastal wetlands.

- **Sea-level rise is very likely to accelerate, inundating hundreds of square miles of wetlands and land.**
  Projections, that include accelerating melting of ice, extend to more than 1 foot by mid-century and 3 feet by late century. If the highest rates are realized under the higher emissions scenario, most tidal wetlands would be lost, about 200 square miles of land would be inundated, and an even greater sea-level rise would occur in subsequent centuries.

- **Rains and winds from hurricanes are likely to increase, but their frequency cannot be predicted.**
  The destructive potential of Atlantic tropical storms and hurricanes has increased since 1970 in association with warming sea surface temperatures. This trend is likely to continue as ocean waters warm. Whether Maryland will be confronted with more frequent or powerful storms depends on storm tracks that cannot yet be predicted.



Mention effects of climate change in Maryland and most people would think first of the threat of coastal inundation due to sea-level rise and the increased risks of storm damage. The record storm surge flooding associated with the passage of Hurricane Isabel in 2003 is still fresh in the minds of Marylanders. With its 3,100 miles of tidal shoreline and extensive low-lying lands, especially on the Eastern Shore, Maryland's coastal zone is particularly vulnerable to climate change. Indeed, the central charge to the Adaptation and Response Working Group of the Commission on Climate Change is to "recommend strategies for reducing the vulnerability of the State's coastal, natural, and cultural resources and communities to the impacts of climate change, with an initial focus on sea-level rise and coastal hazards (e.g., shore erosion, coastal flooding)." The Commission is thus tasked with developing appropriate guidance to assist the State and local governments with identifying specific measures (e.g., local land use regulations and ordinances) to adapt to sea-level rise and increasing coastal hazards.

This section explores what we know about sea-level rise in Maryland and the Chesapeake Bay region, and applies the latest models and scientific results that provide insights into the sea-level rise that may be experienced during the present century and beyond. Projections are made for the higher and lower emission scenarios as has been done for temperature and precipitation in Section 3. The section further explores current scientific knowledge of the likely consequences of global warming for extratropical storms, such as Nor'easters, and the tropical cyclones that we know as hurricanes. The potential impacts on tidal wetlands, coastal lands and development, and storm surges are then evaluated.

SEAS RISING OR LAND SINKING?

As mentioned in Section 1, sea level rose rapidly as glaciers melted after the peak of the last Ice Age 20,000 years ago. At that time, the Atlantic shoreline was near the edge of the continental shelf, more than 80 miles off Ocean City, and the rivers ran across the present shelf to the sea. By 8,000 years ago, sea level had risen to the point of flooding the lower Susquehanna River valley, creating a tidal estuary, the nascent Chesapeake Bay (Figure 7.1).[83] The rate of sea-level rise during this period of rapid melting of glaciers was about 16 mm/year. (Throughout this discussion, metric units are used for annual rates to facilitate presentation and calculation, but rates over longer periods are converted to feet for ease in comprehension.) By 5,000 years ago, the rise of the ocean virtually ceased, but the Bay continued to deepen and expand, filling the lower valleys of the Potomac, Patuxent, Patapsco, Choptank, and other rivers. This was because the land was sinking as the bulging of the Earth's surface, resulting from the tremendous burden on the crust by the very thick glaciers that occupied what is now Hudson Bay and Quebec, subsided. This rate of subsidence was relatively rapid initially, but continues to this day as a slow-motion rebounding of an event that peaked 20,000 years ago.

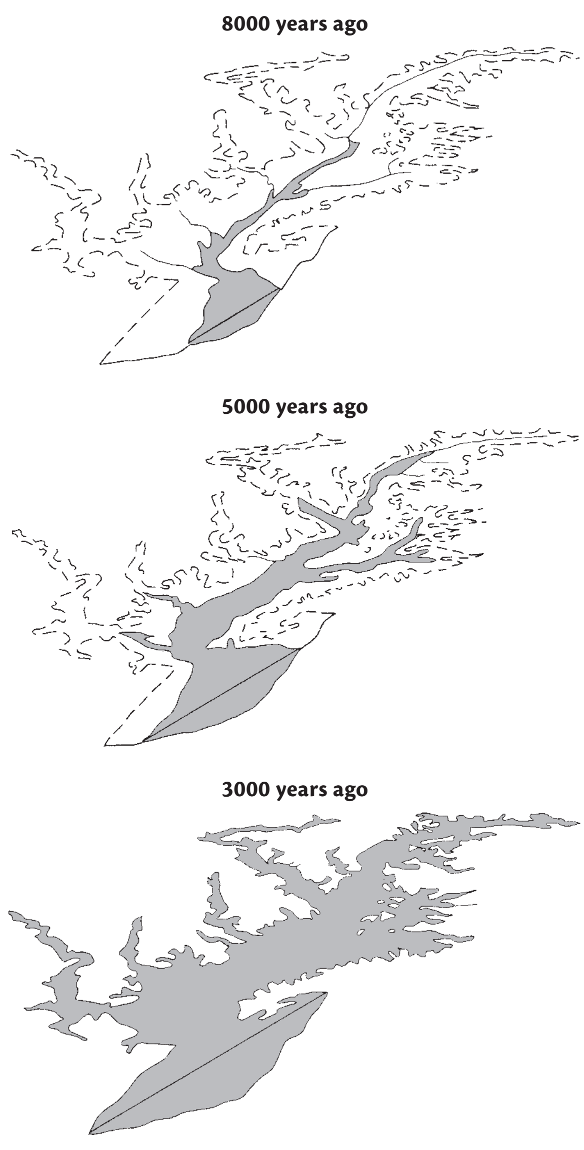


Figure 7.1. The rising ocean began to fill river valleys 8,000 years ago creating the general configuration of the Chesapeake Bay by 3,000 years ago.[83]

Because different coastlines around the world are sinking at different rates—or actively rising in some previously glaciated or geologically active regions —sea-level rise experienced at specific places will differ, even with a comparable rising of the level of the ocean itself. It is, then, appropriate to refer to "relative sea-level rise"—the water level relative to the land at that place. This is typically estimated by tide gauges that have long been fixed in place. The tide gauge record for Baltimore, which is one of the nation's longest, shows that the water levels there are highly variable as a result of weather events, strong seasonal variations, and longer oscillations in the North Atlantic Basin. On the average, however, relative sea level increased approximately one foot over the 20th century (Figure 7.2). Note, however, that for the first 30 years of the record the rate of relative sea-level rise was slower, with a disproportionate part of the rise in the mean level coming since 1930.

Sea level at Baltimore rose by 1 foot during the 20th century, mostly since 1930

Analysis of many such tide gauge records from around the world, including those from more geologically stable locations, allowed the IPCC to conclude that the global mean sea-level rise, once the effects of land subsidence or emergence are removed, was approximately 1.8 mm/year between 1961 and 1993.[2] Relative sea level at Baltimore rose at a rate of about 3.5 mm/year, indicating the local rate of subsidence was 1.7 mm/year or roughly half a foot per century. The effects of regional land subsidence on relative sea-level rise is apparent

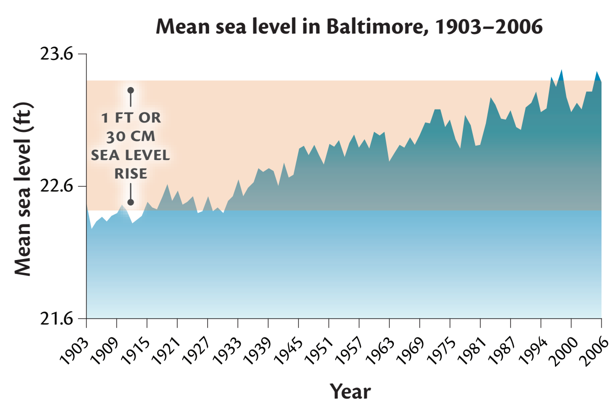
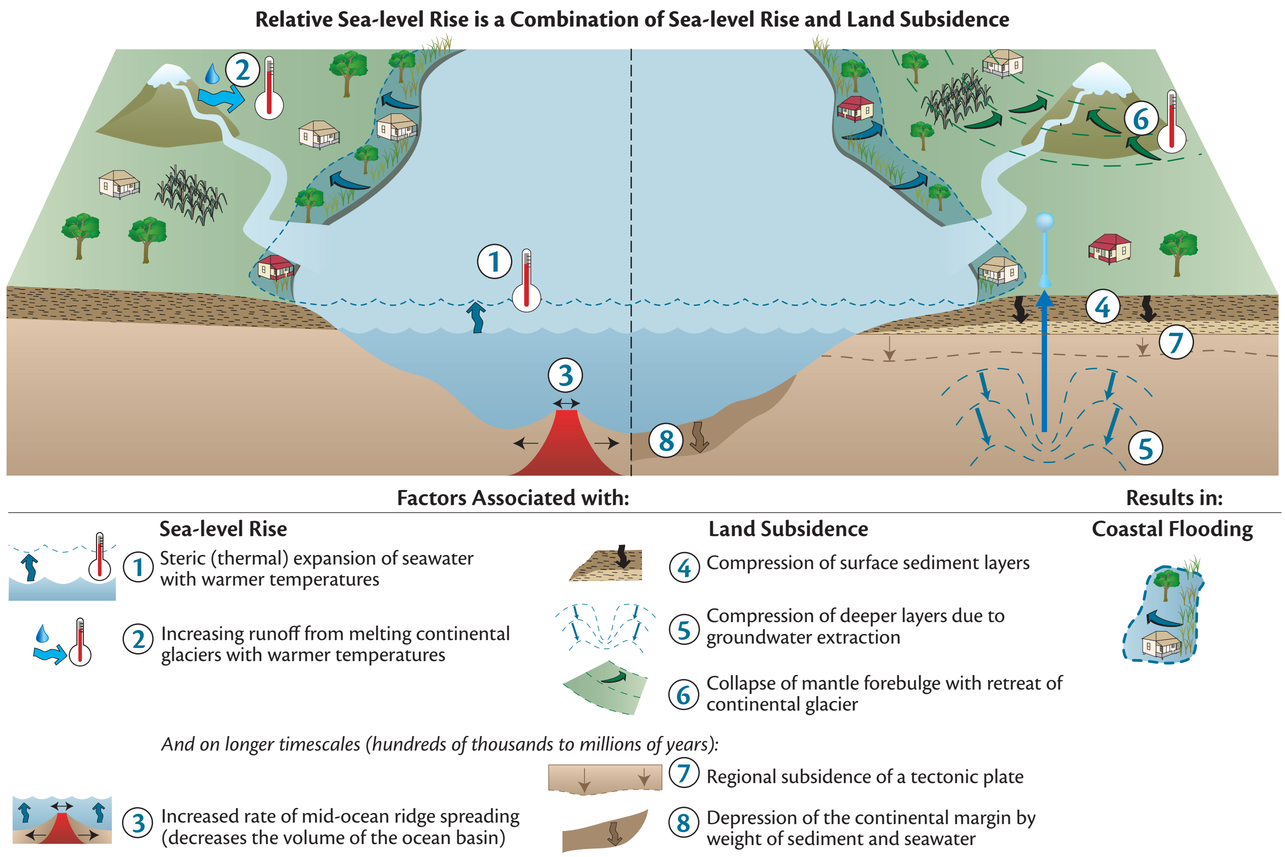


Figure 7.2. Tide gauge record for Baltimore.



by comparing tide gauge observations along the Atlantic coast (Figure 7.3).[84] Glaciated areas to the north experienced less relative sea-level rise than those located in the glacial forebulge region that are still subsiding. This subsidence (reflected by the difference between relative sea-level rise and the global mean) diminishes to the south of the Chesapeake Bay region. Note, however, that subsidence rates vary within the Bay region, with

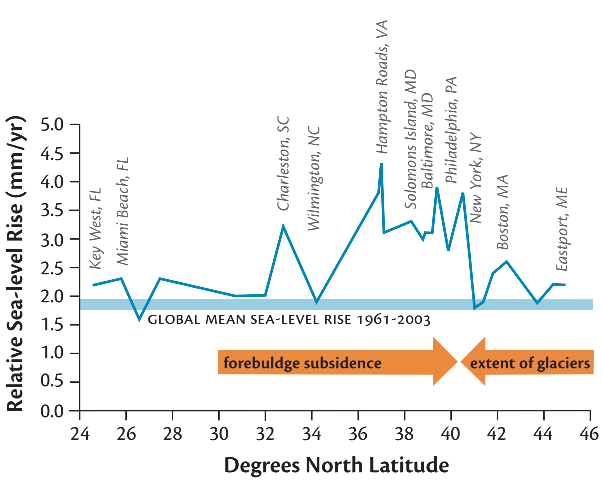


Figure 7.3. Relative sea level rise during the later 20th century along the U.S. Atlantic coast compared to the global mean sea level rise during 1961-2003 (band represents the confidence limits around the mean).[2]

Hampton Roads (Norfolk) experiencing a relative sea-level rise of 4.2 mm/year. This is likely the result of groundwater extraction from permeable rock or sediments, which can cause localized subsidence of the ground surface. Similar localized areas of greater subsidence resulting from large groundwater withdrawal may exist around Solomons and Cambridge, Maryland. However, for the Chesapeake Bay as a whole, the relative sea-level rise of about one foot during the 20th century resulted from near equal parts of subsidence and global sea-level rise. And, there is no reason to expect that the regional forebulge subsidence, which is in the process of adjusting over thousands of years, will be different than what was observed over the past century.

GLOBAL SEA-LEVEL RISE

The limited records available indicate that global sea level, adjusted for land movements, was nearly stable during the 19th century but began to increase around the turn of the century and then accelerate from the 1930s onward (Figure 7.4). Based on tide gauge data, the mean rate of sea-level rise was estimated by the IPCC to have been 1.8 mm/year between 1961-2003.[2] Since late 1992, there have been satellites deployed with the capability of very accurately measuring their altitude over the ocean's surface. Large numbers of measurements can be averaged over a 10-day period to develop precise maps of the surface of the ocean. Based on analysis changes in the ocean's elevation between 1993 and 2003, the IPCC noted a global average of 3.1 mm/year (black line in Figure 7.4), although the level of various regions of the ocean changed at different rates. While the degree to which the differences with sea-level rise estimates derived from tide gauges represent methodological differences or an actual acceleration of the rate of global sea-level rise has not been fully resolved, such an acceleration is consistent with the observed warming of the ocean

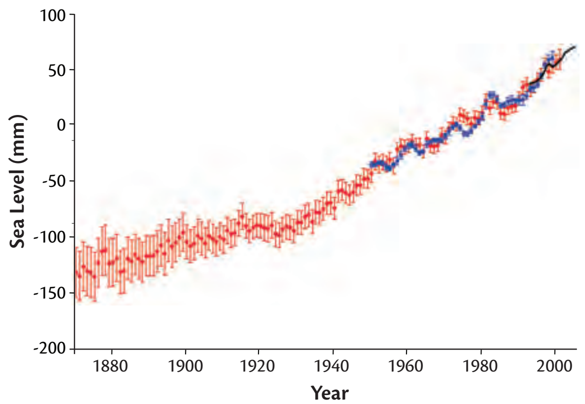


Figure 7.4. IPCC compilation of global data since 1870 shows acceleration of sea level rise during the 20th century.[2] The blue curve shows coastal tide gauge measurements since 1950 and the black curve is based on satellite altimetry.

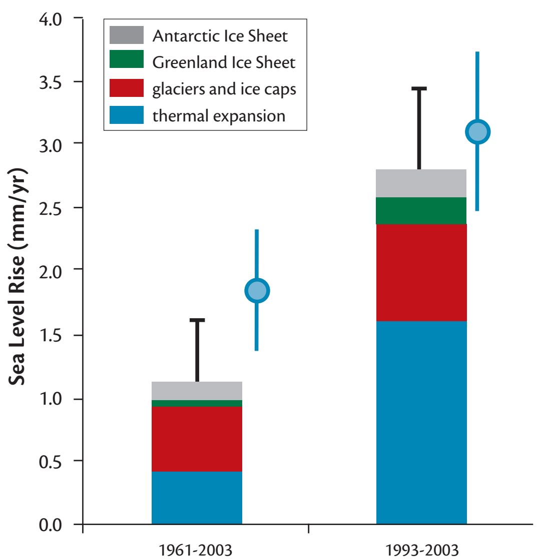


Figure 7.5. The IPCC attempted to estimate the factors responsible for increasing the ocean's volume, including thermal expansion and melting of glaciers and polar ice sheets.[2] These are compared with the global mean (dot) and range of observed sea-level rise. These estimates come closer to explaining the higher rates of sea level rise based on satellite observations during 1993-2003.

surface and melting of glaciers, both of which expand the ocean's volume (Figure 7.5).

Sea-level rise during the recent past is caused primarily by expansion of the volume of the warming ocean and, secondly, by the observed melting of glaciers and ice caps. The melting of the massive polar ice sheets on Greenland and western Antarctica were only a small component of sea-level rise, although the contribution of Greenland seems to be growing. It is unlikely that the total melting of the Greenland Ice Sheet would occur this century and produce the kind of 25-foot inundations seen in popular dramatizations of sea-level rise, although this could happen sometime in the future.

FUTURE SEA-LEVEL RISE

How much sea-level rise will Maryland experience over the coming century in a warming climate? The IPCC projected that global sea level would rise by 7 to 15 inches under the lower emissions (B1) scenario and 9 to 20 inches under the higher emissions (A2) scenario, although the IPCC specifically stated that these projections cannot "provide a best estimate or an upper bound for sea-level rise."[2] Adding to those projections the expectation that land subsidence in coastal Maryland would continue at the rate observed during the 20th century yields the relative sea-level rise projections labeled as IPCC projections in Figure 7.6. These projections suggest that Maryland would experience a rise in sea level ranging from just slightly more than the one foot experienced during the past century to more than twice that amount. However, the IPCC sea-level rise projections have been widely criticized as too conservative because they do not account for rapid changes in ice flow that could be experienced.

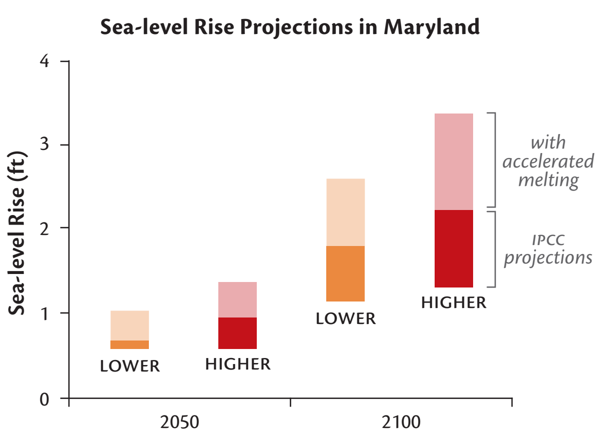


Figure 7.6. Projected relative sea level rise in Maryland during the 21st century under the higher and lower emissions scenarios.

The IPCC readily admitted that such effects were excluded because these ice flow dynamics could not reliably be modeled when its Fourth Assessment was being prepared and cautioned that sea-level rise could be higher as a result.

The melting of ice floating on the sea has no effect on sea level, much as ice cubes melting in a glass do not cause the glass to overflow. But, how much higher could sea-level rise if losses of ice that rests on land accelerate? This was estimated by examining three scientific reports appearing since the publication of the IPCC Fourth Assessment. They projected potential 21st century sea-level rise using three different methods. One used a statistical approach relating sea-level rise to observed temperature increase[85]; another assumed that the continuation of the rate of recently observed acceleration of ice loss, primarily from glaciers and ice sheets[86]; and a third estimated an upper limit of ice sheet contribution during the 21st century in projecting sea-level rise in the state of Washington.[87] The statistical model projected a mean increase of 34 inches in global sea level under the higher emissions (A2) scenario, compared to the IPCC projection of 9 to 20 inches. A word of caution, though, in that the statistical range of possibilities extended to 47 inches in the range of scenarios tested. Remarkably, the other two studies produced estimates of accelerated melting that, when added to the IPCC projections, resulted in very similar global sea-level rise at the end of the century under the higher emissions scenario. When coastal Maryland subsidence rates are taken into account, the additional relative sea-level rise based on the assumptions of these studies is represented in Figure 7.6 by the lighter-colored extensions above the darker-colored boxes that represent the IPCC projections. This suggests a sea-level increase of as little as 0.6 feet (probably unlikely because this is scarcely above the 20th century rate) to much as 1.3 feet could be experienced along the Maryland's coast by the middle of the century. By the end of the century, accelerated melting could produce a relative sea-level rise from 2.7 feet under the lower emissions scenario to 3.4 feet under the higher emissions scenario.

Accelerated ice melting could result in 3 feet of sea-level rise if emissions continue to increase

These adjusted estimates based on the IPCC projections should not be considered as model forecasts, but as reasonable bases for assessment and

Jane Thomas

A mature buffer zone helps reduce nutrient runoff from entering a saltmarsh on a tributary of the Chester River, Maryland.

planning that take account of the admitted high-end uncertainties in estimating future sea levels. They do not consider the upper bounds of the confidence limits presented in the statistical study, but can be used with confidence in concluding that it is likely that Maryland will experience sea-level rise of 2 feet by the end of the century. Further, this estimation indicates that, at this time, there is no scientific basis for projecting sea level rise of more than 4 feet during this century. Of course, sea-level rise will not stop at the end of the century and an important difference between the higher and lower emissions scenarios is that the higher emissions scenario is much more likely to move global temperatures over a threshold that would lead to the irreversible melt down of at least the Greenland Ice sheet, that would result during succeeding centuries in the 25-foot inundation of cities depicted in some frightening animations.

COASTAL WETLANDS

This section assesses the impacts of sea-level rise on shorelines and low lying lands. Section 8 will further explore the consequences of sea-level rise on the Chesapeake Bay and Maryland's Coastal Bays. An important part of these coastal ecosystems is, however, the coastal wetlands that fringe the estuaries. Maryland has some 200,000 to 285,000 acres of coastal wetlands[88] that provide critical nursery grounds for commercially important fisheries, important feeding grounds for migratory waterfowl, and home to furbearers and other wildlife. These wetlands buffer shorelines from erosion during storms, trap sediments and associated nutrients and pollutants, and provide a variety of outdoor recreational opportunities, such as sport fishing, hunting, kayaking, and bird-watching. The quantity and quality of these resources and opportunities available for future generations of Maryland residents will be directly affected by climate change.

Tidal wetlands will persist only if they build vertically through the accumulation in their soils of mineral (sand, silt, clay) and organic (plant material, especially plant roots) matter at a pace equal to or greater than sea-level rise—otherwise they will become submerged and convert to shallow open water habitat. In addition, given the generally shallow slopes over much of the Maryland coastal zone, those tidal wetlands that are able to keep pace with sea level will migrate and expand inland, but only so long as there are no barriers to migration (such as shore stabilization structures, houses, and roads).

As sea level rises, the fate of coastal wetlands in Maryland will be determined largely by how the needed build-up of soils is impacted by natural processes, human activities and the effects of the changing climate. Changes in the river runoff and shoreline erosion would affect the mineral sediment available for soils. Droughts could affect the accumulation of organic matter. More intense storms and greater storm surge could erode wetlands, but also transport mineral sediments onto the wetlands

When sea level rises, tidal wetlands must build up the soil or migrate inland


Jane Thomas

The loss of wetlands at the Blackwater National Wildlife Refuge, Maryland, due in part to sea-level rise, erosion, and subsidence.

and affect accumulation of organic matter by the negative effects of salt-water intrusion on plant growth.

Wetland survival during sea-level rise will vary among coastal wetlands depending on their location and the degree to which they are able to build up the soil surface. Marshes behind barrier islands on the seaside Eastern Shore increase their soil level vertically primarily as a result of sand driven over the islands during storms. An increase of storm intensity or frequency could build and expand the marshes as sea levels rise. Estuarine marshes depend more on organic matter and fine-grained resuspended sediments to build their soils. Without some significant source of mineral sediments such as discharge from a river, organic soils can only build so fast to keep up with sea-level rise—beyond some threshold, the marshes begin to deteriorate as plants die because their roots become continuously inundated and wetlands convert to shallow ponds.

As sea level has risen in the Chesapeake Bay, the gradual inundation of the low lying land on the lower Eastern Shore has led to the formation of tidal marshes that are built atop submerged uplands, particularly in Dorchester and Somerset counties. Accretion rates in these marshes are typically less than the current rate of sea-level rise.[89] At the Blackwater National Wildlife Refuge, land surface adjustments related to shallow soil subsidence[90] and possibly to groundwater withdrawal[91] have locally increased the rate of relative sea-level rise, contributing to severe wetland loss.[89] In addition, the effect of local stressors on vegetation growth, including intense herbivory by nutria, burning of the marsh for wildlife management, and altered flooding and salinity patterns related to roads and other construction activities, may be limiting soil buildup needed to counteract sea-level rise, which contributes to severe wetland loss.

Coastal wetlands, such as at Blackwater National Wildlife Refuge, are already deteriorating

If sea level were to rise at 6 mm/year, most of the remaining wetlands would be converted to open water (Figure 7.7).[92] Marsh elevation is not accreting appreciably under present rates of sea-level rise.[86] Consequently, it is unlikely that these marshes could build additional soil to keep pace without some external sediment subsidy. The placement of sediment dredged from channel maintenance in the Chesapeake Bay is currently under evaluation as a way to sustain these drowning wetlands.

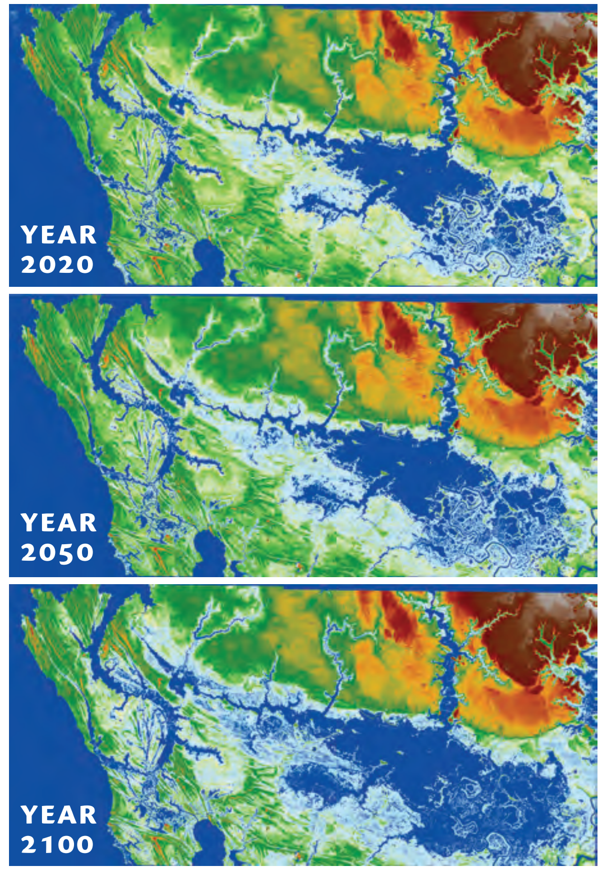


Figure 7.7. Projected inundation of coastal wetlands at Blackwater National Wildlife Refuge that would result from 6 mm/year sea level rise.[92]

Coastal responses to accelerated sea-level rise are difficult to predict over an area as large as Maryland, but a panel of wetland experts considered existing knowledge of responses and likely climate changes to project wetland survival for the Chesapeake Bay and Coastal Bays during this century.[93] Three relative sea-level rise scenarios were evaluated: 3 mm/year (approximating the current rate), 5 mm/year, and 10 mm/year. The fate of the wetlands was assigned to one of three possible outcomes: keeping pace, marginal (able to maintain elevation under optimal conditions, and loss (flood to the point of loss of

Intensive development and the loss of marsh impact the health of Maryland's Coastal Bays.

emergent vegetation). The findings summarized below are intended to provide a regional perspective and should not be applied to site-specific cases:

- **For the Maryland Coastal Bays:** marshes are able to keep pace with 3 mm/year of sea-level rise; at 5 mm/year, their ability to do this would be marginal and depend on the frequency of storms to mobilize and deliver sediments; and, at 10 mm/year, there would be marsh loss to shallow open water.
- **For the Chesapeake Bay:** estuarine marshes on the lower Eastern Shore are already experiencing high rates of loss and their survival is considered marginal at 3 mm/year and subject to substantial loss under either of the accelerated rates; estuarine marshes in the northern portion of Chesapeake Bay and on the western shore are keeping pace with 3 mm/year, but would be marginal at 5 mm/year and subject to loss at 10 mm/year; and, tidal freshwater marshes and swamps accumulate both mineral sediment and large quantities of plant organic and are considered sustainable under accelerated sea-level rise assuming salinities do not increase and sediment supplies are maintained.

To put these expert judgments in the context of the sea-level rise projections under the higher and lower emissions scenarios (Figure 7.6), based on the IPCC projections, the rate of sea-level rise over the first half of the century is likely to range from 3.5 to 5.8 mm/year, with the average for the higher emissions scenario 4.7 mm/year versus 3.8 mm/year under the lower emissions scenario. Except in tidal freshwater environments or where there is a significant supply of mineral sediments, the survivability of coastal wetlands is likely to be marginal, at least under the higher emissions scenario.

During the second half of the century sea level is projected to rise, based on the IPCC, by an average of 4.8 mm/year under the lower emissions scenario versus 5.7 mm/year under the higher emissions scenario, however, the upper end of the range under higher emissions is 7.8 mm/year. Consequently, the difference in the path of global emissions of greenhouse gases is likely to determine whether there is marginal survivability of at least some of Maryland's tidal wetlands and the predominance of wetland loss. However, with accelerated melting, the rate of sea-level rise could exceed 10 mm/year by the middle of the century, resulting in loss of the substantial majority of Maryland's 430 square miles of tidal wetlands. While some new tidal wetlands will be created over land that is presently dry, the dry land and nontidal wetlands potentially available for inland migration is only about 10% of the area of existing tidal wetlands.[94]

A recently completed, parallel analysis by the National Wildlife Federation[94] also projected losses of a majority of the brackish marshes, tidal swamps, and estuarine beaches in the Chesapeake Bay under a 27-inch rise in sea level by the end of the century. Clearly, the intertidal habitats that are important to the characteristics and productivity of the Chesapeake Bay ecosystem are at risk as a consequence of global warming.

EROSION & INUNDATION

In addition to causing the deterioration and landward migration of coastal wetlands, projected sea-level rise will cause the erosion and retreat of shorelines and, ultimately, the inundation of presently dry land. Based on general estimates derived from the Maryland Department of Natural Resources airborne surveys using a highly accurate laser instrument called LIDAR (Figure 7.8), it is roughly estimated that over 180 square miles of land would be inundated by the end of the century under the higher emissions scenario, assuming the

Potential Inundation on Maryland's Eastern Shore

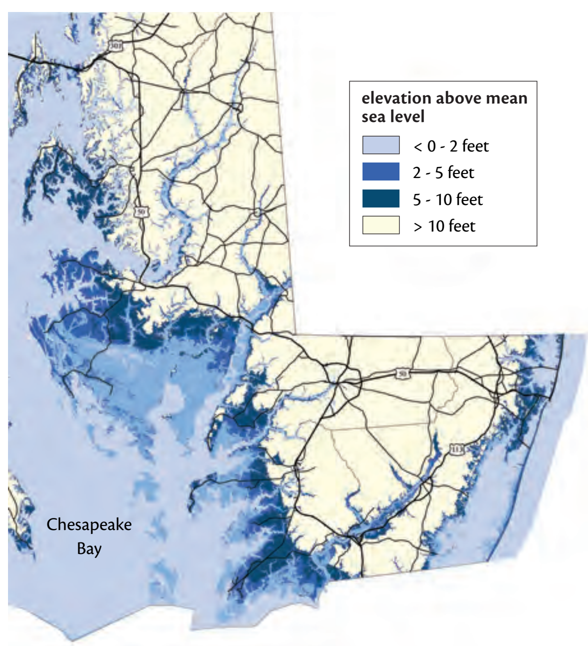


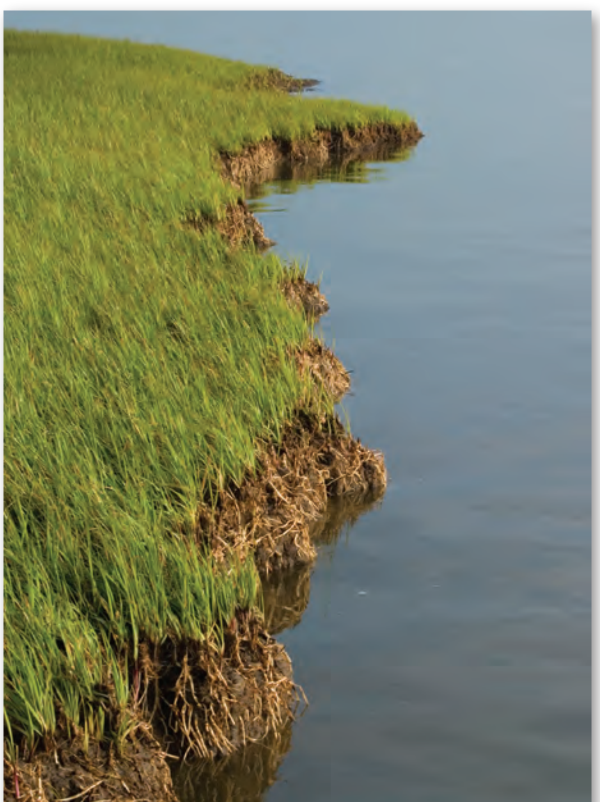
Figure 7.8. Extensive areas of wetlands and low-lying lands less than 2 feet above mean sea level (light blue) are likely to be innundated this century. Lands with elevations between 2 and 5 feet (medium blue) are also potentially at risk. Image based on aircraft LIDAR mapping by the Maryland Department of Natural Resources.

higher sea level rise rates driven by accelerated ice melting (Figure 7.6). If the growth of greenhouse gas emissions is not mitigated, the inundation of land could be more than 60% if the growth of emissions were reversed by mid century, based on comparison of sea-level rise projections under higher and lower emission scenarios. The extent of inundation of dry lands will, of course, be dependent on steps taken to respond to rising sea level, but these estimates reflect the amount of present land that will be below the level of normal spring high tides. One has to also keep in mind that as sea level rises, the volume of the Chesapeake Bay will increase and this will affect the normal range of the tides, in general, making the high tides a little higher (see Section 8).

Over 180 miles of land could be inundated if greenhouse gas emissions are not reduced

Most of the land subject to inundation is naturally located in the lowest lying parts of the State, notably along the Chesapeake Bay side of the lower Eastern Shore in Dorchester, Wicomico, and Somerset counties (Figure 7.8). Several islands (including Smith Island) and necks in this region, some inhabited, may be completely inundated or cut off within this century. Outside of this region, parts of Talbot, St. Mary's, Anne Arundel, and Baltimore counties are similarly susceptible. Assuming the projection included accelerated melting (resulting in sea-level rise to just over 3 feet; Figure 7.6), the homes of thousands of Marylanders would be lost. With a relative sea-level rise of just half that, which should be regarded as likely within the century, 264 miles of roadway, 226 miles of rail line, and 31% of the port facilities in Maryland would be at risk of inundation.

In addition to inundation, of course, substantial shoreline erosion will very likely occur, but the distance of shoreline retreat will vary greatly by location, depending on the land forms, soils, exposure, structural protection, and other factors. Even shorelines characterized by high bluffs are susceptible to retreat due to undermining and slope failure. The barrier islands of Maryland's ocean shore already experience morphological changes through erosion and overwash. If sea-level rise accelerated to 5 mm/year, as projected under the higher emissions scenario sometime during the middle of the century, it is very likely that northern Assateague Island, south of Ocean City, would fragment with one or more new inlets opening to the Coastal Bays.[95] This would dramatically impact not only this National Seashore but also the Coastal Bays, by exposure to waves and storm surge.



Adrian Jones

Eroding Chesapeake Bay shoreline.

STORMY WEATHER AHEAD?

The relationship between climate change and storms has received much attention after the devastation of Hurricane Katrina in 2005, which produced record storm surge and property loss and awakened the nation to its vulnerability. This relationship has been hotly debated within the scientific community, but another U.S. Climate Change Science Program (CCSP) synthesis report recently provided a consensus perspective based on the latest scientific results and analysis.[13] The Atlantic tropical storm and hurricane destructive potential increased since 1970 in association with warming Atlantic sea surface temperatures. And, it is likely that the annual numbers of tropical storms, hurricanes, and named hurricanes increased over the past 100 years during which the sea surface temperatures also increased. Also, it is very likely that the increase of greenhouse gases contributed to this ocean warming. The CCSP synthesis concluded that it is likely that hurricane rainfall and wind speeds will increase in response to global warming, but could not predict any change in frequency in hurricanes during this century. Two very recent studies have actually projected a decrease in hurricane and tropical storm frequency, but an increase in their wind intensity and rainfall.[96]

There has been a northward shift in the tracks of strong non-tropical storms, such as Nor'easters, but evidence is inconclusive in the Atlantic to draw conclusions about the strength of these storms. The CCSP synthesis concluded that there are likely to be more frequent strong non-tropical storms, with stronger winds and more extreme wave heights.

The degree to which Maryland will be confronted with more frequent or powerful storms depends heavily on the storm tracks, which scientists are not yet able to predict for future decades. However, because of the above projections of storm intensification and because hurricanes will be able to travel farther north as a result of the warming sea surface conditions, it is likely that Maryland will experience more powerful hurricanes or tropical storms and more powerful and frequent non-tropical storms than in the 20th century. It is not now possible, however, to quantify this increased risk.

While more intense storms (for example, with higher wind velocity and greater precipitation) generally produce greater storm surge (raising of the water level by high winds and reduced atmospheric pressure), the storm surge experienced depends greatly on the size, approach, and speed of the storm. For example, Hurricane Katrina produced much higher storm surge along the Mississippi Gulf Coast than Hurricane Camille, which hit more or less the same area with higher winds. Hurricane Isabel in 2003 produced record storm surges throughout much of the Chesapeake Bay because its path carried it up the western side of the Bay, with its counterclockwise winds driving water north all the way.[97] But, its storm surge was higher by about one foot than a large storm with a similar track that hit in the 1930s—the difference being the relative sea level rise that had taken place since then (Figure 7.2). This means that assessments of future vulnerability to storm surges must take into account both the moving baseline of sea-level rise and the greater potential of more intense storms.

NASA

The 2003 Hurricane Isabel makes landfall on the Mid-Atlantic.

www.wetlandswatch.org

Flood damage caused by Hurricane Isabel, Benedict, Maryland.

Section 8

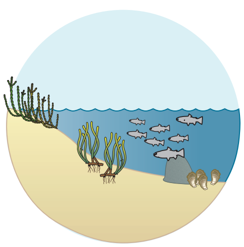
CHESAPEAKE BAY & COASTAL ECOSYSTEMS

KEY POINTS

- **Chesapeake and Coastal Bay restoration goals will likely be more difficult to achieve.**
  Increased winter-spring runoff washing more nutrients into the bays, higher temperatures, and stronger density stratification tend to exacerbate water quality impairment, alleviation of which is the prime restoration objective. Nutrient loads would have to be reduced beyond current targets to achieve water quality requirements.

- **Living resources will very likely change in species composition and abundance with warming.**
  A mixture of northern, cool water species and southern, warm water species currently resides in the Chesapeake Bay. Northern species such as soft shell clams and eelgrass are likely to be eliminated by later in the century. Southern species are very likely to increase in abundance because of milder winters.

- **As ocean water becomes more acidic, shellfish production could be affected.**
  Increasing atmospheric carbon dioxide has already lowered pH, a trend that is very likely to continue. Recent research indicates that the rate at which oysters and other coastal shellfish build their calcium carbonate shells will likely be affected, but whether this would occur in Maryland waters has not been evaluated.



In many respects, the Chesapeake Bay defines Maryland, extending through the center of the state, providing abundant resources, rich cultures, a port to the world, and commanding a major commitment for its protection and restoration. The changing climate will have multiple and complex effects on the Chesapeake Bay as well as on Maryland's Coastal Bays and the nearshore ocean environment. Warming of water temperatures throughout the year, earlier warming and later cooling, changes in precipitation and freshwater runoff, sea-level rise, and stronger winds and tropical and non-tropical storms will affect these coastal ecosystems and economies, including navigation, energy, tourism, and fishing industries. As discussed in the previous section, sea-level rise is very likely to have major consequences for coastal wetlands and shorelines, but will also deepen the bays, affecting both water circulation and biota.

Climate change will complicate the effects of nutrient pollution, the reduction of which is a central objective of the restoration and protection of the bays. Milder winters could lead to increased disease and parasitism in coastal living resources and changes in the species able to live here. Not all effects on Maryland's coastal ecosystems and industries will necessarily be negative. Shorter winters could mean longer growth seasons for blue crabs and improved fishery yields. Reductions in the frequency of ice formation could allow oysters to grow along shorelines and in very shallow water, much as they do in South and North Carolina.

The projected changes in temperature, precipitation, droughts, and floods that would affect coastal ecosystems during the century are described in Section 4; the likely consequences of global climate change on sea levels and storm intensity are described in Section 7. It is very likely that temperature and sea level will increase with the limits projected in Figures 4.2 and 7.6, respectively. For the reasons discussed in Section 4, there is less confidence in the trends and extent of precipitation and runoff.

Moving the Chesapeake Bay south along the coast as depicted in Figure 4.7 is a way to put the warming of the Bay in context. The Bay is displaced by matching the projected future Bay summer-fall temperatures with those presently experienced in estuarine waters to the south.[98] Warming by 2050 under either emissions scenario is likely to change seasonal temperatures to those currently experienced in North Carolina estuaries. The emissions scenarios would make a big difference by the end of the century, however, with conditions approximating present day southern North Carolina under the lower emissions scenario but south Florida under the high emissions scenario!

But, the vision of the future Chesapeake Bay harboring shrimp and alligators should be counter-balanced with caution. Warming will likely not geographically shift ecosystems; the Chesapeake is not likely to be just like Pamlico Sound by the middle of the century, harboring the exact same fish, plants, and animals and supporting similar coastal industries. Rather, changes in these ecosystems cannot be fully predicted and will probably yield novel species combinations, ecosystem adjustments, and mixes of living resources. Differences in the physical environment (for example, tidal range) will continue and changes in river flows and salinity will also affect the future ecosystems. Furthermore, geographic barriers may exist for more southern species to invade the Chesapeake Bay as conditions favor their colonization and native species could adapt to new conditions if they occur gradually.

NUTRIENT POLLUTION

Over-enrichment by human nutrient inputs, or eutrophication, has degraded the entire Chesapeake Bay ecosystem in pervasive ways, and reducing nutrient pollution is the lynchpin of the Chesapeake Bay Program. The Chesapeake 2000 Agreement commits the Bay states and federal government to reduce nutrient inputs in order to restore the quality of tidal waters sufficient to remove them from their listing as impaired, and this was determined to require a 48% reduction of nitrogen loading and a 53% of phosphorus loading, derived from a 1985 base load.[99] Reversing and controlling eutrophication is also a central management objective for the Coastal Bays.[100] While nutrients are essential for productive estuaries, excess nutrients contribute to reduced water clarity, loss of submerged vegetation, and low oxygen in bottom waters during summer months (hypoxia or so-called "dead zones"; Figure 8.1). By affecting temperature, precipitation and runoff, sea level and winds, and possibly nutrient loading, climate change will affect the capacity of Maryland's estuaries to assimilate nutrients and recover from eutrophication.

Reducing nutrient pollution is critical for restoring Chesapeake and Coastal Bays

River flows, nutrients, and hypoxia

Freshwater inflows into the Chesapeake Bay affect salinity and circulation and, thereby, the distribution of organisms and the functioning of the ecosystem. Freshwater inflow typically peaks during the spring as snow melts and precipitation increases.[101] The spring flow delivers a pulse of nutrients that, along with light and rising temperatures, fuels a bloom of microscopic planktonic algae, particularly diatoms, in the upper- to mid-Bay.[93] The spring

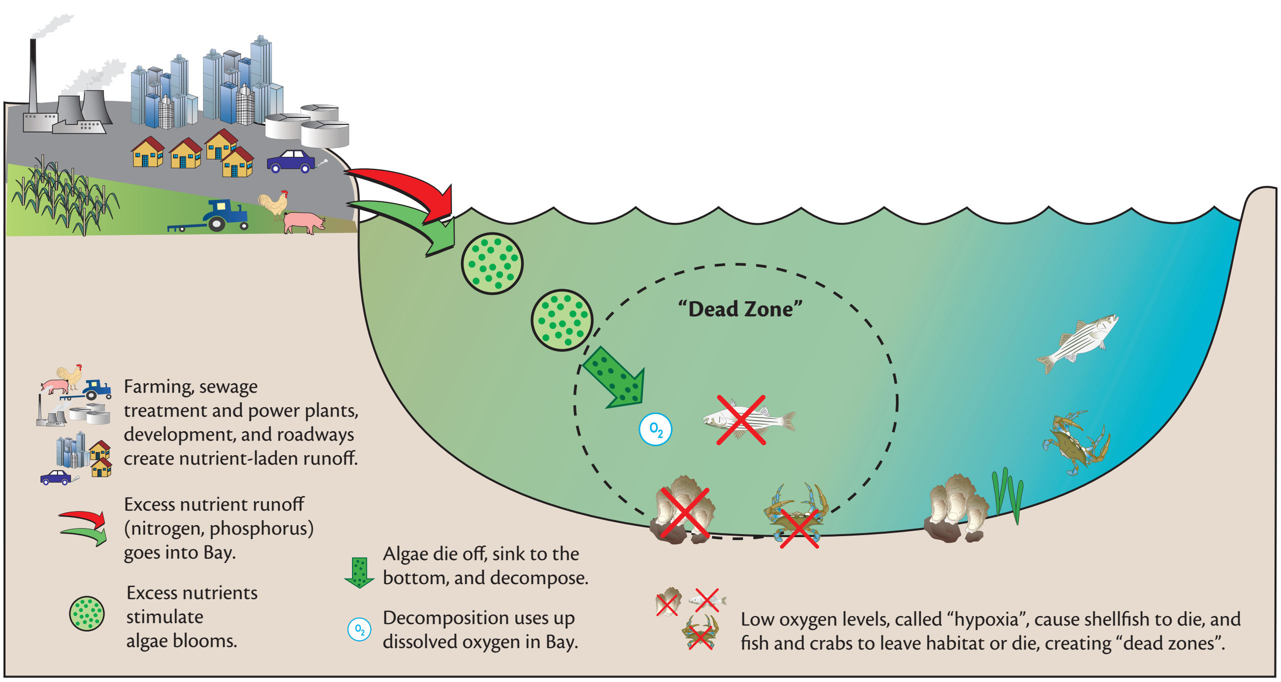


Figure 8.1. Processes contributing to severely low dissolved oxygen levels (hypoxia) in the Chesapeake Bay,

phytoplankton bloom, maintained by the nutrient input and sufficient mixing of the water column, is largely not consumed by zooplankton. Most of the biomass produced sinks to the bottom where it is eventually decomposed by bacteria as temperatures warm toward the summer. The respiration of bacteria consumes dissolved oxygen, which is not replenished by mixing because the bottom water is cooler and saltier, and therefore denser. This density stratification prevents reoxygenation of bottom waters, but when mixing events occur, the nutrients released by microbial decomposition stimulates more algal blooms, thus continuing a vicious cycle that maintains hypoxic (low oxygen) or anoxic (no oxygen) conditions.

Climate models project increasing winter temperatures (by an average of 4 and 7°F for lower and higher emissions scenarios, respectively; Figure 4.2) and rainfall (by about 10-13% under either scenario; Figure 4.8) over the century for Maryland. On the other hand, warming over the Susquehanna River Basin is very likely to reduce the storage of water in the form of snow in the watershed[7] and therefore even out the inflows to the Bay during the winter-summer period. A reduction in the peak spring inflows could result in a reduced spring phytoplankton bloom as nutrients would be delivered more evenly over the winter and spring. Warmer winter temperatures could cause an earlier occurrence of a smaller spring bloom centered in the upper Chesapeake Bay.

Dead zones are likely to expand with higher temperatures and precipitation

These outcomes are largely speculative and based on understanding of recent conditions, but illustrate the complexity of the physical, chemical, and biological process that regulate the production of organic matter in the nutrient-enriched Chesapeake Bay. Of course, these processes will also be subject to change as the climate changes. Temperature increases affect the production of phytoplankton biomass and the grazing of this

Caroline Wicks

An excess of nutrients can lead to large algal blooms that cover shorelines.

Jane Hawkey

Stormwater runoff from roads and parking lots enter Maryland waterways.

biomass by zooplankton.[102] A reduction in winter-spring phytoplankton biomass has been observed in Narragansett Bay, Rhode Island, during unusually warm winters.[103] In particular, and potentially quite significantly, if relative sea level were to increase by as much as 3 feet, as considered in Section 7, the volume of the Chesapeake Bay would increase by about 14%, shifting the salinity gradient, changing physical processes resulting from mixing of fresh and ocean water, and increasing the volume of bottom waters susceptible to hypoxia.

In spite of this complexity, climate change is likely to exacerbate hypoxia. Warmer waters can hold less oxygen to begin with, delivery of nutrients from the watershed would increase with increased precipitation and runoff, and salinity decreases and temperature increases may increase density stratification between surface and bottom waters. Considering these facts, it is more likely than not that hypoxia will worsen as a result of 21st century climate change unless greater reductions in nutrient loading are achieved and sustained. [104,105]

Harmful algal blooms

Harmful algal blooms (HABs) are a growing problem affecting aquatic ecosystems worldwide, including the Chesapeake Bay.[106] These blooms yield high densities of algae that negatively affect other organisms or produce toxins harmful to animals.[107] Humans may be affected by HAB toxins either through direct exposure or by consumption of seafood containing the toxins. The Chesapeake Bay and the Coastal Bays are home to several potential HAB-forming species, including dinoflagellates (e.g., *Pfiesteria piscicida, Prorocentrum minimum, Karlodinium micrum*), a raphidophyte (*Heterosigma akashiwo*) and a cyanobacterium (*Microcystis aeruginosa*).[108] HABs are commonly associated with nutrient over-enrichment, although many other factors affect their occurrence and prevalence. Some species of harmful dinoflagellates, such as *Prorocentrum*, and cyanobacteria (blue green algae) seem to be favored and grow faster under high temperature.[109]

Climate change is very likely to produce warm surface water temperatures and prolonged density stratification between surface and bottom waters conditions that favor dinoflagellate and blue green algal species, some of which are HAB-forming. But without more specific evidence and consideration of other moderating effects, such as predators and competitors, it is not possible to conclude that HABs will increase as a result of warmer temperatures alone. Nutrient inputs will remain the key factor in controlling algal blooms in the warmer bays.

Effects on harmful algal blooms are difficult to predict

Habitat squeeze

The high oxygen requirements for respiration under high temperatures and expansive dead zones act to reduce the habitats that can be used by fish such as striped bass, or rockfish as they are locally known. These factors may co-occur to the point of acute stress and fish kills, which already occur with some frequency in the Chesapeake Bay and in poorly flushed tidal creeks and canals in the Coastal Bays. Alternatively, the fish might swim away to avoid the stressful conditions in what might otherwise be preferred habitats. This can lead to increased risk of predation and capture by fishers or to increased competition within the reduced, remaining habitat (Figure 8.2). The high densities of fish in the few

www.severnriverkeeper.org

Weems Creek fish kill due to low dissolved oxygen, June 2007.

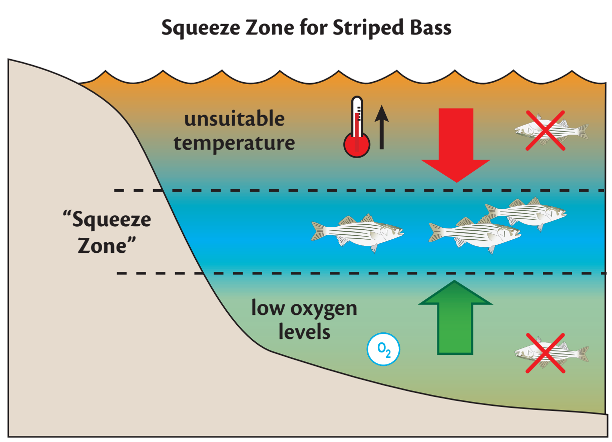


Figure 8.2. Climate change could compress the habitats suitable for striped bass by increasing surface water temperature to physiologically stressful levels and expanding the volume of bottom waters experiencing hypoxia or anoxia.

remaining suitable areas can also increase the risk of disease and parasitic infection or infestation, contributing additional stress to a fish that is already behaving, feeding and growing below par. Habitat squeezes in the Chesapeake Bay due to the degraded water quality and warming temperatures since 1950 may have already contributed to local extinctions of sturgeons, which are among the least tolerant Chesapeake Bay species to hypoxic summertime conditions.

Management implications

Although still far from reaching the restoration goals for the Chesapeake Bay, considerable reduction of nitrogen and phosphorus loads to the Bay has been accomplished though large public investments in waste treatment facilities and land management practices to reduce the runoff of nutrients. In addition to effects that climate change might have on hypoxia, harmful algal blooms, and habitat suitability, it could affect agricultural practices and forest health, and increase the frequency of flooding in ways that deliver more nutrients to the estuaries and worsen the symptoms of eutrophication as well as cause additional challenges in those sectors. If this happens, nutrient loads would have to be reduced beyond current targets in order to meet the water quality need to restore living resources.

> Greater reductions in nutrient loads may be required to achieve restoration goals

ESTUARINE SEDIMENTS

The sediment that lines both the shoreline and the bottom of Chesapeake Bay and the Coastal Bays also shapes the varied habitats of its productive ecosystem. If this sediment remains on the shore or on the bottom and if inflowing rivers run clear, then the clarity and productivity of the Bay's waters are only limited by the nutrient supply and perhaps the stratification. However, if sediment is stirred into these waters, by waves, currents, and their associated turbulence, or delivered by muddy rivers, then it may deprive submerged vegetation of needed light, deprive oysters their ability to sustain viable reefs in the face of siltation, and alter the foraging or predation of animals dependent on visual cues. Because a portion of the bottom sediment is easily erodible, estuarine circulation creates a zone of maximum turbidity near the head of Chesapeake Bay.[110] Although this turbidity maximum is confined to a limited reach of the estuary, it constitutes an ecosystem crucial to early life stages of important fisheries.[111]

Over geological time, estuaries are ephemeral

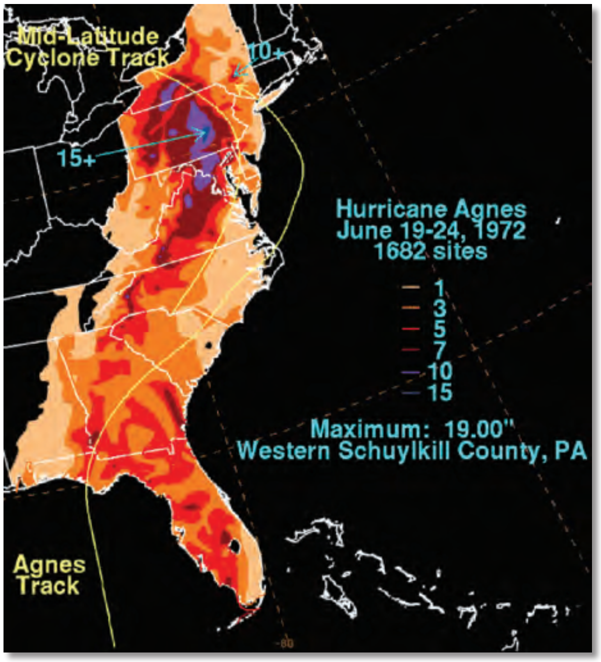
Jane Thomas

A plume of sediment, possibly from an adjacent construction site, fills a river.

features, ultimately losing the battle between sea-level rise which acts to create them and the movement of sediment off the land to fill their shallow depths. With the slowing of the rise of sea level 5,000 years ago (Figure 7.1), despite the fact that land subsidence was still raising the water levels, the filling of the Chesapeake Bay with sediments was also occurring, both from the head with sediments coming down the Susquehanna and the other great rivers and from the mouth with sand transported into the mouth of the Bay from the continental shelf. Land clearing during the 17th and 18th centuries resulted in large influx of sediments, filling in many smaller tributaries that were navigable during the colonial period. Continued relative sea-level rise a century ago, dominated by the sinking of the land rather than the rising of the ocean (see Section 7), eroded shorelines and upland deposits, bringing more sediments into the estuary. The gradual disappearance of Chesapeake Bay islands provides a graphic testament to this progression.[112]

The processes that control delivery of sediment to the Bay's waters—shoreline erosion, resuspension, or erosion in the watershed and subsequent delivery by rivers—are, in turn, controlled by the weather. As in other bodies of water, sediment transport in the Bay and its watershed occurs as a comparatively slow, inexorable process occasionally punctuated by episodes of wholesale erosion and deposition driven by violent storms. Hurricanes are especially effective because they combine extreme winds and extreme precipitation. As far as sediment is concerned, extreme precipitation is the greater concern because it rapidly erodes the watershed. Increased flashiness in runoff due to both land development and, more recently, attributable to climate change washes more sediment off the land surface and erodes stream beds. Storm-driven water flow can be devastatingly effective in moving large quantities of sediment in a short interval. As Hurricane Agnes passed through the Chesapeake watershed in 1972, dropping 3 to 6 inches of rain onto already saturated soils, some 31 million metric tons of sediment were swept into the Bay, depositing 40 years worth of sediments based on the average deposition rate.

The scale and geometry of Chesapeake Bay make it particularly vulnerable to tropical cyclones that travel a path with their center or eye moving on the west side of the Bay.[113] While eastern-track storms act to force water out of the Bay, these western storm tracks create destructive storm surges, such as occurred during the recent 2003 Hurricane Isabel. The linear nature of the Bay and its larger tributaries enables long fetches that allow efficient transfer of wind forces that drive these larger surges; these surges enhance the natural two-day oscillation of water level in the Bay.



NOAA

Hurricane Agnes rainfall accumulations.

As discussed in Section 7, global climate is very likely to accelerate sea-level rise and thus the erosion and inundation wetlands and low-lying lands. Erosion, as the shoreline retreats inland, will disperse sediment into the Chesapeake Bay and Coastal Bays, further contributing to the excess turbidity that limits light penetration. Stronger hurricanes and non-tropical storms, which are likely in this warming era, will increase the probably of sustained heavy downpours such as experienced during Hurricane Agnes. Such large storms that are accompanied by heavy and widespread precipitation throughout the watershed can have pervasive and lasting impacts on coastal ecosystems. Hurricane

J. Stein

Shoreline erosion from storms.

Agnes not only added a huge quantity of sediments to the Chesapeake Bay, but also added nutrients and organic matter, devastated oyster reefs and aquatic vegetation beds, and affected key species, with repercussions to the ecosystem lasting for decades.

LIVING RESOURCES

Present mixture of cool and warm species

The Chesapeake Bay is famous for its role in supporting spawning, nursery, and feeding habitats for diverse and important living resources. Historically, U.S. fisheries for shad, herrings, striped bass, menhaden, and oysters were centered here in the Chesapeake Bay. The Chesapeake Bay remains one of the most important nurseries for striped bass, croaker, eels, and blue crabs. The Atlantic menhaden fishery is now principally limited to the lower Chesapeake Bay, reflecting the productive feeding conditions that occur there during summer and fall months. Size, surrounding geography, tides, currents, and other physical features all contribute to the Chesapeake Bay's productive food webs. But the diversity and year-to-year abundances of living resources also depend heavily on the Chesapeake Bay's latitude and seasons. The Chesapeake Bay represents a transition zone between more southerly ranging temperate-subtropical species and more northern range boreal-temperate species. Interestingly, the Chesapeake Bay also shows the greatest seasonal temperature range of any other major U.S. Atlantic estuary. Therefore, in the future, warming in the Chesapeake will likely diminish the role of boreal-temperate species (Figure 8.3) and affect seasonal temperature fluctuations, which currently have an important role in nursery function and how food webs and fish communities are structured.[114]

Chesapeake Bay is a transition zone between northern and southern species

Shift to warm species

More northerly, cool temperature species such as eelgrass, soft shell clams, and sturgeons have already been in decline in the Chesapeake Bay. Soft shell clams occur at their southern limit in the Chesapeake Bay and their Maryland landings have declined from over 6 million pounds in the 1960s to less than 300,000 pounds in recent years.[115] Trends of diminished production of soft shell clams in Europe are related to climate, with poor juvenile production linked to warming at the southern extreme of its range in the Netherlands portion of the Wadden Sea.[116] Warming in the Chesapeake and Coastal Bays, coupled with existing stresses due to disease, pollution, and sediments, is likely to eliminate commercial harvests of the once economically important soft shell clam in the coming decades and may extinguish its local populations all together. As indicated below, warming will also confound efforts to restore eelgrass and sturgeons, compounding the other stresses, such as turbid waters and hypoxia, presently limiting their recovery.

Atlantic croaker is a subtropical fish that is already making significant inroads in temperate estuaries like the Chesapeake and Delaware Bay. Croaker juveniles can reside during winter months in Mid-Atlantic estuaries but can occasionally experience lethally cold temperatures, particularly to the north. During recent decades, more moderate winter temperatures in the Chesapeake Bay have increased juvenile growth and survival. Indeed during the last twenty years, Chesapeake landings

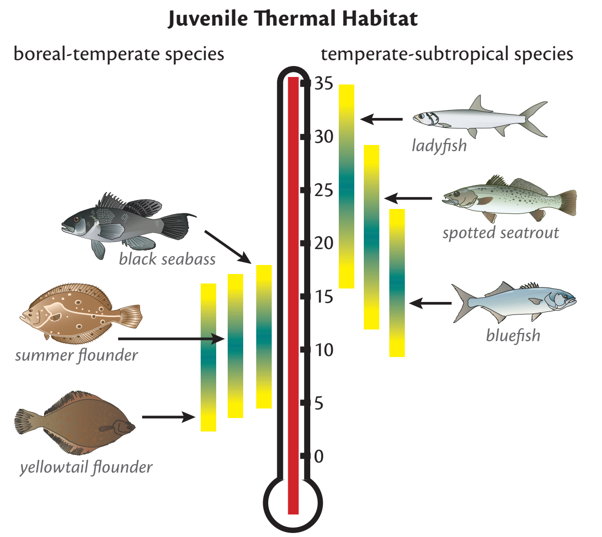


Figure 8.3. Thermal ranges for juvenile fishes native to U.S. Atlantic coastal waters (temperature in degrees C).[114]

Atlantic croakers are expanding their range in the Mid-Atlantic.

of Atlantic croaker have increased ten-fold to 8.6 million pounds in 2006 and now exceed commercial landings for striped bass (3.6 million pounds).[117]

The Atlantic croaker belongs to the drum family, which also include black drum, red drum, weakfish, spotted and speckled sea trout, spot, and Northern and Southern kingfish. Other members of this family of fishes, together with other more sub-tropical species, are likely to become more frequent and longer term visitors to the Chesapeake Bay. Fish species that already occur in Virginia coastal waters that should also become more prevalent and abundant with increased coastal water temperature include southern flounder, cobia, spadefish, Spanish mackerel, mullet, tarpon, and pinfish. On the other hand, more temperate species such as yellow perch, white perch, striped bass, black sea bass, tautog, summer and winter flounders, silver hake, and scup will be stressed by warming of the coastal waters.

Milder winters could also allow brown and pink shrimp to complete their life cycles in the Chesapeake and Coastal Bays, where they are now only occasional summertime visitors. These shrimp are abundant in North Carolina (e.g., Pamlico Sound), where they support important fisheries. Establishment of shrimp populations in the Chesapeake Bay could result in important commercial opportunities in the future, but would also have important but unpredictable effects on both the prey and predators of shrimp.

Warming could also favor the establishment of invasive populations of nonnative species. This is particularly true for species from distant parts that hitchhiked on or in the ballast water of ships. Also, species may escape captivity and establish local populations. For example, the beautiful lionfish, a native of the Indo-Pacific and popular with salt-water aquarists, was inadvertently introduced in Florida in the early 1990s and has expanded its range northward to North Carolina, achieving populations equal in number to those of native groupers.[118] Adding an additional species, such as the lionfish, to the mix has the potential to adversely affect native fishes through competition for prey and habitat and by directly eating native juveniles. With warming of coastal ocean temperatures, the lionfish is expected to continue a northward range expansion (Figure 8.4). Similarly, warmer waters may aid the spread (accidental or otherwise) of northern snakehead fish, which now occurs in the Potomac River[119], to other parts of the Chesapeake watershed.

Warmer winter temperatures could open the door to more non-native, invasive species

NOAA

Figure 8.4. Locations in the Atlantic Ocean where lionfish have been reported as of May 2003.

Changed seasonality

Several important fish species show cycles of dominance that are the opposite of each other. Bluefish were abundant in the 1970s and 1980s but then declined during the recent period of high striped bass abundance. These cycles are thought to be due to the seasonal patterns of temperature and precipitation. Winter and early spring conditions seem particularly important in 'setting the clock' for patterns of juvenile production observed during the subsequent summer and fall seasons. Cold winter temperatures and high winter flows are associated with high abundance later in the year of juvenile Atlantic silversides (an important forage fish), striped bass, white perch, and Atlantic needlefish.[120] Species associated with the converse—low winter flows and high winter temperatures—include bluefish, spot, bay anchovy, and northern puffer.

Wikipedia Commons

Striped bass from the Chesapeake Bay.

Shifts between these two groups occur even when winter temperatures differ less than 2°F, well within the range of warming projected in the next fifty years. Species will adapt to some degree to changing environmental changes, but because this will require generational time scales, lowered abundance of the group of species that includes striped bass are likely for the Chesapeake Bay.

Milder winters would lead to longer growing seasons for species such as sea grasses, oysters, blue crab, eels, white perch, and the resident portion of the striped bass population. Blue crabs become functionally dormant during winter months when temperatures drop below 50°F. Below 41°F in bottom waters, winter temperatures become lethal.[121] Winter temperature projections indicate a 20% reduction in the number of days with less than 50°F by 2050 and, under the higher emissions scenario, a 36% reduction by 2100. The projections suggest that by mid-century there would be no severe winters with more than a week of water temperatures below 41°F. These warmer conditions are likely to shorten the time it takes for blue crabs to grow and reproduce, leading to increased productivity and yield to commercial fisheries. Of course, this assumes that there would be sufficient prey for blue crabs and that warming during the summer does not reduce the growth rate or increase the death rate as a result of greater disease incidence or expanded hypoxia.

Milder winters could mean longer growing seasons for species such as blue crabs

The degree to which the Chesapeake Bay freezes over is already much reduced in comparison to fifty years ago. The reduced occurrence of ice in shoreline habitats could permit oysters to colonize sheltered shorelines and very shallow waters to form reefs that emerge at low tide, much as they do now in North Carolina. Such reefs could provide new opportunities for restoration and aquaculture by enabling access and enforcement of protection of rebuilding or leased bottom reefs.

Warming and the shifting of seasons are likely to affect migration and spawning behaviors of Chesapeake Bay fish. Striped bass, shads and other fish that migrate into the Chesapeake for spring spawning will likely shift their arrival times to earlier dates. Such a shift is already apparent in migrating fish in other regions. Spawning migrations by Atlantic salmon in the Connecticut River are now over ten days earlier than in 1978.[122] American shad migrated five weeks earlier in 1993 than in 1949 in the Columbia River.[123] Changes in timing of spawning migrations by adult fish can influence early survival and growth of their offspring. For instance, fish larvae in the Chesapeake Bay rely on spring plankton blooms to support their growth and development. Early spawning migrations by adults could result in a 'mismatch' [124] between spawning and plankton blooms needed to support the growth and survival of larvae (Figure 8.5).

Another type of mismatch that can occur is between migration timing and fishing regulations. If changes in the timing of migration are sufficiently large, they may impact the timing and duration of a fishing season. For example, the Maryland 'trophy' striped bass recreational season targets post-spawning individuals. Here, early spawning could effectively reduce the fishing season if the season has a fixed start date. In response to increasing temperatures, management agencies may need to explore temperature-specific regulations, rather than fixed fishing seasons.

The Great Shellfish Bay

Native Americans referred to it as Chesepiooc, or

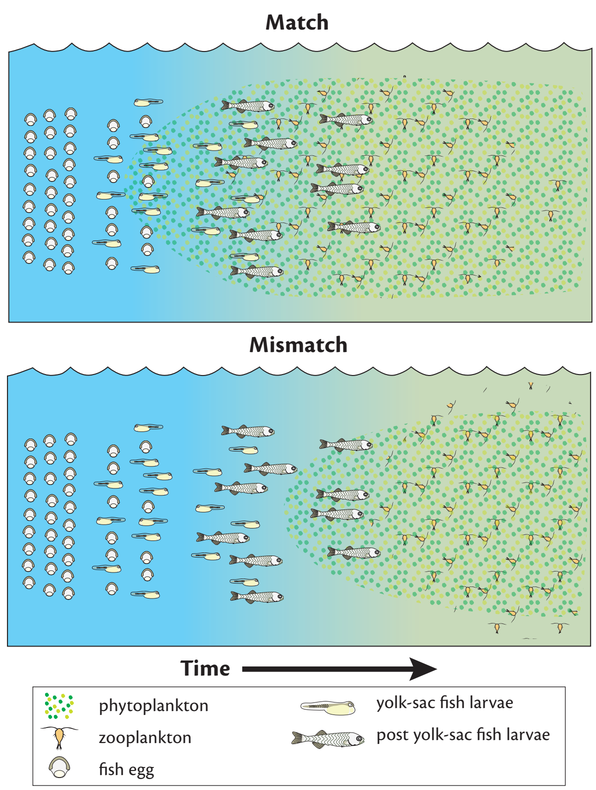


Figure 8.5. Matching of first-feeding fish larvae with the timing of zooplankton peak abundance. A match occurs when spawning is well-timed and there is overlap between the occurrence of first feeding larvae and peaks in zooplankton abundance and favors early growth and survival. Mismatches of timing and location correspond to poor growth and survival conditions.

great shellfish bay, because of the vast abundance of oysters that once characterized the Chesapeake Bay. Decimated initially by overharvesting that resulted in removal of their reefs themselves and later by introduced diseases, native oysters are present at a very small fraction of their original abundance. Substantial efforts are underway to try to determine how to increase oyster aquaculture and to restore oyster reefs for the role they play in providing habitat for other organisms and clearing up estuarine waters by their filter feeding.

Variations in climate have always been important in determining the success of oysters. Temperature and precipitation—through its effect on salinity—affect reproduction, the development of larvae, and the survival of newly settled oyster spat. Still, through the 1970s, the abundance of juvenile oysters in one year was heavily influenced by the abundance of the adult parents the year before.[125] Recently, it appears that at such low abundance, the number of adults has relatively little influence on the number of juveniles, which is now predominantly determined by water temperature and particularly salinity.[126] If higher river runoff regularly lowers Bay salinity, fewer juvenile oysters would be expected to survive, but if sea-level rise increases the volume of the Bay sufficiently to increase salinity, the reverse would be true.

The two prevalent oyster diseases, commonly called Dermo and MSX, are also likely to respond to climate change. Dermo epidemics are more severe in Chesapeake Bay after dry and warm winters. Increased water temperatures cause more rapid cell growth by the Dermo parasite once it has infected an oyster.[127] As conditions have warmed, Dermo has extended farther up the East Coast, even to New England.[128] But it may be the case that the Chesapeake Bay is already warm enough so that temperature is not a factor limiting Dermo epidemics except under higher salinity conditions. MSX is also more prevalent in oysters after dry and warm winters and less so following cold winters (less than 37°F) and under low salinity.[129] Successive cold winters keeps MSX in check, but, as this becomes less likely with the warming waters of the Chesapeake Bay and Coastal Bays, this disease is likely to remain at least as prevalent if not more so.

Warmer conditions have allowed oyster diseases to spread

Overall, the net effects of climate change on oyster populations, aquaculture, and restoration are difficult to project. They will depend not only on the direct effects of salinity and temperature on oyster growth and survival, but importantly on how the changing conditions affect the prevalence and virulence of the disease organisms, which warmer conditions should favor. Still, it should be remembered that native oyster populations prosper in Gulf Coast estuaries, which experience higher temperatures and more variable salinities.

Aquatic vegetation

Submerged aquatic vegetation (vascular plants that live underwater) constitutes a very important component of the Chesapeake Bay and Coastal Bay ecosystems. These plants increase water quality in shallow water areas by reducing the resuspension of sediment and releasing oxygen to the sediments, thereby enhancing nutrient recycling. The vegetation provides habitat for many animals, including blue crabs, which use it as a refuge from predators during early life.[130] There is currently a worldwide decline in coastal submerged plants, or seagrasses, including in the Chesapeake Bay and Coastal Bays.[131] Much

NOAA

Oyster reef, Chesapeake Bay.

Jane Hawkey

Aquatic vegetation provides habitat for juvenile fish and crabs.

of this loss is a result of nutrient over-enrichment, which increases shading by phytoplankton and stimulates the growth of algae on the blades of vegetation, thereby reducing the light needed for photosynthesis.[93]

Aquatic vegetation requires suitable temperature, salinity, nutrients, and, in particular, light.[132] Climate change could affect, directly or indirectly, all of these variables. As in the case of fish and other animal species, aquatic plant species have different latitudinal distributions that are closely related to their temperature tolerance. The dominant aquatic plant species under the higher salinity conditions of the lower Chesapeake Bay and the Coastal Bays is eelgrass (*Zostera marina*), a boreal-temperate species with a southern limit of distribution in North Carolina.[133] Largely as a result of declining water quality and increased light limitation, eelgrass has become much less abundant in Maryland bays. During the high salinity and high water clarity conditions that existed in the 1960s, eelgrass was found as far up the Chesapeake Bay as Kent Island, but now is largely limited to the Tangier Sound region (Figure 8.6), where it provides valuable habitat for early juvenile blue crabs and refuge for the highly vulnerable soft stages of adults.

Eelgrass is at risk of elimination and other species will replace it

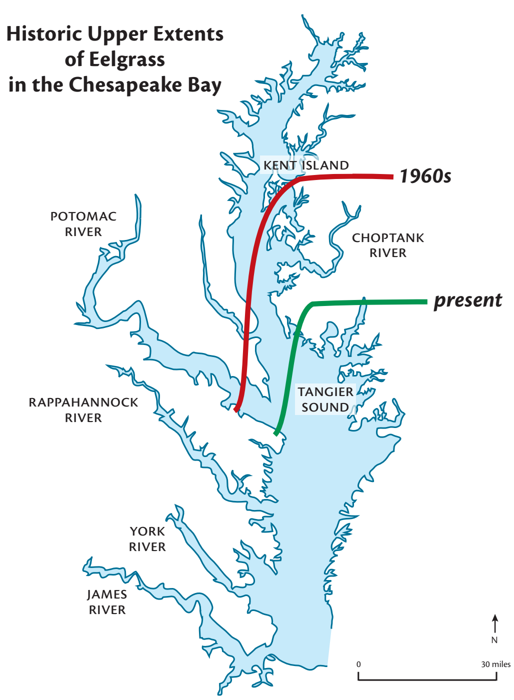


Figure 8.6. Changes in the distribution of eelgrass (*Zostera marina*) in the Chesapeake Bay.

At high summer temperatures, eelgrass photosynthesis cannot keep pace with its respiration and the plant loses its leaves and even its below-ground rhizomes may die.[134] During unusually hot summers, for example in 2005, the dieback of eelgrass was extensive and recovery in the following year was dependent on the bank of seeds left in the sediment. Because eelgrass seeds do not remain viable for over a year, if there were a succession of hot summers, eelgrass populations could be eliminated from the Bay. Consequently, the outlook for eelgrass in the warming bays is not promising. By mid-century, it is as likely as not that eelgrass beds will no longer exist in the Chesapeake Bay under the lower emissions scenario, and likely that it will be functionally eliminated under the higher emissions scenario. It is very likely that eelgrass will be completely extirpated by the end of the century under either scenario. It is possible, however, that shoalgrass (*Halodule beaudettei*), a subtropical species that is abundant in higher salinity portions of North Carolina's sounds could colonize the Chesapeake Bay and Coastal Bays as the winters warm. However, it does not tolerate low salinity as much as eelgrass and, thus, its distribution in the upper Bay would be more limited. Shoalgrass is also more ephemeral and provides less robust habitat than eelgrass.

As sea level continues to rise, increasing water depths will reduce the light available to aquatic vegetation where it presently occurs. However, the vegetation could migrate shoreward and even occupy areas that are presently tidal wetlands or dry land. However, as wetlands erode away, hard clay-rich deposits often remain, a consolidated remnant of older wetland soils. These clay deposits are not suitable soils for submerged vegetation and until covered by a veneer of sand will not be colonized.[135] With the increased volume of the Chesapeake Bay because of accelerated sea-level rise, higher salinity conditions are likely to extend farther up the Bay. While greater intrusion of salinity may be beneficial to seagrasses such as eelgrass and shoalgrass (if it successfully colonizes the Bay), it could constrict the habitat suitable for plants originating from fresh waters, such as redhead grass and sago pondweed, that are prevalent in lower salinity regions, where aquatic vegetation is currently expanding as water quality improves.[93]

While the net effects of climate change on aquatic vegetation are difficult to predict because of the complex and interacting effects of temperature, salinity, water quality, and sea level, it is very likely that the biomass, species composition, and distribution of aquatic vegetation in the Chesapeake Bay and Coastal Bays will be significantly affected by climate change.

OCEAN ACIDIFICATION

In addition to its greenhouse effect, the increase in the concentration of carbon dioxide in the atmosphere is gradually acidifying, or lowering the pH, of the ocean. Much of the carbon dioxide that is released from human activities is actually taken up by the ocean, moderating its effect on global warming. However, when carbon dioxide dissolves in sea water, it decreases its pH. From the beginning of the industrial era, pH has declined about 0.1 units from its normal 8.18, and may decline by a further 0.3 to 0.5 units by 2100.[2] While this will not make the oceans actually acidic (below 7 pH units), such a decline in pH affects the ability of organisms to create shells or skeletons of calcium carbonate because lowering the pH decreases the concentration of the carbonate ions that are required.

Ocean acidification is the sleeper issue of global change, because not only are the potential effects on the world's coral reefs profound, but the process of acidification also reduces the ocean's capacity to absorb more carbon dioxide from the atmosphere. The effects of ocean acidification have just recently been receiving attention, most of which is focused on corals and the plankton of the open ocean. Recent studies have shown that mollusks that are ecologically and economically important in coastal waters may be vulnerable to the effects of ocean acidification. Mussel and oyster calcification rates were projected to decline by 25 and 20%, respectively by the end of the century[136], as well as the ability of oyster larvae to form their thin shells when pH was reduced to 7.4 through addition of carbon dioxide.[137]

Declining ocean pH affects ability of oysters and other shellfish to form shells

Research on the processes and effects of acidification in Mid-Atlantic estuaries and coastal waters has scarcely begun. Important questions remain regarding the interaction of the bicarbonate created when carbon dioxide dissolves in these waters with other chemical constituents. This will affect the level of acidity likely to be experienced and the effects that might be realized not only on mollusks, but also crustaceans, starfish, and other organisms that create calcareous skeletons.

Holly Weiss

Maryland beach.

Ben Fertig

The native eastern oyster, *Crassostrea virginica*.

Section 9

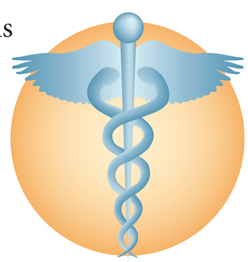
HUMAN HEALTH

KEY POINTS

- **Health risks due to heat stress are very likely to increase if emissions are not reduced.**
Under the higher emissions scenario, in particular, heat waves are projected to greatly increase risks of illness and death before the end of the century, with an average of 24 days per summer exceeding 100°F. Some, but not all, of these increased risks can be reduced by air conditioning and other adaptation measures.

- **Respiratory illnesses are likely to increase, unless air pollution is greatly reduced.**
More ozone, responsible for multiple respiratory illnesses, is formed under prolonged, high temperatures. Releases of air pollutants (nitrogen oxides and volatile organic compounds) that cause ozone to be formed have been declining, but would have to be reduced much more to avoid a reversal in progress toward achieving air quality standards.

- **Increased risks of pathogenic diseases are less likely.**
The mortality due to vector-borne and non-vector borne diseases in the United States is low because of public health precautions and treatment. Climate change might affect the exposure of Marylanders to pathogens such as the West Nile virus, but precautions and treatment could manage this risk.



Human well-being is obviously affected by the weather and the changing climate will have multiple ramifications for human health as well as comfort and enjoyment. Human health has the greatest sensitivity to climate change with regard to heat stress; the effects of storms that generate floods and extremely high winds; air pollution effects, particularly as they cause or exacerbate asthma and other respiratory maladies; and diseases caused by pathogens that are borne by insects and other vectors, water, and food.[138] The risk of storms and floods are addressed earlier in this assessment. Here the potential impacts of climate change-related heat waves, air quality, and pathogenic diseases on human health in Maryland are evaluated.

HEAT WAVES

Global warming is likely to result in substantially higher temperatures both in winter and summer in Maryland. While there could be some benefits in terms of reduced deaths from cardiovascular disease (for example, as result of milder winters) Maryland's population experiences very few deaths with its temperate climate related to extreme winter temperatures. Rather, most assessments in the United States have appropriately focused on the health risks of extreme heat. In six out of ten recent years, heat has been the leading weather-related killer in the United States.[7]

Concerns about the increased health risks from heat waves caused by global warming are not far-fetched. The death of an estimated 35,000 people, attributable to the August 2003 heat wave in Europe, was a sobering experience.[139] Parts of France experienced seven consecutive days with temperatures more than 104°F and 14,800 people died in that country alone. The situation in Europe

NOAA

Dawn brings on the day's heat.

was particularly acute because the population was not acclimated to warm summers and there was little air conditioning. Most of those who died were elderly. Closer to home, a 1995 heat wave in Chicago resulted in an estimated 696 deaths.[140] While the European heat wave was related to unusual weather patterns and not primarily to climate change, climate models predict frequent summer conditions not unlike those in 2003 during the latter part of the 21st century, indicating that, for many purposes, the 2003 event can be used as an analog of future summers in climate impact assessments.[141]

Heat stress can result in illnesses caused by heat cramps, fainting, heat exhaustion, and heatstroke and result in death.[142] Except for cramps, heat-related illnesses are the result of the body's failure to regulate its internal temperature. Our bodies respond to hot weather by an increase in blood circulation and increase in perspiration, both in an attempt to rid the body of heat. The effectiveness of such heat loss is reduced when air temperature and humidity increase. The ability to increase circulation may be limited by heart rate and the blood volume, which is reduced because of the loss of body fluids.

Several factors can increase the risk of heat-related illness. Both individuals over 65 and the very young are at higher risk because they have less ability to control internal temperatures and are more susceptible to dehydration. Reduced physical fitness, obesity, existing illnesses, and the use of medicinal drugs such as stimulants and beta-blockers all increase the risk of heat stress. Individuals not acclimated to high temperature or suffering from exertion are also more susceptible. City dwellers, particularly those of lower economic status who cannot afford air conditioning, are at greater risk because of the urban heat island effect, where buildings and paved surfaces hold the heat well into the night.[143] Many of those who die of heat stress live alone and do not seek treatment or are not discovered until it is too late. And most of those who die in urban areas as a result of heat stress succumb during the night, when temperatures are expected to rise even more than during the daytime.[42]

The average annual frequency of days with a maximum temperature exceeding 90°F in Maryland is projected to grow gradually over the century, but more dramatically later in the century. Near the end of the century under the lower emissions scenario, the model averages project about 64 days per year would exceed 90°F and 10 days per year would exceed 100°F (Figure 4.4). Under the higher emissions scenario, these numbers would grow to 95 and 24 days per year, respectively. These numbers would be higher in urban areas due to the urban 'heat island' effect. These projections are generally similar to those derived by the Northeastern Climate Impacts Assessment for Philadelphia (Figure 9.1).[7] Put another way, these projections indicate that toward the end of the century under the high emissions scenario, it would be a rare summer day when the high temperature did not top 90°F and there would be nearly a month where temperatures reached 100°F. A considerable increase in 90°F days is very likely inevitable, even if greenhouse gas emissions were reduced around the middle of the century (lower

With continued growth in emissions, 24 days per summer are projected to exceed 100°F

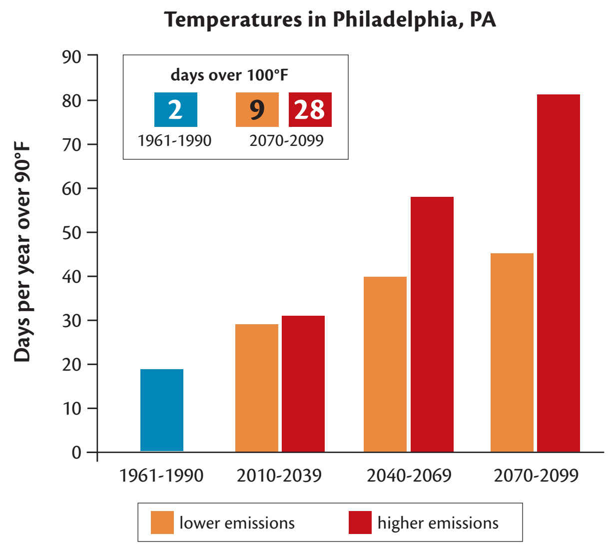


Figure 9.1. Model projections of number of days per year that the maximum temperatures would exceed 90°F and 100°F in Philadelphia according the NECIA.[7] The higher emissions scenario employed assumed more rapid growth of greenhouse gas emissions than the higher emissions scenario in this assessment.

Andrea Hetherington

Cooling off in the intense summer heat.

emissions scenario), but only about half as many 100°F days would occur if emissions were reduced.

Of course, as the frequency of very hot days increases so does the likelihood that there will be a successive number of these days, i.e., a heat wave. Based on the model projections, there is a high probability that, late in the century, heat waves with daily temperatures exceeding 90°F would last more than 60 days under the higher emissions scenario. Under the low emissions scenario in most years, heat waves would not exceed 20 days. The difference between the scenarios is even greater for severe heat waves such as experienced in Europe in 2003 (successive days with temperature exceeding 100°F).

Based on these temperature and heat wave projections, Maryland is likely to confront substantially increased heat-related health risks by the mid-century and beyond. By late in the century under the high emissions scenario, this situation is likely to become very serious, with life threatening conditions developing nearly every year, particularly in the Baltimore and Washington urban areas because of the urban heat island effect and more at-risk individuals living there. Beyond threatening life for the most vulnerable, these oppressive conditions would curtail outdoor activities and diminish productivity in commercial activities requiring outdoor work. Under the lower emissions scenario, heat-related health risks would increase substantially from the present condition but much less so than with the unmitigated growth in emissions.

Heat-related health risks likely to increase significantly in urban environments

Of course, there are steps that can be taken to lower these health risks. Within limits, acclimation to higher outdoor temperatures and various adaptation measures can lower the incidences of heat-related deaths. Adaptation measures include effective early warning and response plans for heat waves, air conditioning, and better education about personal precautions, such as drinking more fluids, wearing light colored and loose fitting clothing, and limiting outdoor activity. Over the longer term, building codes can be designed to reduce the urban heat island effect, for example, by increasing the tree canopy and including reflective or green roofs. More frequent and severe heat waves will very likely increase requirements for air conditioning, extend the air-conditioning season, and increasing peak-load electricity demands at the very time there will be a premium on energy conservation to mitigate greenhouse gas emissions.

AIR QUALITY

Global climate change could affect human respiratory health by changing levels of air pollutants and the types and levels of pollen. For the United States, impacts of climate change on ground level, or tropospheric, ozone are much more likely to be more important than for other air pollutants. This is due to the importance of high temperature in the formation of ozone as well as the large areas of the country currently affected by ozone levels exceeding national standards (Figure 9.2). Central Maryland is among the most affected regions in the nation.

Ozone can affect human health by irritation of the respiratory system, reducing lung function, aggravation of asthma by increasing sensitivity to allergens, increased susceptibility to respiratory infections, and inflammation and damage to the lining of the lungs, causing chronic obstructive pulmonary disease (COPD). Effects can range from coughing and shortness of breath to permanent

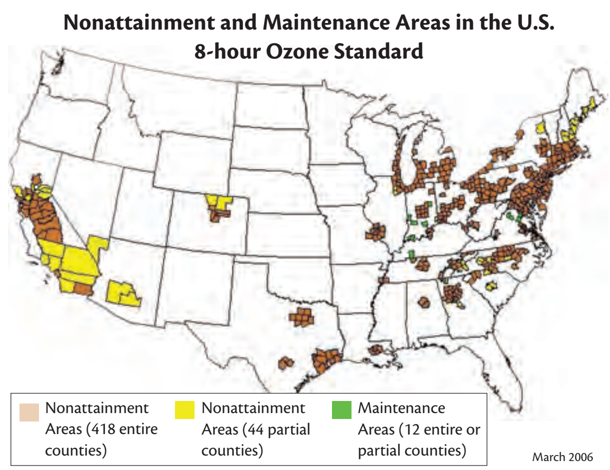


Figure 9.2. Counties not attaining the 8-hour ozone standard include most Maryland counties.

University of North Carolina

Physicians review lung x-rays.

scaring of the lungs and even death. Central Maryland has some of the highest incidence of asthma and acute respiratory illness in the country. It is estimated that about 2,000 Marylanders die each year because of chronic lower respiratory illnesses.

Maryland has made substantial progress in controlling air pollution. Baltimore and Washington areas are on a path leading to compliance with the National Ambient Air quality Standards (NAAQS) by 2009, but changes in the global background could reverse this progress and require even deeper reductions of the pollutants responsible for ozone formation. Human activities do not emit ozone per se, but our activities result in the release to the atmosphere nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs). NOx and CO are emitted mainly by the combustion of fossil fuels and VOCs are emitted from incomplete combustions of fuels and the evaporation of petroleum fuels and chemicals and by certain plants. These compounds react with oxygen in the atmosphere in the presence of sunlight to create ozone (O3; Figure 9.3).

The process of ozone formation depends on high air temperatures, which explains why we do not have ozone alerts during the winter even though emissions of NOx and VOCs are just as high then. As Figure 9.4 shows, there is a clear relationship between the maximum temperature at the Baltimore-Washington International Airport (BWI) and ozone concentrations in the Baltimore non-attainment area.[144] Furthermore, heat waves (multiple successive days with very high temperatures) create the optimum conditions for ozone formation. This is apparent in the Baltimore non-attainment area where the number of days where ozone concentrations exceed the 8-hour "Code Orange" standards in a year shows

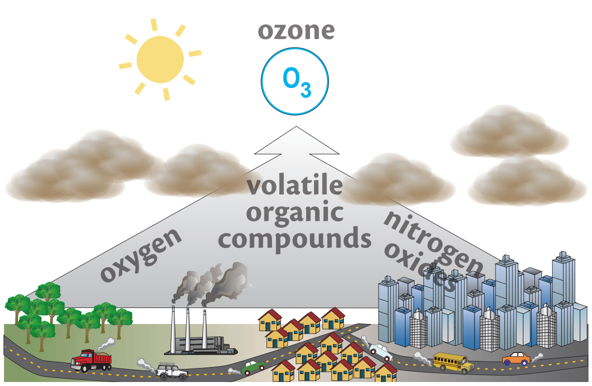


Figure 9.3. Ozone is created by the chemical reaction of air pollutants in the presence of sunlight.

The top image shows the reduced visibility (25 miles) in the downtown Washington, D.C. area in July 2006. The bottom image was taken in October 2005 where the visual range was 55 miles.

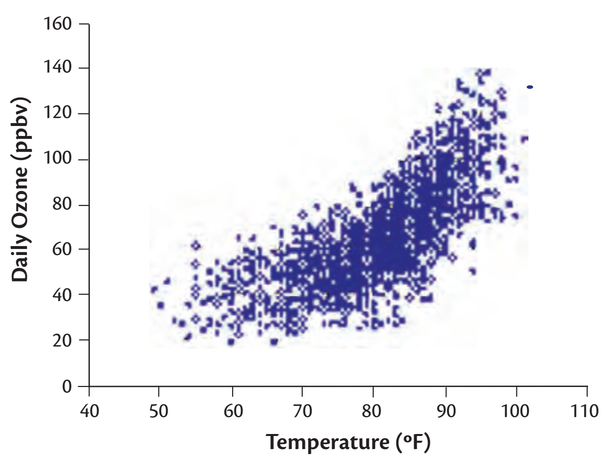


Figure 9.4. More ozone is formed under higher temperatures. Peak 8-hour ozone concentrations in the Baltimore region for May-September, 1994-2004, compared to maximum temperature at BWI Airport.[138]

close relationship with the number of days where maximum temperatures exceed 90°F (Figure 9.5).

Climate change is also likely to decrease the occurrence of cyclonic waves (low pressure system with associated weather fronts), thus lengthening

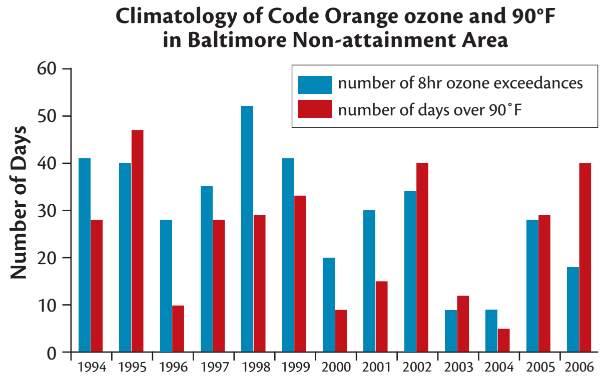


Figure 9.5. Heat waves (multiple days with temperatures exceeding 90°F) increase the buildup of ground-level ozone.

the duration of stagnant, high pressure events (hot and hazy periods) and delay the onset of cold fronts that clean up air pollution episodes.[145] Such smog episodes not only decrease the visual range but can also cause human illness and death due to higher concentrations of fine particulate matter. The persistent Bermuda High leads to weak or stagnant winds, high daytime temperatures, and intense UV radiation reaching the Earth's surface. Pollution and VOCs build up from gasoline vapors and even trees, particularly pines and oaks that are favored by global warming. All of this is exacerbated by the urban heat island effect.[146]

Ozone alert days likely to grow, requiring more aggressive reduction of air pollution

Based on the increase in summer temperatures and heat waves and these changes in weather patterns, scientists have projected anything from a 3-5 ppb[147] to a 10-20 ppb[148] increase in 8-hour average ozone concentrations over the eastern United States by the end of the century, assuming emissions of the ozone-precursor pollutants remain constant. One recent study projected a 28% increase in the average number of days exceeding 8-hour ozone standards for Baltimore and a 50% increase for Washington, D.C. by 2050.[149] On the other hand, if emissions of NOx are reduced by 50%, then ozone concentrations could, according to another study, actually decline by 11-28% despite the warming conditions.[150] The decline in observed ozone concentrations in the Baltimore region for given temperature ranges (Figure 9.6) provides clear evidence of the importance of reducing precursor emissions.

In summary, it is very likely that without significant additional reductions in air pollution by NOx and VOCs, ground level ozone concentrations will increase and pose additional health risks to people residing in central Maryland. In addition to mitigation by reducing pollutant emissions, adaptive responses are similar to those for heat stress: warning systems, air conditioning, avoiding exertion and outdoor activity, and increasing tree cover.

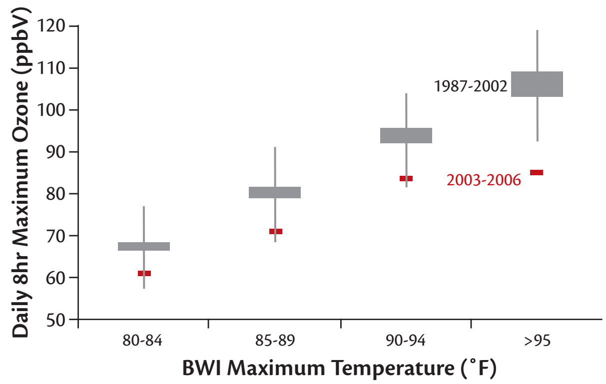


Figure 9.6. Maximum ozone concentrations have declined for each temperature range in recent years as a result of the reduction of emissions of air pollutants.

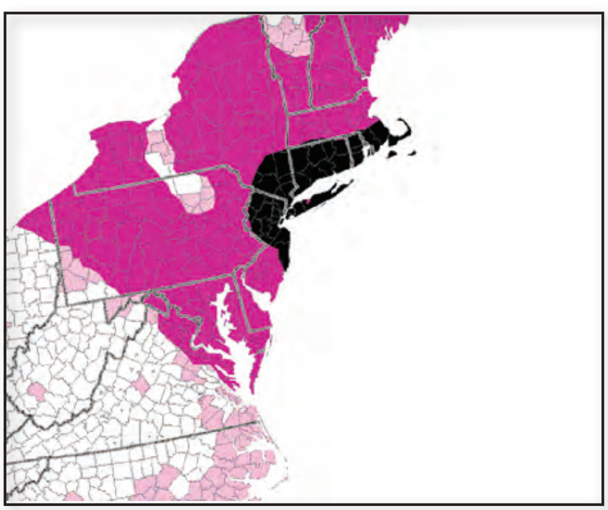
Maryland Power Plant Research Program, MD DNR

There are 34 power plants operating in Maryland as of 2006.

PATHOGENIC DISEASES

Climate change can increase human exposure and vulnerability of diseases caused by pathogenic microorganisms.[138] These include diseases borne by various animal vectors, such as malaria, dengue, Lyme disease, and encephalitis, a type of which may be caused by the West Nile virus. Global warming could increase the range or abundance of the animal vectors. Climate change could also affect exposure to non-vector borne diseases such as hantavirus, cryptosporidiosis, and cholera. The incidence and associated mortality of most of these diseases in the United States is relatively low because of public health precautions and the availability of treatment. For Maryland, the increased risks due to heat stress and respiratory impairment are likely to be more serious than for pathogenic diseases.

Moreover, it is difficult to project how climate changes would impact pathogenic transmission and human health because of the complexity of climatic effects on vectors and other environmental factors.[138] Cryptosporidiosis is an intestinal disease caused by a bacterium that is abundant in livestock feces and can be transported during high rainfall events. The bacterium is small and resistant to chlorination, making it difficult to kill or filter out of water supplies. Lyme disease has become the most important vector-borne diseases in the United States and a large majority of cases occurs in the Northeast, although it is less prevalent in Maryland than in the states to the north. The ticks that transmit Lyme disease prefer cooler temperatures during the summer, so the projected warming could reduce tick populations and disease risk.[7] Continued encroachment of suburbs into former woodlands presents a far greater risk for contraction of Lyme disease. Outbreaks of West Nile virus in humans seem to occur when extreme heat and drought are followed by heavy rains. It is thought that birds that host the virus migrate to wetter areas during the drought and the mosquitoes that normally prey on birds switch to humans when they hatch following the rains.[7]



American Lyme Disease Foundation, Inc.

The dark pink area, which includes most of Maryland, represents a medium density of host-seeking ticks that have been shown to be infected with Lyme disease bacteria.

University of Maryland

Heavy rains and coastal flooding combined with warm weather provides perfect conditions for an explosion of mosquitoes.

Section 10

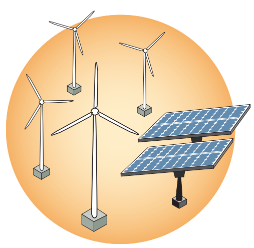
IMPLICATIONS FOR MITIGATION & ADAPTATION

KEY POINTS

- **Reduction of greenhouse gas emissions has substantial benefits for Maryland.**
  Mitigation of global emissions by mid-century would very likely result in significantly lower sea-level rise, reduced public health risks, fewer extreme weather events, less decline in agricultural and forest productivity, and loss of biodiversity and species important to the Chesapeake Bay. Even more serious impacts beyond this century would be avoided.

- **Develop adaptation strategies for human health, water resources, and restoration of bays.**
  Adaptation strategies to reduce coastal vulnerability should plan for a 2 to 4 foot rise in sea level during the century. The Commission should evaluate additional adaptation strategies related to human health, water resources, forest management, and restoration of the Chesapeake Bay and Maryland's Coastal Bays.

- **Organize and enhance Maryland's capacity for monitoring and assessment of climate impacts.**
  A more extensive, sustained, and coordinated system for monitoring the changing climate and its impacts is required. Maryland is in a strong position to become a national and international leader in regional-to-global climate change analysis and its application to mitigation and adaptation.



This assessment of the impacts of climate change on Maryland was undertaken as one of three integrated components of the Plan of Action of Maryland's Commission on Climate Change. To that end, it is appropriate to draw implications from the impacts assessment to inform the other efforts to mitigate climate change by reducing greenhouse gas emissions and to adapt to changes likely, thereby reducing Maryland's vulnerability. This concluding section briefly summarizes the findings of the impacts assessment related to those two objectives.

MITIGATION

Reducing emissions soon is required

The Intergovernmental Panel on Climate Change has demonstrated that on a global scale, there are likely to be large changes in climate and substantial and serious effects on natural ecosystems, resources, and human populations and societies.[3] The IPCC showed that some of these changes are inevitable because they have already begun and cannot easily be stopped, even with dramatic and immediate reductions in greenhouse gas emissions. However, the path that humankind will follow in either continuing to increase those emissions or reducing them will have a large effect on the extent of climate change and magnitude of its consequences.

This assessment seeks to identify both those changes in Maryland that are likely inevitable and those changes that can be avoided with action to reduce emissions through the use of the lower and higher emissions scenarios. A point made earlier bears repeating: the higher emissions scenario is not

CSIRO

Improved fuel economy and less vehicles on the road could provide some reduction in greenhouse gas emissions.

and does not represent a ceiling nor the most extreme changes that are likely, and the lower emissions scenario is not a floor and does not represent the minimum effects that may be achievable. Currently, emissions are growing faster than the higher scenario assumes. The IPCC estimated that it would require early reductions of global greenhouse gas emissions of 50 to 85% by 2050 to constrain the increase in the global mean temperature to 3.6 to 4.5°F,[3] a level of warming generally thought to have dangerous consequences, and would, therefore, still have many negative consequences as this report attests. Under the lower emissions scenario used in this assessment, the emissions in 2050 would be declining but still be about 30% higher than today. For that reason, the IPCC is planning to develop scenarios incorporating earlier and more dramatic emission reductions in its future assessments.

For the most part, the projections of impacts under the lower and higher emissions scenarios are similar or only modestly different at the middle of the 21st century. This is hardly surprising because the cumulative emissions are little different between the two scenarios by that point in time (Figure 3.3). The differences become starker towards the end of the century, even though the lower emissions scenario shows only about a 50% reduction in emissions by that time. Thus, the lower emissions scenario projections represent what might be considered the maximum change that could be expected if the mitigation strategies now being advanced in international negotiations are implemented. With that in mind, the following are some of the more severe impacts projected for late 21st century climate change in Maryland that could potentially be avoided by global action to reduce greenhouse gas emissions during the first half of century:

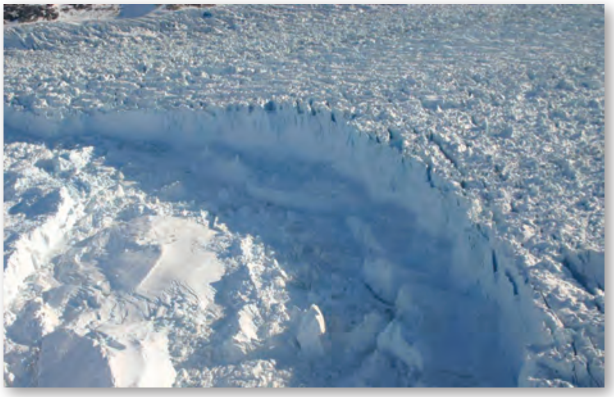
- Sea-level rise of up to 3.5 feet as opposed to less than 2 feet; the loss of virtually all coastal wetlands; inundation of more than 100 square miles of presently dry land and loss of the homes of thousands of Marylanders; and the likely initiation of a 20-feet or more rise in sea level in later centuries as a result of unstoppable melting of polar ice sheets.
- Heat waves lasting most of the summer, with an average of 30 days each summer exceeding 100°F (like Phoenix but with high humidity) creating life-threatening conditions in Maryland's urban environments during most years; and increased respiratory health risks due to ground-level ozone concentrations unless pollution emissions are dramatically reduced.

Wikipedia Commons

Record energy use and heat waves often coincide.

- More extreme rainfall events, but also longer lasting summer droughts, not unlike the unusual conditions seen in Maryland over the past year.
- Declines in agricultural productivity, which may be initially enhanced due to warmer temperatures and higher carbon dioxide concentrations, as a result of severe heat stress and the summer droughts.
- Reduced forest productivity and ability to sequester carbon, after a modest increase during the first half of the century, as a result of heat stress, seasonal droughts, and outbreaks of pests and diseases; the loss of maple-beech-birch forests of Western Maryland and an increase in pine trees in the landscape of the rest of the state; and the withdrawal of northern bird species such as the Baltimore oriole from Maryland.
- The permanent loss of important species such as eelgrass and soft shell clams from the Chesapeake Bay; highly stressful summer conditions for striped bass and other fish as the dead zone expands and surface waters heat up; and a substantially more difficult challenge in restoring the health of the Bay by reducing nutrient pollution.

Limiting the projected impacts in this assessment to the 21st century undervalues the full benefits of mitigation of greenhouse gas emissions taken early in the century. The impacts of unmitigated climate change will not stabilize in 2100 but continue beyond, in some cases at an accelerated pace. In fact, some responses have a long lag effect, meaning that the effects will continue to grow over centuries.[2] This is particularly true for sea-level rise



NASA/Wallops

This image shows the calving front, or break-off point into the ocean, of Helheim Glacier, located in southeast Greenland. The image, taken in May 2005, shows high calving activity associated with faster glacial flow. This glacier is now one of the fastest moving glaciers in the world.

because of the slow process of warming the ocean and the continued melting of polar ice sheets. If emissions continue to grow at the pace of the higher emissions scenario or greater, it is likely that the climate system will be committed to an accelerated melt down of the polar ice sheets over the next few centuries that could not be stopped by reducing greenhouse gas emissions. Lest one think that is such a long time in the future, remember that European colonization of Maryland began 374 years ago and Maryland became a state 227 years ago.

Impacts of climate change will not stabilize in 2100, and sea level will continue to rise

Changing conditions affect mitigation

Conditions will change in ways that affect mitigation options. For example, forests that are stressed by heat and low soil moisture during the summer will cease to take up and hold (or sequester) carbon from the atmosphere. Instead, they will tend to release stored carbon back into the atmosphere as carbon dioxide. Heat stress will increase the demand for air conditioning and extend the cooling season. At times, air conditioning will not be a luxury, but a matter of survival. This would offset mitigation savings through energy conservation and increase peak electricity demand, which determines the generation capacity required.

Some of the projected climate changes are likely to make the accomplishment of present environmental objectives more difficult, for example, attaining ozone concentration standards by reducing air pollution or achieving the Chesapeake Bay restoration goals by reducing nutrient agricultural and urban runoff of nutrients and sediments. However, most of the projected impacts of climate change will not be realized until the middle of the century or later, and some are not yet very predictable. Therefore, there is ample opportunity to continue to pursue those environmental objectives aggressively because this would lessen the impacts of climate change later on. Freezing action due to the uncertain effects of climate change would result in unavoidable and more severe consequences.

ADAPTATION

Sea-level rise and coastal vulnerability

Based on the current scientific understanding of the complex processes that will affect future sea level as considered in the projections of this assessment, it is prudent to plan now for one foot of relative sea level rise by the middle of the century and at least two feet by the end of the century. For major, long lifetime investments in property and infrastructure, it would be prudent to consider an additional margin of safety by planning for a four foot rise in sea level. New observations of the global and local rates of sea level rise, new scientific understanding of the processes of melting of polar ice sheets, and improved capabilities for long-range storm forecasting could alter this advice, but more severe impacts are not likely to be realized until the second half of the century. Consequently, plans and policies should be periodically reevaluated with regard to this emerging understanding and the progress in reducing greenhouse gas emissions.

Subsequent adaptation strategies

The Maryland Commission on Climate Change will

Adrian Jones

Coastal development is vulnerable to sea-level rise and storm surge.

continue to evaluate adaptation strategies in addition to sea-level rise and coastal vulnerability over the next year or more. Although detailed evaluation of adaptation options is beyond the scope of this report, the assessments provided here should serve as a useful basis for evaluation of adaptation strategies appropriate for Maryland in the areas of human health (heat and respiratory stress), water resources (particularly emphasizing the Potomac Basin, groundwater resources, and reducing the effects of urbanization on flooding and stream health), forest management (changing sequestration potential and managing forest succession, diseases and pests), and restoration of the Chesapeake Bay and Maryland's Coastal Bays (building on the recent analysis of the Scientific and Technical Advisory Committee of the Chesapeake Bay Program). These issues are ripe for further evaluation by the Commission.

Monitoring, assessment, and forecasting

In general, there is insufficient monitoring of Maryland's climate, environmental conditions, and resources to characterize their present state and variability. Now that we realize that all of these are changing and will be changing more rapidly in the future, a better system of observations is required—one that is reliably continuous, strategically targeted, and thoroughly integrated. Reliable observations, interpreted with scientific understanding, and innovative models can dramatically reduce uncertainty about the path of climate change in Maryland and its consequences, allowing us to make better informed and wise decisions about the State's future. It is clear that traditional approaches to adaptation will not suffice in a future that no longer resembles the past. Climate models can be downscaled to incorporate locally important phenomena, such as urban heat island and forest cover effects, and resolve important differences across our slice of the Mid-Atlantic landscape.

Maryland is in a strong position to become a national and international leader in regional-to-global climate change analysis and its application to mitigation and adaptation. There is already considerable, world-recognized expertise within our public and private universities on which to build. And, Maryland has the unmatched advantage of the location of the Goddard Space Flight Center, which leads the National Aeronautics and Space Administration's earth science program at Greenbelt; headquarters of the National Oceanic and Atmospheric Administration's line offices at Silver Spring; and National Weather Service's Climate Prediction Center soon to be relocated to College Park. Marshalling and enhancing this capacity for continually improving climate impact assessment would greatly benefit not only our State of Maryland, but our planet, Earth.

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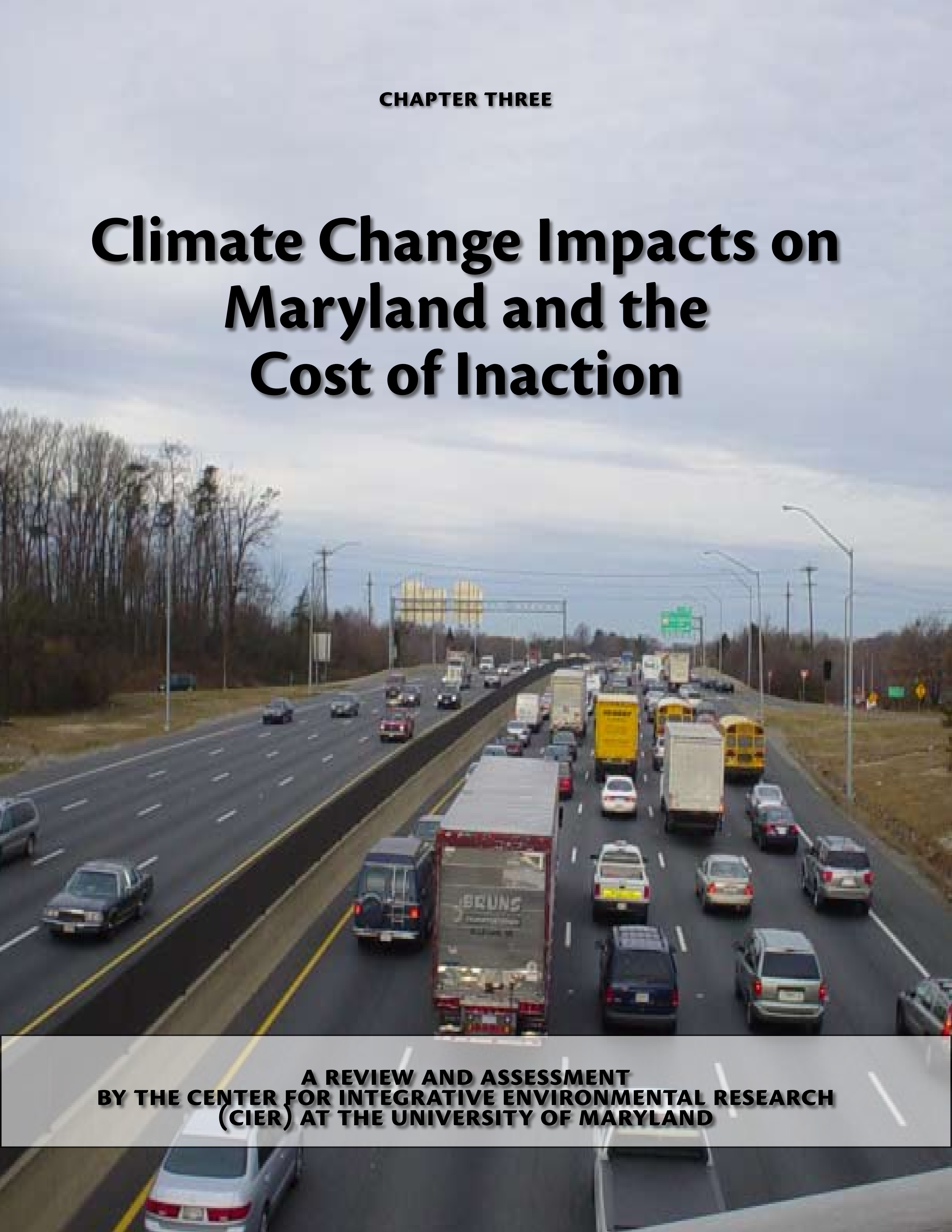
Jane Hawkey

Turk's Cap lily, a native of the Chesapeake Bay watershed.

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

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 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_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 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

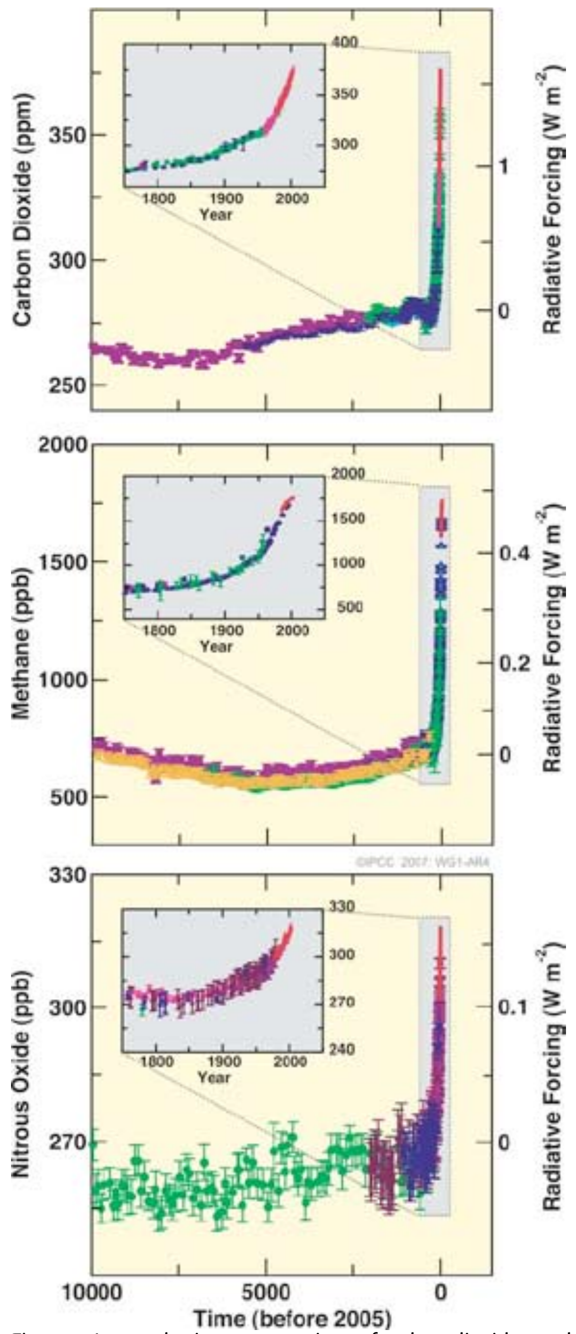
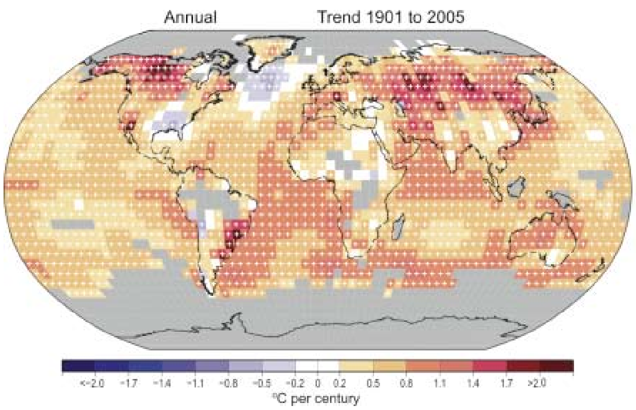
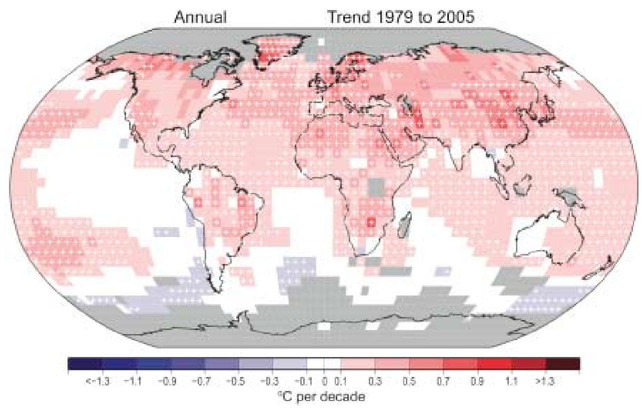


Figure 1: Atmospheric concentrations of carbon dioxide, methane and nitrous oxide (Source: IPCC 2007a)





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

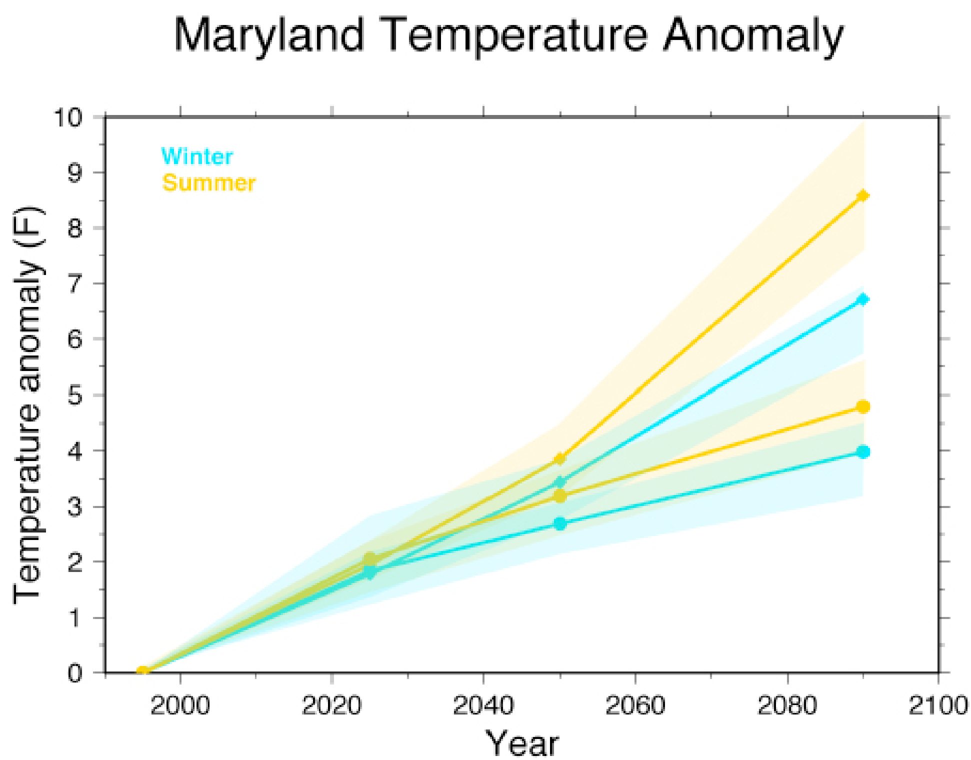


Figure 3. Temperature anomalies in Maryland under two emission scenarios (Source: MCCC – STWG 2008)

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.

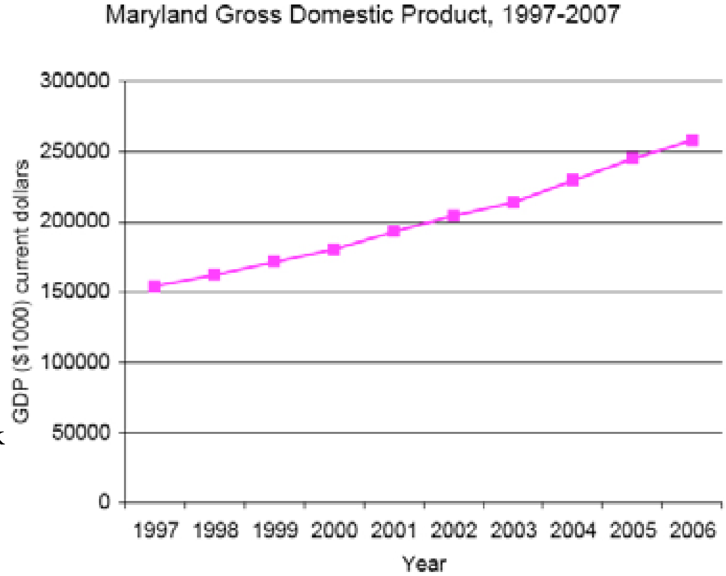


Figure 4. (Source: Bureau of Economic Analysis, 2007)

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.

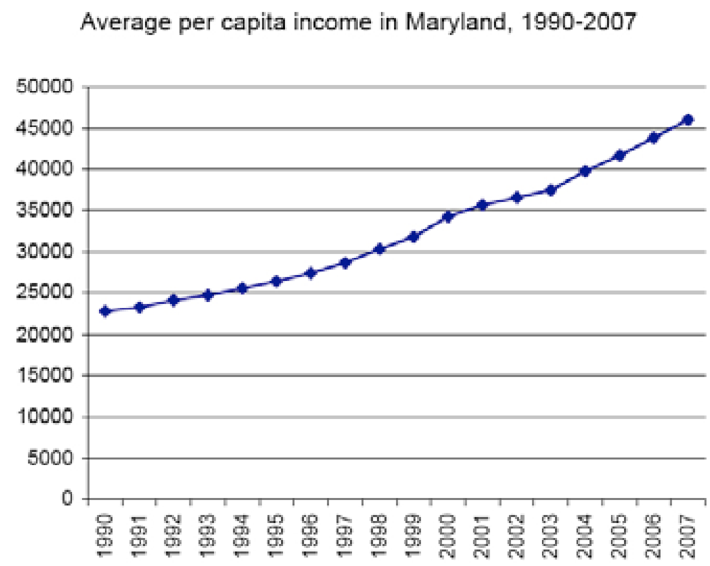


Figure 5. (Source: Bureau of Economic Analysis, 2007)

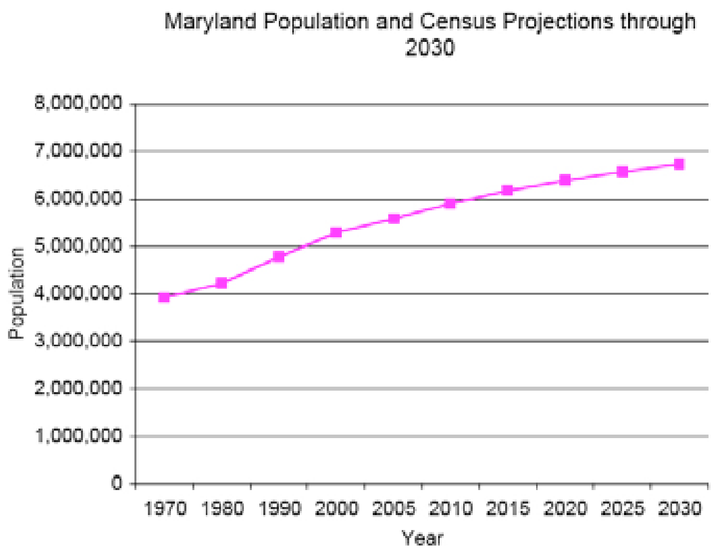


Figure 6. (Source: Maryland Department of Planning, 2007)

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).

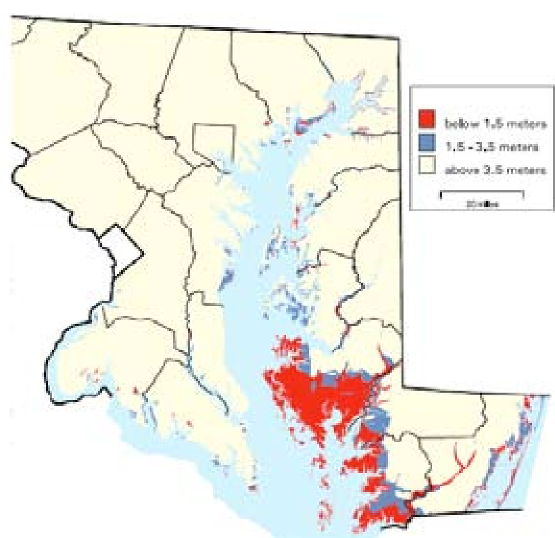


Figure 7. Inundation scenarios resulting from sea level rise and episodic flooding (Source: Titus and Richman 2000)

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_2 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

Species	*Likely Trend*	*Climate Change Impacts*
Winter flounder	High Loss[1]	Temperatures could exceed habitable range
Soft-shelled clam	High Loss	Temperatures could exceed habitable range
Rockfish	Medium / Low Loss[2]	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 *Dermo* and *MSX*
Brown shrimp	Potential Gain[3]	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 change4 (Source: Glick et al. 2007).

[1]Potential loss of species altogether in the Chesapeake Bay
[2]Likely decline in species range or viability in the Chesapeake Bay
[3]Likely expansion of species range or viability in the Chesapeake Bay
These probable effects were identified based on available information, but significant changes in key paramaters such as temperature and salinity are likely to have wide-ranging unpredictable effects on llife cycles and food webs

Crop	50% increase in CO_2 (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)***[5]	***Cold slope***[6]	***Hot slope***[7]
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

[1]Percentage change in mortality per degree centigrade
[2]Cold slope = average slope of the estimated relative risk curves at temperatures lower than MMT
[3]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 impactsfrom 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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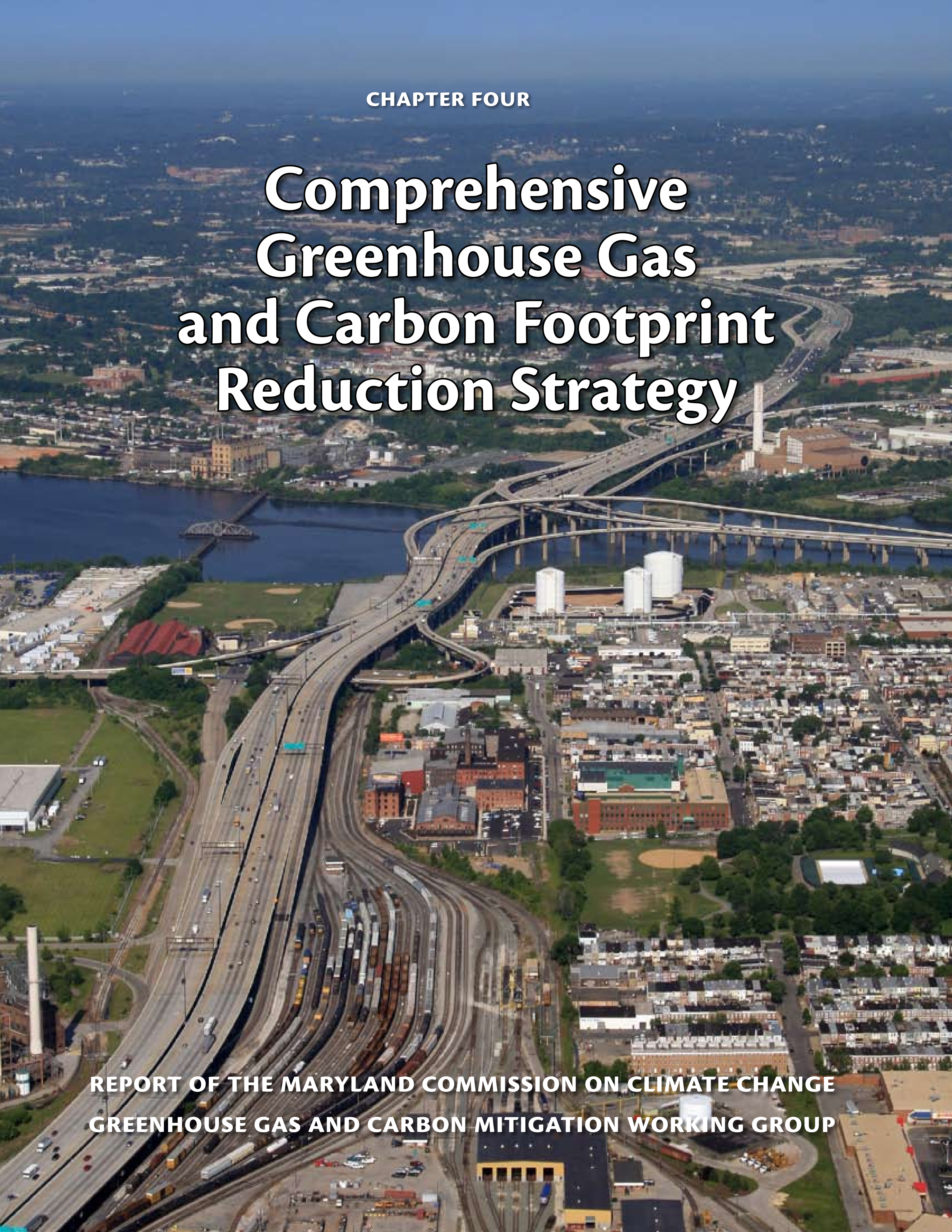

CHAPTER FOUR

Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy

REPORT OF THE MARYLAND COMMISSION ON CLIMATE CHANGE
GREENHOUSE GAS AND CARBON MITIGATION WORKING GROUP

GREENHOUSE GAS AND CARBON MITIGATION WORKING GROUP

Chair: Tad Aburn (Maryland Department of the Environment)
Co-Chair: Malcolm Woolf (Maryland Energy Administration)

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Department of Planning
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Maryland Emergency Management Agency
Maryland Energy Administration
Maryland General Assembly
Maryland Insurance Administration
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Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy

Report of the Maryland Commission on Climate Change

Greenhouse Gas and Carbon Mitigation Working Group

August 2008


START
TODAY
CREATE

TABLE OF CONTENTS

EARLY ACTIONS ARE KEY

Not Your Grandfather's Air Pollution

Greenhouse gases (GHGs) are not like other air pollutants. Ozone and other pollutants create hotspots over a city or a region and typically dissipate in period of hours, days or weeks. GHGs, on the other hand, accumulate in the atmosphere and stay there for a very long time. A pound of carbon dioxide (CO_2) we emit today by driving a car or using electricity generated by burning fossil fuels, such as coal, may still be in the atmosphere decades to hundreds of years from now. (In this sense it *is* your grandfather's air pollution.) Industrial GHGs have even longer residence times. For example, sulphur hexafluoride (SF6), used as insulation in electronic switching equipment and other industrial applications, has a residence time of several *thousand* years.

It does not matter if the GHG is emitted in Maryland, China, or elsewhere – the climate impact is the same.

What Happens When GHGs Accumulate?

Simply stated, the accumulation of GHGs in the atmosphere traps heat from the sun and warms the planet. As synthesized by the Intergovernmental Panel on Climate Change (IPCC), when GHG concentrations in the atmosphere – expressed in CO_2 equivalents or CO_2e – reach 445-490 parts per million (ppm), it will increase the annual mean temperature of the Earth's surface 2 - 2.4°C (3.6 - 4.3°F) above pre-industrial levels. The scientific evidence assembled by the IPCC indicates that temperature increases above this level are very likely to result in dangerous consequences in terms of food production, biodiversity, and initiation of uncontrollable and unpredictable changes in the Earth's climate system, such as rapid melting of polar ice caps and changes in the ocean circulation that regulate the planet's climate. Thus, GHG concentrations would have to be held to around 450 ppmCO_2e to avoid this level of global warming.

So What's the Rush?

To stabilize GHGs at this level requires substantial early action because it now seems that atmospheric concentrations are fast approaching, if they haven't already reached, 450 ppm. Furthermore, considering the atmospheric residence time of the CO_2 and other GHGs that have been and are being emitted, global reductions in emissions by 60 to 85 per cent below 2000 levels would be required by 2050 in order to reach the 450 ppm level of stabilization. Because developed countries such as the United States are responsible for the majority of the GHG emissions and have much higher emissions on a per capita basis than developing nations, they would have to achieve reductions on the high side of this range in order to achieve this result. Consequently, governments ranging from the European Union to a number of states in the United States have been adopting policies and goals based on reducing emissions at least to 1990 levels by 2020. These climate action plans call for taking immediate actions to stem the growth in emissions and then beginning to reduce them, with a heavy emphasis on energy efficiency and conservation. The ***Climate Action Plan*** sets long-term goals of achieving 90 per cent reductions in emissions by 2050, relying on new energy sources and technologies that will have to be developed.

> "The climate crisis is real and while it threatens our shorelines today, its causes and symptoms threaten life on our planet in the generations ahead unless we act.
> As a state and -- I would submit to you -- as a nation and a planet, there's no time to delay. We have to take control of our own future in the face of this threat. The decisions we make today will determine, in a very real way, the future character of our state and nation."
>
> Governor Martin O'Malley
> September 26, 2007

Commission's Science-based GHG Reduction Goals

The Commission recommends reducing Maryland's GHG emissions by 25 per cent to 50 per cent below 2006 levels by 2020 and a goal of 90 per cent below 2006 levels by 2050. It also recommends interim reduction targets of 10 per cent reductions by 2012 and 15 per cent reductions by 2015, again using the 2006 baseline. The basis for these targetss is laid out in this Chapter and in the Commission's ***Interim Report***. These targets, like those of the European Union and leadership U.S. states, are based on the scientific conclusions of the IPCC regarding the level and pace of reductions that industrialized societies will need to achieve in order to keep global concentrations of GHGs below the 450 ppm threshold.

Continued Efforts to Work with Stakeholders

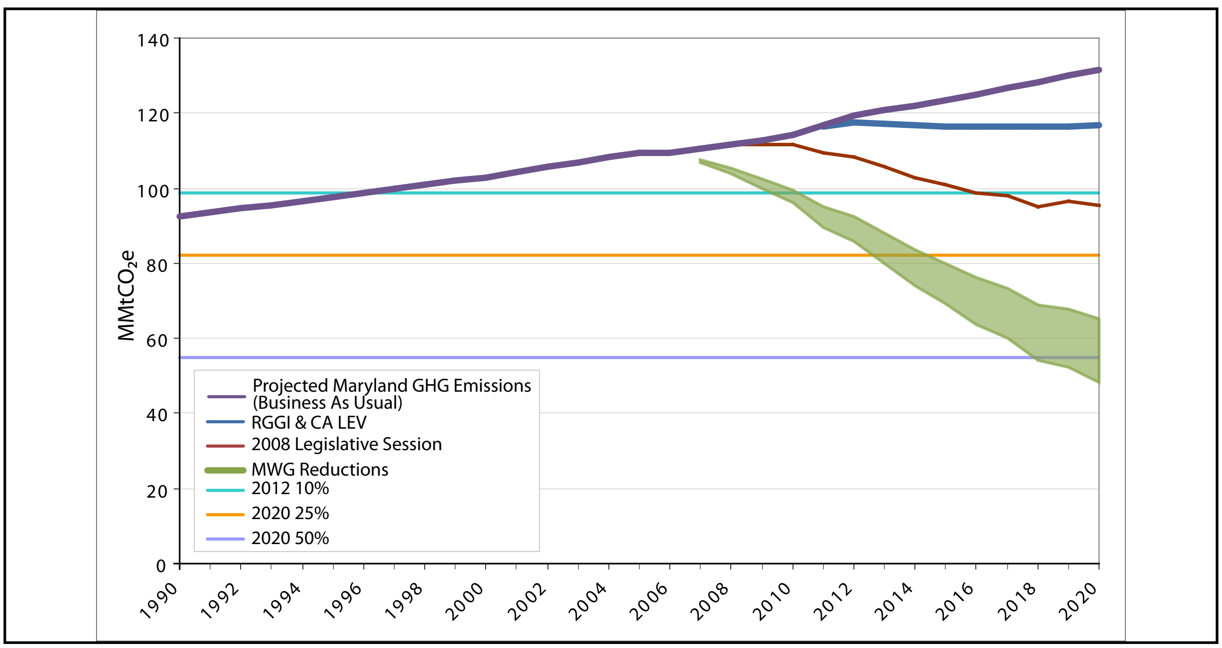
As the Commission and the Mitigation Working Group (MWG) developed the policy options in the ***Plan***, many additional stakeholders expressed an interest in being involved as the State begins to implement the strategies contained in the ***Plan***. Because of this, the lead implementation agencies will be setting up strategy-specific stakeholder processes for appropriate measures.

For example, there was tremendous interest from stakeholders to work with the State on how the Regional Greenhouse Gas Initiative (RGGI), a regional cap-and-trade program focused on the power sector, may evolve over time or blend into a federal program. Because of this interest, the Maryland Department of the Environment (MDE) has already begun to set up a separate stakeholder process focused on just this issue.

More Is Needed

Although Maryland has taken some important first steps, as illustrated in the "alligator jaws" graph below, more reduction programs are needed to "close the jaws" and stabilize emissions below the critical atmospheric concentration of 450 ppm CO_2e by 2050. The Commission has developed forty-two policy options that, if implemented aggressively, could close the jaws and, in fact, could reduce emissions below the 25 per cent reduction goal for 2020 at a net savings to Maryland citizens, businesses and the State's overall economy.

GHG Reduction Potential from Maryland's Recent and Proposed Actions



As the graph above illustrates, Maryland has already made significant progress in enacting programs that will dramatically reduce GHG emissions. The Maryland Clean Cars Program (CA LEV), RGGI, and the recent 2008 legislation aimed at GHGs get Maryland about 70 per cent of the way to our 2020 goal (25 per cent reduction).

STEPS IN THE RIGHT DIRECTION

Maryland has already taken some important early actions toward reaching these goals.

- *The Healthy Air Act.*
  Adopted as State law in 2006, the Act included a provision for Maryland to join the Regional Greenhouse Gas Initiative (RGGI), a groundbreaking cap and trade program designed to reduce CO_2 emissions from power plants in participating states in the Northeast and Mid-Atlantic. The Maryland allocation in RGGI is expected to reduce CO_2 emissions by approximately 8.7 million tons by 2020. Maryland will participate in RGGI's historic first auction of CO_2 allowances in September 2008, the first ever in the U.S.

- *The Clean Cars Act.*
  Adopted as State law in 2007, this law requires implementation of the California Clean Cars program (CA LEV). By requiring more rigorous emissions standards beginning in vehicle model year 2011, it will start reducing GHG emissions in Maryland as early as 2010, achieving reductions of about 6 million metric tons by 2020.

- ***EmPOWER Maryland** Program.*
  Launched by Governor O'Malley in July 2007 and codified by the General Assembly in its 2008 Session, this program is designed to reduce per capita electricity use by Maryland consumers by 15 per cent in 2015. This could reduce GHG emissions by about 7 million tons in 2020.

- *Commission on Climate Change.*
  Governor O'Malley established the Commission by executive order in April 2007 to advise the Governor and General Assembly on matters related to climate change and to develop a ***Climate Action Plan***.

- *2008 Legislation*
  As summarized in Chapter 7 of this ***Plan***, nearly all of the Commission's Early Action recommendations for legislation were adopted as law in the General Assembly's 2008 Session. Significant early reductions will be achieved through the following 2008 laws:
    - ***EmPOWER Maryland** Energy Efficiency Act of 2008*
    - *Regional Greenhouse Gas Initiative – Maryland Strategic Energy Investment Program*
    - *High Performance Buildings Act of 2008*
    - *Renewable Portfolio Standard Percentage Requirements – Acceleration*

  The General Assembly adopted other laws in 2008 designed to reduce GHG emissions that weren't part of the Commission's Early Action recommendations. These include increased grants and tax incentives for solar and geothermal installations, a law to spur development around transit stations, low interest loans for energy efficiency projects, and establishment of the Maryland Clean Energy Center. These are discussed in greater detail in Chapter 7.

It Won't Get Any Easier: Living Within a Greenhouse Gas Budget

Staying below the 450 ppm threshold is another way of saying we must live within a GHG budget. How we spend this account depends on policy decisions we make today. We can think of it in this way: a program that keeps a ton of GHGs out of the atmosphere today is worth more than the same program started five years from now, because five years of GHG accumulation will be avoided if we start today. Let's consider two scenarios:

1. **"Business as Usual" Scenario.** Under this scenario, we spend most of our GHG account in the early years by continuing activities that cause GHGs to accumulate rapidly. This requires us to borrow against future years. Like compounding interest on an unpaid credit card debt, the accumulating GHGs will make our payments – the needed emissions reductions per year – larger every year we delay, until we may reach a point where the reduction measures are vastly harder, or impossible, and too expensive, and our 2020 and 2050 goals are not achievable. Our "glide path" to leveling off and staying below the 450 ppm threshold in these time frames may simply become too steep to travel.

2. **"Early Action" Scenario.** Under this scenario, we budget the timing and pace of our GHG expenditures by implementing early and significant GHG reduction programs now, and phasing in medium- and long-term programs on an aggressive "ramp up" schedule. In so doing, we avoid continued rapid GHG accumulations – the compounding interest – and stabilize and start reducing emissions by about 2012. This puts us on a sustainable glide path to our 2020 and 2050 goals without overspending our GHG account and borrowing with interest against the later years. ***Even programs that won't yield reductions in the early years may need to be launched now in order to ramp up to their full effectiveness within the needed time frame.***

CLIMATE CHANGE OR GLOBAL WARMING?

The term climate change is often used interchangeably with the term global warming, but according to the National Academy of Sciences, "the phrase 'climate change' is growing in preferred use to 'global warming' because it helps convey that there are [other] changes in addition to rising temperatures."

Climate change refers to any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). Climate change may result from:

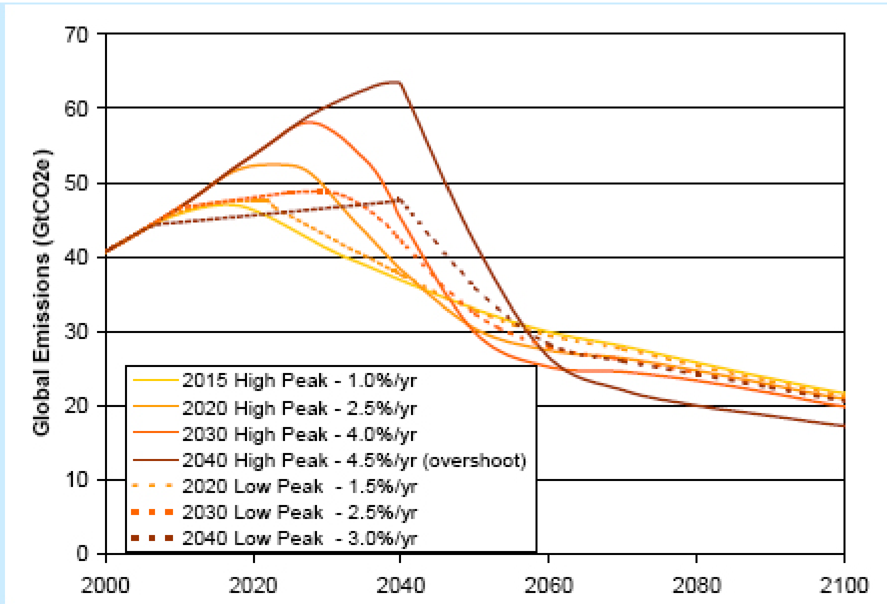
- natural factors, such as changes in the sun's intensity or slow changes in the Earth's orbit around the sun;
- natural processes within the climate system (e.g. changes in ocean circulation);
- human activities that change the atmosphere's composition (e.g. through burning fossil fuels) and the land surface (e.g. deforestation, reforestation, urbanization, desertification, etc.)

Global warming is an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere, which can contribute to changes in global climate patterns. Global warming can occur from a variety of causes, both natural and human induced. In common usage, "global warming" often refers to the warming that can occur as a result of increased emissions of greenhouse gases from human activities.

Source: U.S. EPA

THE COST OF DELAY: A GLOBAL PERSPECTIVE

The graph below illustrates different pathways to global stabilization of GHGs. By delaying reductions (shifting the peak to the right), the larger tonnage of emissions in early years (higher peak) requires steeper, more rapid emission cuts in later years (expressed in %/yr) to reach the same stabilization goals.



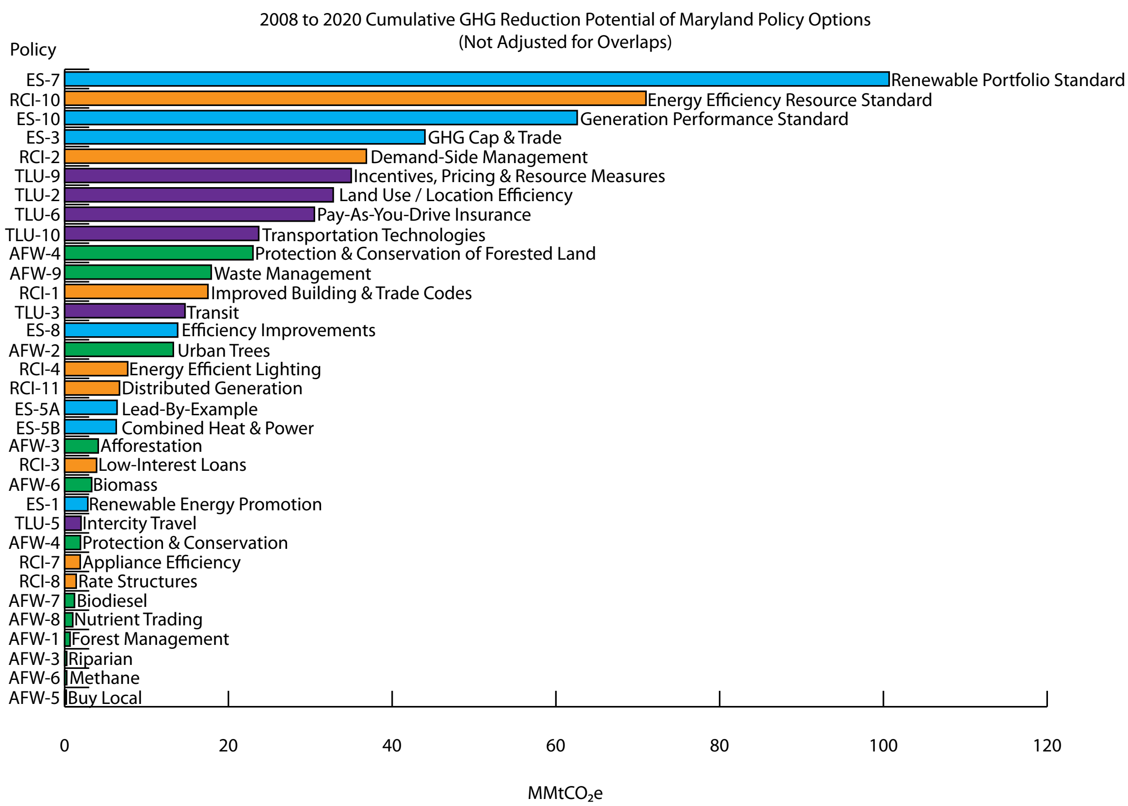
"There is a high price to delay. Delay in taking action on climate change would make it necessary to accept both more climate change and, eventually, higher mitigation costs. Weak action in the next 10-20 years would put stabilization even at 550 ppm CO_2e beyond reach – and this level is already associated with significant risks."

The Economics of Climate Change: The Stern Review, Executive Summary, p. xv.

Excerpted from: Stern, Nicholas. The Economics of Climate Change: The Stern Review. Cambridge: Cambridge UP, 2007; Executive Summary, p. xii. Commissioned by the Chancellor of the Exchequer, reporting to both the Chancellor and to the Prime Minister of Great Britain. HM Treasury. <http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_Report.cfm>.

EARLY ACTIONS: BIG HITTERS IN MARYLAND

The graph below illustrates the cumulative GHG reductions achieved between 2008-2020 by each quantified policy recommendation of the Commission. The bars on the top show policies that would achieve the largest tonnage of reductions between 2008 and 2020. The policy options are described and analyzed in detail later in this Chapter and in Appendix D to this ***Climate Action Plan***.



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Tilt Studio, Inc. would like to thank everyone who participated in our Baltimore Green Week Create Change™ program. A special congratulations goes out to our challenge winners!

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SHRINKING OUR FOOTPRINT WILL GROW MARYLAND'S ECONOMY

The Commission has identified a suite of cost-effective GHG reduction programs which, if implemented, will benefit Maryland consumers, businesses and the State's economy as a whole.

Energy Efficiency – The Low Hanging Fruit

Energy efficiency is the fastest and least expensive approach available to reduce GHG emissions. Most of the Commission's policy recommendations for reducing energy demand can be implemented right now. According to the *EPA-DOE National Action Plan for Energy Efficiency*, energy efficiency will not only help to address GHG emissions but actions in this area can also lower energy bills, help stabilize energy prices, enhance electric and natural gas system reliability, and reduce harmful air pollutants. In fact, in some states with well-designed energy efficiency programs, these programs are saving energy at an average cost of about one-half of the typical cost of building new electric power generating sources.

Maryland research suggests even greater savings for our State. A study funded by Maryland's Department of Business and Economic Development (DBED) and the Maryland Energy Administration (MEA) and carried out by the Baltimore-based International Center for Sustainable Development (ICSD) found that energy efficiency can reduce energy costs to homeowners, businesses, institutions and government at a cost 60 per cent to 70 per cent cheaper than building new generating capacity in Maryland.

As noted earlier, Maryland has already launched some important energy efficiency programs such as ***EmPOWER Maryland***, RGGI, and Maryland Clean Cars, which will start yielding GHG emission reductions as early as 2009. This ***Climate Action Plan*** includes many energy efficiency programs that will yield additional early, significant and cost-effective GHG reductions. They are examined in greater detail in the Commission's Recommended Policy Options section, later in this Chapter.

Growing Clean Energy Industries and Green Collar Jobs

Maryland can position itself as a national leader in developing clean energy industries and growing an indigenous green collar work force. The ICSD study found that by developing clean energy industries, Maryland could create between 144,000 and 326,000 jobs in the State over the next 20 years, contributing $5.7 billion in wages and salaries to Maryland citizens, boosting State and local tax revenues by $973 million and increasing gross state product by $16 billion. It noted that Maryland's existing capacity to capture energy efficiency savings suffers from a lack of businesses that deliver energy efficiency services, such as energy service companies and home weatherization contractors.

Other examples of Maryland's robust business and job opportunities abound. They include: designing and constructing green buildings; retrofitting older buildings with energy efficient appliances and technologies; expanding and maintaining public transit systems; designing, constructing, and operating windmills, biomass generators, and solar collectors; and research and development (R&D) in a wide array of new practices and technologies.

The ICSD study found that although a number of states are investing aggressively in the clean energy industry, valued at $50 billion a year worldwide and growing at the rate of 30 per cent a year, Maryland is lagging behind in this sector and missing out on huge economic development and job growth potential. As one example, it found that Maryland has vast untapped renewable energy resources that could produce from 30 per cent to 137 per cent of all the State's electricity from solar photovoltaics and on-shore and off-shore wind power at costs often competitive with conventional sources.

Shrinking Energy Bills

In addition to paying lower monthly utility bills through energy savings from RGGI, ***EmPOWER Maryland*** and other programs recommended in the ***Climate Action Plan***, Maryland consumers will be able to offset higher prices at the gas pump through the Maryland Clean Cars program, as well as other programs designed to reduce vehicle miles traveled such as Smart Growth and Transit-oriented Development, and a suite of policy options proposed by the Commission for the transportation sector.

ECONOMIC BENEFITS FROM RGGI

- **Lower utility bills for consumers**
- **Net economic benefit to State**
- **Job creation**

The University of Maryland's Center for Integrative Environmental Research (CIER) has studied the economic impact to Maryland of joining the Regional Greenhouse Gas Initiative (RGGI), the multi-state cap and trade program designed to cut GHG emissions from power plants. CIER concluded that through its participation in RGGI, Maryland's citizens will enjoy lower utility bills and a positive economic benefit to the State, increasing the gross state product by about $100 million by 2010 and $200 million by 2015 and subsequent years, and creating approximately 1,200 new jobs statewide by 2010 and 2,800 jobs by 2025.

WHAT WE DO IN MARYLAND MATTERS IN MARYLAND

Maryland Is Small – Why Should We Care?

Small Geography, Big Footprint

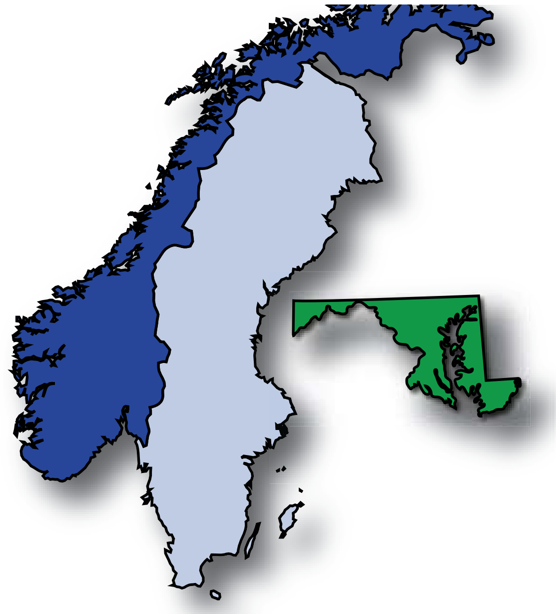
Although Maryland is a small state, it is responsible for as nearly many GHG emissions as Sweden and Norway combined. Our gross emissions have increased by about 18 per cent since 1990, a faster rate of growth than the U.S. as a whole. Per capita GHG emissions by Maryland citizens also grew between 1990 and 2005, during a period when per capita emissions for the U.S. as a whole decreased. Relative to its size, Maryland has a big and growing carbon footprint. As a GHG "Bigfoot", it is incumbent on our State to take leadership responsibility to shrink both our statewide and our per capita GHG emissions.

Local Actions Yield Local Benefits

In addition to stimulating economic development and creating jobs, GHG reduction programs will have other local benefits for Maryland citizens. For example, reducing GHG emissions will also reduce air and water pollutants in Maryland. Planting urban trees – a key recommendation of the Commission – is an effective strategy for reducing GHGs because trees sequester carbon and cool nearby buildings, reducing the need for air conditioning and the demand for electricity. By contributing to lower summertime temperatures at street level, trees also improve our ambient air quality. The lower temperatures slow the formation of ground-level ozone and reduce concentrations of volatile organic compounds, nitrogen oxides, fine particulate matter and other air and water pollutants.

Other synergies abound. Managing forests for enhanced carbon sequestration also promotes forest health, biodiversity and water quality and reduces soil erosion. Smart Growth and transit-oriented development programs not only reduce GHGs by reducing vehicle miles traveled, they also reduce air pollution, highway congestion and lost productivity, as well as public expenditures for roads, sewers and water infrastructures and school bus transportation driven by development sprawl. Agricultural nutrient trading programs promote soil carbon sequestration and protect the Chesapeake Bay by reducing nitrogen and phosphorus loads from fertilizer run-off.

Maryland, a relatively small state, releases nearly as much GHGs as Sweden and Norway combined



Maryland's water-based livelihoods, cultural heritage and unique quality of life derive from the Chesapeake Bay and its many tributaries. Our exceptional vulnerability to sea level rise reposes a unique leadership responsibility on Marylanders to reduce our State and personal GHG footprints. We have a tremendous amount to lose. We also have a tremendous amount to gain.

State Leadership Is Pushing Federal Action

It's true that acting alone, Maryland can't reduce the world's GHGs by much. But together with more than half of the states in the U.S. that have adopted climate action plans, our cumulative impact is significant and we are moving the federal government to adopt comprehensive climate change legislation, a vitally needed step toward achieving reductions globally.

LESSONS LEARNED IN MARYLAND

Top 10 Things We Need From a Federal Program to Build the Federal-State Partnership Needed to Address Climate Change

1. A comprehensive national program that demonstrates leadership and allows the United States to be a strong, committed, pro-active voice in the international debate over global warming.
2. A strong effective national cap-and-trade program that creates a level playing field and directs allowance or auction proceeds to achieve greenhouse gas (GHG) reductions as expeditiously as possible.
3. A system, like the one now being piloted by the Regional Greenhouse Gas Initiative (RGGI), that insures that allowance or auction proceeds from a national cap-and-trade program are converted into maximum reductions in GHGs as quickly and efficiently as possible. Because the fastest path to GHG emission reductions is through energy efficiency and conservation, State and Local governments, working in partnership with citizens and the business community, are uniquely positioned to develop and implement programs to maximize energy efficiency, energy conservation and GHG reduction for each dollar spent.
4. Recognition of the strong connection between transportation choices and reducing GHGs in a process like the Clean Air Act's Transportation Conformity requirements to insure that GHG reduction efforts and transportation planning work hand-in-hand.
5. A process for coordinating with coastal states on adaptation policies.
6. A national program to implement the GHG reduction requirements of the California Low Emission Vehicle Program (CA LEV).
7. More and stronger national standards for energy efficiency (lighting, appliances, etc.).
8. Recognition that there is more a to comprehensive, national GHG reduction program than just cap-and-trade and that there is a critical role for State and Local governments in reducing GHG emissions from other critical areas like smart growth, transportation, energy efficiency, agriculture and programs to reduce Vehicle Miles Traveled (VMT) and adaptation.
9. Recognition and support for the comprehensive, cutting edge work, now being undertaken in many states to incubate and develop economy-wide climate action plans to address GHG reductions on all fronts.
10. A well funded, national research and development program to kick-start technological development, like clean-coal technologies, zero emission vehicles and new technologies for energy efficiency, that is needed to achieve very deep reductions in GHG emissions.

UNCERTAINTY IN EMISSION ESTIMATES AND EMISSION REDUCTIONS

It is important to understand the range of uncertainty there is with greenhouse gas emission calculations. Calculating emission reduction potential is not an exact science and there are numerous assumptions that need to be made for each policy. These assumptions are always based on the most recent data but there is certainly a need to caveat both the emission projection calculations and the emission reduction calculations with a degree of uncertainty.

Greenhouse gases in Maryland will continue to rise unless policies are developed at the local and national level to meet the challenge.

Other reasons for uncertainty include:

- **The emission inventory created for this report was a "top-down" inventory and should not be considered a compliance level inventory**
- **The process of creating a consumption-based emission inventory is relatively complex and certainly new to Maryland**
- **Many of the policy options reviewed overlapped to some degree. The emission estimates were carefully evaluated to ensure overlap was minimal but it is important to note for transparency that this adds to the uncertainty of the final emission reduction estimates**

The Commission discussed the uncertainty issues and it is important to note for the reader of this report that concerns exist over the clarity of the emission reduction calculations. These numbers were generated by some of the nation's most qualified experts and reflect the "state of the science" as current but should not be considerd absolute.

The technical team that conducted the analysis discussed different approaches for communicating this uncertainty. After lengthy discussion, it was concluded that an explicit, quantitative estimate of the uncertainty was beyond the scope of the current effort. There was an agreement, however, to communicate the uncertainty associated with the aggregated reductions (of all mitigation strategies) using a range. The range uses 80 per cent of the estimate for the lower bound and 100 per cent for the upper bound.

THE INVENTORY

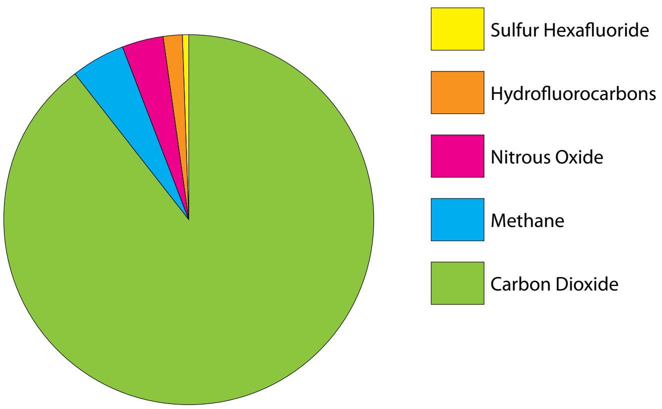
GHG Emissions in Maryland

- More detail on the inventory and forecast is available in Appendix C.

- Carbon dioxide (CO_2) comprises about 90 per cent of Maryland's GHG emissions, when considering the CO_2 emission equivalents in terms of their impacts on global warming.

- The remaining emissions, while not as prevalent as CO_2, can be more reactive in the atmosphere so it is important that they are not ignored.

- For the purposes of this analysis, most GHG emission inventory engineers use the term $MMtCO_2e$, which stands for Million Metric Tons of CO_2 equivalent - a mathematical formula that equates all GHG emissions to CO_2 to facilitate comparisons.



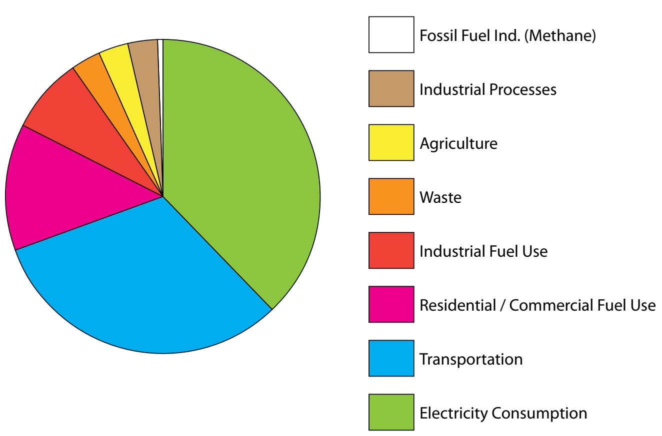
Major GHG Emission Sources for Maryland

This graph shows the GHG emissions associated with Maryland's footprint in 2007. The graph includes emissions from within the State's borders and emissions from out-of-state that are created by consumption in Maryland.

- Approximately 30 per cent of the electricity used in Maryland is imported.

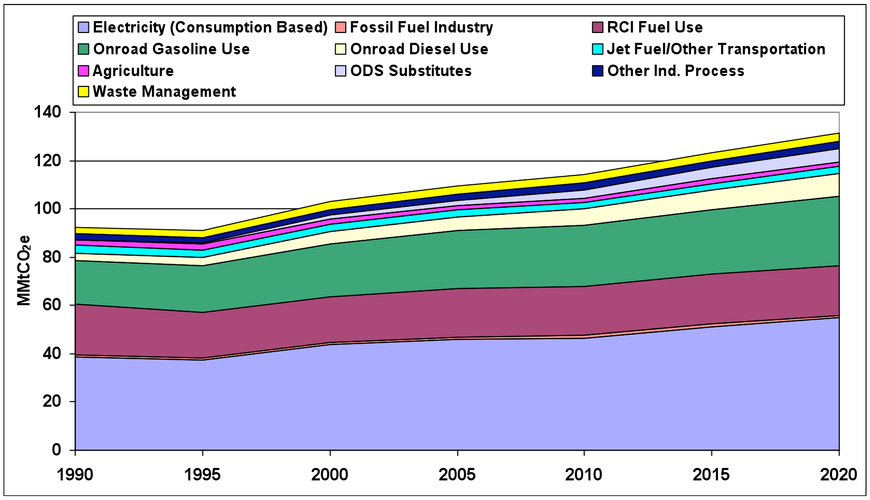
- Maryland is very similar to the national average when it comes to GHG emissions.

- The largest source sectors in Maryland are Electricity Consumption (38 per cent) and Transportation (32 per cent).



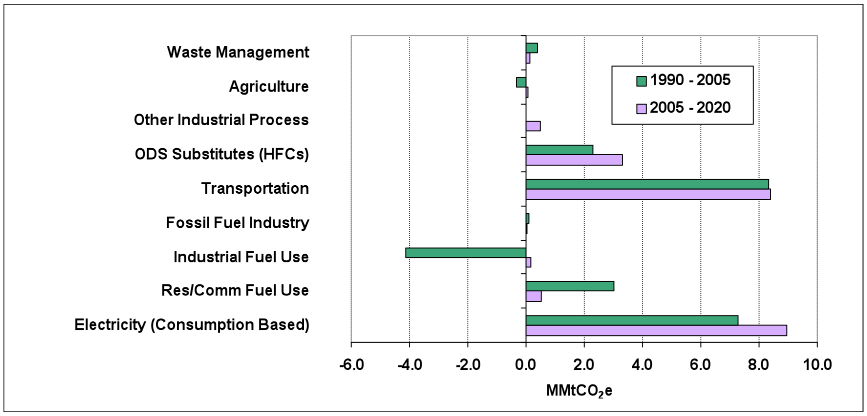
Are Maryland's GHG Emissions Growing?

- Due to increases in population and consumption, Maryland's GHG emissions are expected to continue to grow.
- The chart to the right shows projected growth out to 2020 in a "Business As Usual" scenario that does not include any programs to reduce GHGs.
- In total, if you take a snapshot of 2007, Maryland's total emissions are in excess of 100 million metric tons of CO_2 equivalent.
- Based on these projections, Maryland can expect to exceed 130 million metric tons of CO_2 equivalent by 2020 without any new CO_2 reducing programs.



In What Sectors are Maryland's GHG Emissions Growing?

- The chart to the right shows historical and predicted GHG emissions by sector.
- The green bars represent historical emission trends from 1990 to 2005. The purple bars represent 2005 to predicted 2020 totals.
- A few source sectors show a net loss in future emissions growth – agriculture and industrial processes
- Historically industrial fuel use was a decreasing emissions source, but according to projections, Maryland could expect a slight increase in emissions from that source sector.
- Overall, the two largest sources – transportation and electricity (energy supply) showed significant growth in emissions from 1990 to 2005 and are expected to continue to grow between 2005 and 2020 in a "Business As Usual" scenario.



Refining the Inventory

One of the policies recommended by the Commission is to have MDE develop a more detailed and comprehensive inventory and forecast. This will be a major effort for MDE over the next three years. The recommendation on inventory development is discussed in more detail later in this Chapter.

National GHG Reporting Requirements on the Horizon

The work of updating and refining Maryland's inventory will be made easier as a result of recent Congressional action. As part of its omnibus spending bill for FY2008 ("Reconciliation Omnibus Act", H.R. 2764), Congress appropriated funds to the Environmental Protection Agency (EPA) to adopt rules requiring the mandatory reporting of GHGs in all sectors of the U.S. economy. The stated purpose is to provide data that will inform and support development of national climate policy. The mandate covers all six GHGs and both upstream and downstream sources. Upstream sources include fuel and chemical producers and importers (e.g., oil refineries, natural gas processors, HFC producers). Downstream sources include GHG emitters such as power plants, iron and steel plants and cement manufacturers. EPA will establish reporting threshold levels. It is directed to publish draft rules by September 2008 and adopt final regulations by June 2009. It will build on the work of existing mandatory and voluntary GHG registries such as The Climate Registry, of which the Maryland Department of the Environment (MDE) is a founding member.

EARLY VOLUNTARY ACTION – CLIMATE REGISTRIES

The Climate Registry (TCR) is a voluntary initiative to establish a single greenhouse gas (GHG) registry for North America. It is supported by a Board of Directors including representatives from Maryland, 38 other U.S. States, the District of Columbia, 7 Canadian provinces, 6 Mexican states, and 3 Native American nations.
Encouraging early reductions is a critical element of Maryland's plan. TCR is intended to be a tool that early voluntary reducers can use to "bank" their reductions for potential credit at a later date.

MDE is a founding reporter, tracking and accounting for the Department's GHG emissions. TCR has developed a rigorous standardized protocol for reporting GHG emissions. This is based on the World Resources Institute and World Business Council for Sustainable Development's "The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard." TCR has also developed a protocol for third-party verification of reported GHG emissions, and software, the Climate Registry Information System (CRIS), for calculating and reporting emissions.

TCR is an example of voluntary programs around the country to encourage greenhouse gas tracking. Other examples include ICLEI: Local Governments for Sustainability, which assists cities around the world with tracking and reducing their GHG emissions, and the American College and University Presidents Climate Commitment (ACUPCC), which requires completion of an emissions inventory and a plan for becoming neutral in the college or university's impact on climate. TCR is working with ICLEI to develop a local government and community emissions reporting protocol and with ACUPCC to smooth out differences in programs.

Ben Longstaff, IAN Image Library (www.ian.umces.edu/imagelibrary/)

Background

On April 20, 2007, Governor Martin O'Malley signed Executive Order 01.01.2007.07 (the Order) establishing the Maryland Commission on Climate Change (the Commission). The Executive Order is in Appendix A.

The Commission's creation is based on near universally accepted science, as well as physical evidence here in Maryland, supporting the theory that the world's climate is changing and that human activities are contributing factors. It is clear that strong government action is necessary to protect the State's people, property, natural resources, and public investments from the ensuing impacts of climate change. The Commission was therefore tasked with developing a ***Plan*** to address the drivers and consequences of climate change, to prepare for the likely consequences and impacts of climate change to Maryland, and to establish firm benchmarks and timetables for implementing the ***Plan***.

A number of State initiatives over the past several years have provided a foundation for the Commission's work. These include the formulation and implementation of a State Sea Level Response Strategy (2000), passage of the Healthy Air Act (2006), passage of the Clean Cars Act (2007), participation in the Regional Greenhouse Gas Initiative (2007) and the ***EmPOWER Maryland*** initiative (2007).

Structure and Membership

The Commission was supported by three Working Groups whose members were appointed by the Commission Chair, Shari T. Wilson, Secretary, Maryland Department of the Environment (MDE). The Working Groups are as follows: Scientific and Technical Working Group (STWG), chaired by Donald Boesch, President, University of Maryland Center for Environmental Science, and co-chaired by Frank W. Dawson, Assistant Secretary of Maryland's Department of Natural Resources (DNR), and Robert M. Summers, Deputy Secretary of MDE; Greenhouse Gas and Carbon Mitigation Working Group (MWG), chaired by George (Tad) Aburn, Director of MDE's Air and Radiation Management Administration, and co-chaired by Malcolm Woolf, Director, Maryland Energy Administration (MEA); and Adaptation and Response Working Group (ARWG), chaired by John R. Griffin, Secretary of DNR, and co-chaired by Richard Eberhart Hall, Secretary, Maryland Department of Planning (MDP), and Don Halligan, Assistant Secretary of MDP.

These Working Groups and the technical working groups (TWGs) that support them represented diverse stakeholder interests and brought broad perspective and expertise to the Commission's work. The Commission's work was facilitated by a consultant, The Center for Climate Strategies (CCS). Membership rosters for the Commission, its three Working Groups and the TWGs are in Appendix B.

Overarching Goals Of The *Comprehensive Greenhouse Gas And Carbon Footprint Reduction Strategy*

The *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy* is the part of the ***Plan*** that makes recommendations of how to mitigate or reduce GHG emissions.

The *Strategy* was developed using comprehensive input from stakeholders and used the following principles to drive the process:

- Achieve significant long- and short-term emission reductions of GHGs in Maryland
- Demonstrate leadership
- Maximize the cost-effectiveness of the *Strategy*
- Provide savings to Maryland consumers and businesses
- Provide a net economic benefit to the State
- Drive job creation, business growth and economic development in Maryland

As Maryland begins to further analyze and implement the *Strategy*, there will be continued coordination with stakeholders. These same set of principles will be used to guide those efforts.

A Science-Based, Consensus-Building Process

The Commission's work was supported by the science-based, consensus-building stakeholder process of its Working Groups and their respective TWGs. Through these processes, the MWG, the ARWG and the supporting TWGs developed catalogs of policy options for consideration by the Commission. The catalogs built from options developed by other states with climate action plans. The TWGs added to, subtracted from and fine-tuned the Maryland catalogs. The TWGs supported and informed their respective Working Groups on Early Action Items and priorities for further analysis and possible legislation in their respective fields of expertise. The two Working Groups evaluated the TWGs' work and, from this, developed and presented recommendations to the Commission.

The MWG was tasked with development of a *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy*. The *Strategy* (this Chapter) evaluates and recommends Maryland's GHG reduction goals, recommends short-, medium-, and long-term goals and strategies to mitigate GHGs and offset carbon emissions, and provides an implementation timetable for each recommended strategy. TWGs for this Working Group are: Residential, Commercial and Industrial; Energy Supply; Transportation and Land Use; Agriculture, Forestry and Waste; and Cross-Cutting Issues. The goal of the MWG was to develop a comprehensive, aggressive strategy that achieves the GHG reduction goals established by the Commission using a suite of control programs whose costs will provide a net economic benefit to the State and its citizens.

GOALS

Overview

Goals are one of the key elements of state climate action plans. Most state plans include early goals (2010 to 2015), mid-term goals (2020) and longer-term goals (2050). Different strategies may be needed to meet the different goals. Short-term strategies are usually based upon current technologies while longer-term strategies may depend on research and development and be more "technology forcing."

The Science Behind the Goals

As synthesized by the IPCC, the scientific evidence suggests that an increase in annual global mean surface temperature greater than 2 - 2.5°C (3.6 - 4.5°F) above pre-industrial levels is very likely to result in dangerous consequences in terms of food production, biodiversity, and initiation of uncontrollable and unpredictable changes in the Earth's climate system, such as rapid melting of polar ice caps and changes in the ocean circulation that regulates the planet's climate. (See p.26)

To avoid reaching this level of global warming, Earth system models indicate that greenhouse gas (GHG) concentrations in the atmosphere would have to be held to around 450 ppm in CO_2 equivalents, and certainly not more than 550 ppm. To stabilize GHGs at this level requires substantial early action because it now seems that atmospheric concentrations are fast approaching, if they haven't already reached 450 ppm. Furthermore, considering the residence time of the CO_2 and other GHGs that have been and are being emitted, reductions in emissions by 60 to 85 per cent below 2000 levels would be required by 2050 in order to reach this level of stabilization.

Consequently, governments ranging from the European Union to a number of states in the United States have been adopting policies and goals based on reducing emissions at least to 1990 levels by 2020. These climate action plans call for taking immediate actions to stem the growth in emissions and then beginning to reduce them, with a heavy emphasis on energy conservation. The plans set long-term goals of achieving 75-80 per cent reductions in emissions by 2050, relying on new energy sources and technologies that will have to be developed.

The Goal Setting Process in Maryland

The key themes used by the Commission in the goal setting process were:

- Build from the most current science available
- Demonstrate leadership and be aggressive – Maryland has a tremendous amount at risk because of climate change
- Place a high priority on cost-effective implementation strategies to achieve goals
- Incorporate innovative funding mechanisms to limit the need for new public funding
- Maryland is in a unique position to become a national leader in terms of goal setting
- Urge adoption of policies and practices to achieve the earliest possible reductions
- Include a science-based review of the goals at least every four years

The Commission closely modeled efforts in other states, including California and New Jersey, and also paid close attention to the most recent science and goal information being developed by the IPCC and the U.N.

State	Earlier Goals	Mid-Term Goals	Later Goals
California	2000 levels by 2010	1990 levels by 2020	80 % below 1990 levels by 2050
Florida	2000 levels by 2017	1990 levels by 2025	80 % below 1990 levels by 2050
New Jersey	N/A	1990 levels by 2020	80 % below 2006 levels by 2050
Massachusetts	1990 levels by 2010	10 % below 1990 levels by 2020	75 % below 1990 levels by 2050
IPCC	N/A	25 % to 40 % below 1990 levels by 2020	80 % to 95 % below 1990 levels by 2050

MARYLAND'S 6-STEP GOAL SETTING PROCESS

Step 1 - Should The Goals Be Based Upon "Consumption" Or In-State Generation?

- Consumption-based goals are designed to reduce emissions resulting from Maryland's footprint (the activities of Maryland and its citizens). For example, Maryland consumes more electricity then it generates. Our footprint includes the GHG emissions from all the electricity we consume.
- Generation-based approaches simply look at emissions being released within a state's geographic border.
- Most states have used consumption-based concepts in setting goals. ***The Commission's recommended goals are consumption-based.***

Step 2 - What Year Should Be The Starting Point?

- There is a tremendous amount of inconsistency on this issue.
- Many states have used 1990 as a base year. Others have used later years like 2005 or 2006, while others have used 2000. The Commission's goals are based upon reductions from a 2006 base year.
  - » *These are the most recent data*
  - » *Using an earlier year (like 1990) does not communicate the magnitude of the challenge sufficiently because 1990 to 2006 growth has been significant.*
- Generally, in Maryland, a 25 per cent reduction from 2006 levels by 2020 is about equivalent to meeting 1990 levels by 2020.
  - » *Because so many states have used 1990 as a base year, whenever possible, Maryland will include a reference to what the equivalent reductions from a 1990 base would be.*

Step 3 - Should The Goals Be Aggressive Or Bottom-Up Minimums?

- What we'd like to do or what we know we can do?
- ***As a State with a tremendous amount at risk, the Commission felt strongly that Maryland's goals need to be very aggressive to both do our fair share and to demonstrate leadership.***
- Maryland's goals not only set reduction targets to drive State programs and reductions, they are also intended to send a message about the kind of reductions that Maryland believes other states, the federal government and the international community need to be pursuing to combat climate change.
- The Commission also included the feasibility of achieving the goals as part of the goal setting process.
- For example, the 2020 goal includes a minimum regulatory goal of 25 per cent reduction, but also advocates for the development of non-regulatory, market-based tools to reward reductions above 25 per cent and achieve a 50 per cent reduction by 2020.

The Goal-Setting Process

Year	*Maryland's Goals (From a 2006 Baseline)*	*Equivalent Goals (From a 1990 Baseline)*
2012	**10 % Reduction - from 2006 Levels**	**15 % Above 1990 Levels**
2015	**15 % Reduction - from 2006 Levels**	**9 % Above 1990 Levels**
2020	**25 % Reduction - from 2006 Levels**	**4 % Reduction - from 1990 Levels**
2020	**50 % Reduction - from 2006 Levels**	**36 % Reduction - from 1990 Levels**
2050	**90 % Reduction - from 2006 Levels**	**87 % Reduction - from 1990 Levels**

Step 4 - For What Years Should The Goals Be Set?

- Generally states have set early goals (2010 to 2015), mid-term goals (2020) and later goals (2050/2100)
- ***Maryland has set goals for 2012, 2015, 2020 and 2050***
- The 2012 goal is intended to push very hard for early action. A key message from the science is that early reductions are critical.
- The 2015 goal is intended to strengthen and promote early reductions. Some existing Maryland initiatives, like the Clean Cars program and RGGI begin to pay dividends in this time frame.
- The 2020 goal of 25 per cent is intended to provide a regulatory driver consistent with Global Warming Solutions type programs in other states.
- The 2050 goal is designed to provide a regulatory driver that spurs research and development of climate-neutral technologies like clean coal power plants and zero emissions vehicles.

Step 5 - Should The Goals Be Regulatory Or Should They Be Reduction Targets for the State's *Climate Action Plan*?

- Other states have used goals to do both.
  - *California and New Jersey use their 2020 goal as a strict regulatory limit that is enforceable*
  - *Other states have often used the goals to guide their state action plan*
- Maryland's goals will be used to do both.
  - *The 2020 goal of 25 per cent reduction and the 2050 goal of 90 per cent reduction will, like those in California and New Jersey, be used as regulatory goals*
  - *The other goals will be used as reduction targets for the State* ***Climate Action Plan***

Step 6 - Should The Goals Be Science-Based?

- ***Maryland's goals have been developed using the most recent scientific findings on climate change and its drivers.***
- One key theme from the science is to push for early controls
  - *Maryland's 2012 and 2015 goals are intended to drive early reductions*
- Recent IPCC findings encourage industrialized nations to pursue reductions by 2020 in the 25 per cent to 40 per cent range (from 1990) to avoid the most catastrophic consequences of climate change. (See p.26)
  - *Maryland's 2020 goals (25 per cent and 50 per cent) are intended to push for this level of reduction*
  - *Recent and earlier IPCC findings push for global reductions as high as 80 per cent to 95 per cent (from a 1990 base) by 2050.*
- Maryland's 2050 goal is consistent with this level of reduction

RECOMMENDED GOALS

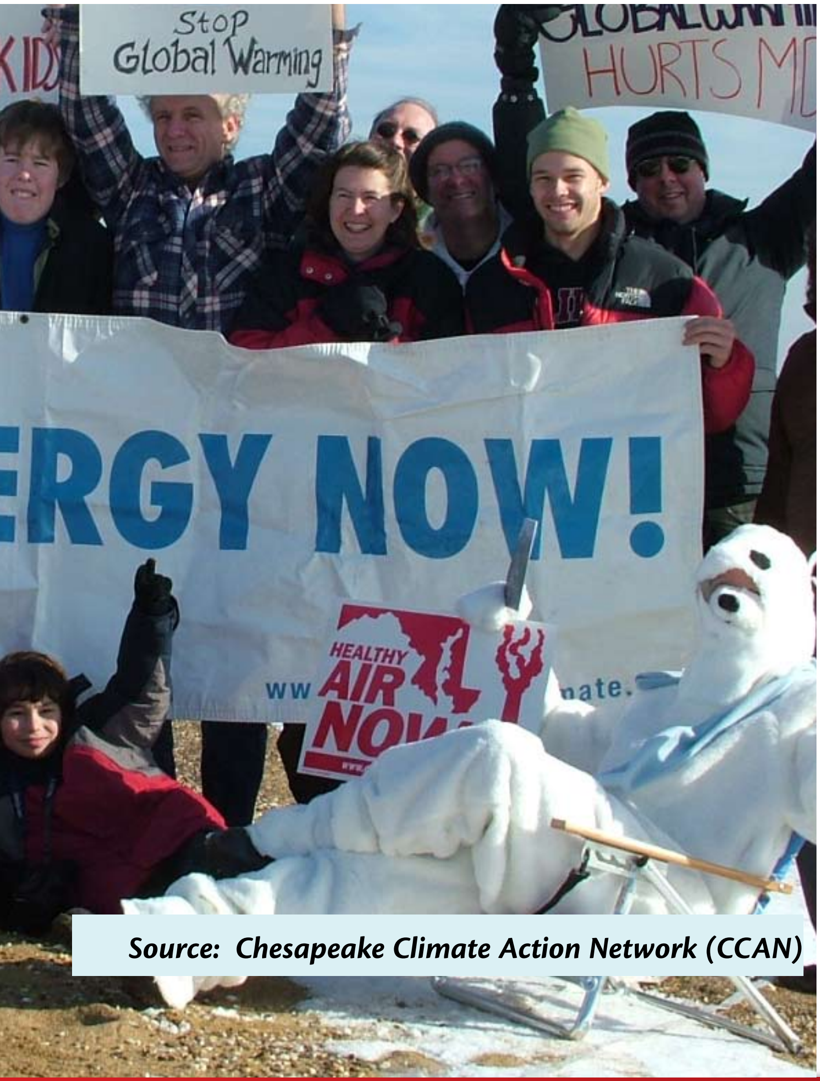
The key themes used by the Commission in the goal setting process were:

- Build from the best and most current science available
- Demonstrate leadership and be aggressive - Maryland has a tremendous amount at risk because of climate change
- Place a high priority on cost-effective implementation strategies to achieve goals
- Incorporate innovative funding mechanisms as much as possible to limit the need for new public funding to implement new programs

Maryland is in a unique position to become a national leader in terms of goal setting

Push for the earliest possible reductions

Mid Course Reviews: Conduct a science-based review of the goals at least every four years



Source: Chesapeake Climate Action Network (CCAN)

Maryland should set early, aggressive GHG reduction goals with specific time frames as follows:

2012

- 10 per cent below Maryland's 2006 GHG emission levels (using a consumption-based approach) by 2012
- To be used as a reduction goal for Maryland's ***Climate Action Plan***

2015

- 15 per cent below 2006 levels by 2015
- To be used as a reduction goal for Maryland's ***Climate Action Plan***

2020

- 25 per cent to 50 per cent below 2006 levels by 2020
- 25 per cent used as the "minimum" enforceable, regulatory driver for the Global Warming Solutions legislation
- 50 per cent used as a science-based, non-regulatory reduction goal for Maryland's ***Climate Action Plan***
- Programs to implement the legislation would reward market-based reductions above 25 per cent

2050

- 90 per cent below 2006 levels by 2050
- A science-based regulatory goal in the Global Warming Solutions legislation
- A driver for research and development of climate neutral technology, programs and innovations

THE IPCC ON REDUCTION TARGETS – 2007

"Table 1 summarizes this analysis, which indicates that in order to achieve a stabilization level of 450 ppmv CO_2 eq., emissions from Annex I Parties would need to be between …
… 25 per cent and 40 per cent below 1990 levels in 2020, and between 80 per cent to 95 per cent below 1990 levels in 2050."[1]

Table 1. Characteristics of greenhouse gas stabilization scenarios

Category	CO_2 equivalent concentration	Global mean temperature increase above pre-industrial at equilibrium using 'best estimate climate sensitivity [a]	Change in global CO_2 emissions in 2050 (% of 2000 emissions)	Range of reduction in GDP in 2050 because of mitigation (%)	Allowed emissions by Annex I Parties in 2020 (% change from 1990 emissions)	Allowed emissions by Annex I Parties in 2050 (% change from 1990 emissions)
I	445-490	2.0-2.4	-85 to -50	Decrease of up to 5.5	-25 to -40	-80 to -95
II	490-535	2.4-2.8	-60 to -30			
III	535-590	2.8-3.2	-30 to +5	Slight gain to decrease of 4	-10 to -30	-40 to -90
IV	590-710	3.2-4.0	+10 to +60	Gain of 1 to decrease of 2	0 to -25	-30 to -80
V	710-855	4.0-4.9	+25 to +85			
VI	855-1,130	4.9-6.1	+90 to +140			

Source: IPCC Fourth Assessment Report (AR4). Contribution of Working Group III. Columns 1-4., table SPM.5; column 5, table SPM.6, columns 6 and 7, box 13.7.
[a]According to the AR4, the best estimate of climate sensitivity is 3 degrees Celsius.

[1]From the United Nations Framework Convention on Climate Change "Synthesis of information relevant to the determination of the mitigation potential and to the identification of possible ranges of emission reduction objectives of Annex 1 Parties" Technical Paper.

July 26, 2007

COMMISSION'S RECOMMENDED POLICY OPTIONS

From a catalogue of about 300 possible policy options for reducing GHG emissions, the Commission approved for further analysis fifty-four priority policy options selected by the MWG. These were identified in the Commission's ***Interim Report***, (Appendix C of the ***Interim Report***). Since then, the MWG's five TWGs have developed and refined each of these policy options from straw proposals into specific policy options. The process then further narrowed the list of policy options to forty-two. (Several options were consolidated and some were eliminated).

Each policy option includes a description, a design, and a goal, and each examines implementation mechanisms, feasibility and barriers, related existing programs, co-benefits, and key assumptions and uncertainties. The estimated reduction in GHG emissions has been calculated for the policy options amenable to quantification (expressed in million metric tons of CO_2 equivalent, or $MMtCO_2e$) based on the stated goal of each policy. The cost or cost savings of achieving the reduction (expressed in dollars per ton) is also calculated for each quantified policy.

The forty-two policy options approved by the Commission form the core of its ***Climate Action Plan*** mitigation recommendations. A summary of each is included in the report of each TWG, later in this Chapter. Some of the policy options have well-developed implementation mechanisms. Because of the scope of the Commission's work and its compressed time frame, the details of implementation for some policy options will need to be further analyzed and worked out by State agencies after this ***Plan*** is submitted to the Governor and the General Assembly. Where this is the case, it is noted in the policy option summary.

The technical analysis that was performed to estimate reductions and cost-effectiveness of the policy options is the best possible analysis that could be completed in a six-month time frame. MDE and other State agencies will conduct additional analysis of many of the policy options over the next several years.

The analysis in this document and the results of these analyses are appropriate for setting the general policy direction for the State of Maryland to pursue in reducing GHGs and addressing climate change. As implementation of the ***Plan*** begins, the inventory and the estimates of reductions and cost-effectiveness will be refined and updated.

Commission's Policy Options Bins

With forty-two measures to consider, the Commission decided to place the policies in "bins" based on the following criteria:

Bin 1: Higher Emission Reductions / Easier to Implement
Bin 2: Lower Emission Reductions / Easier to Implement
Bin 3: Higher Emission Reductions / Harder to Implement
Bin 4: Lower Emission Reductions / Harder to Implement

In addition to placing the forty-two policies into "bins", the Commission also identified lead agencies for each policy option. These lead agencies, that are responsible for further analysis and implementation of the policies, and co-lead agencies or assisting agencies (in parentheses) are identified in the Bin Charts on the following two pages.

Implementation actions for policy options related to land use and planning will be incorporated into the ***State Development Plan*** which will be implemented by the Maryland Department of Planning (MDP), the Smart Growth Subcabinet and all State agencies.

The actual policy options are reviewed and explained later in this Chapter and appendices. The following tables illustrate the Commission's approach.

These abbreviations refer to the Technical Work Group (TWG) that developed the policy options referenced throughout this Chapter:

AFW Agriculture, Forestry and Waste
ES Energy Supply
RCI Residential, Commercial and Industrial
TLU Transportation and Land Use
CC Cross Cutting Issues

Bin 1: Higher Emission Reduction / Easier Implementation

Policy Number	*Policy Name*	*Lead Agency*
ES-3	GHG Cap-and-Trade	MDE
TLU-10	Transportation Technologies	MDOT (MDE)
RCI-10	Energy Efficiency Resource Standard	MEA
CC-4	State & Local Government Lead by Example	MDE (MEA, MDOT)
RCI-4	Improved Design, Construction, Appliances & Lighting in Government	MDE (others)
AFW-9	Waste Management / Advanced Recycling	MDE
ES-7	Renewable Portfolio Standard	PSC (MEA)
RCI-2	Demand Side Management & Energy Efficiency	MEA (PSC)
RCI-1	Improved Building & Trade Codes	DHCD (MEA)

Bin 2: Lower Emission Reduction / Easier Implementation

Policy Number	*Policy Name*	*Lead Agency*
CC-1	GHG Emission Inventories & Forecasting	MDE
CC-2	GHG Reporting & Registries	MDE
CC-3	Statewide GHG Reduction Goals	MDE
CC-5	Public Education & Outreach	MDE (MSDE, MEA)
CC-8	Participate in Regional, Multi-State & National Efforts	MDE
CC-7	Review Institutional Capacity	Commission
CC-10	After Peak Oil	MEA (MDE)
CC-11	Public Health Risks	DHMH (MDE)
RCI-11	Promotion & Incentives for Energy Efficient Lighting	MEA
ES-5	Clean Distributed Generation	MEA (PSC)
RCI-3	Low-Cost Loans for Energy Efficiency	MEA
ES-1	Promotion of Renewable Energy	MEA (PSC)
ES-6	Integrated Resource Planning	PSC (MEA)
RCI-7	More Stringent Appliance / Equipment & Efficiency Standards	MEA
CC-9	Promote Economic Development Opportunities	DBED (MEA)
ES-2	Technology Focused Initiatives for Electricity Supply	MEA
AFW-2	Managing Urban Trees & Forests	DNR
AFW-3	Afforestation, Reforestation, & Restoration of Forests & Wetlands	DNR (MDA)
AFW-4	Protection & Conservation of Agricultural Land, Coastal Wetlands & Forested Land	MDA
AFW-1	Forest Management for Enhanced Carbon Sequestration	DNR
AFW-5	Buy Local Programs	MDA (DNR)

Bin 3: Higher Emission Reduction / Harder Implementation

Policy Number	Policy Name	Lead Agency
ES-8	Energy Improvements & Repowering Existing Plants	MEA (PSC)
ES-10	Generation Performance Standards	MDE (PSC, MEA)
TLU-2	Land Use & Location Efficiency	MDOT (MDP, MDE)
TLU-3	Transit	MDOT (MDP, MDE)
TLU-5	Intercity Travel	MDOT (MDP, MDE)
TLU-6	Pay-As-You-Drive Insurance	MDOT (MDP, MDE)
TLU-8	Bike & Pedestrian Infrastructure	MDOT (MDP, MDE)
TLU-9	Incentives, Pricing & Resource Measures	MDOT (MDP, MDE)
TLU-11	Evaluate GHGs from Major Projects	MDOT (MDP, MDE)

Bin 4: Lower Emission Reduction / Harder Implementation

Policy Number	Policy Name	Lead Agency
AFW-6	Expanded Use of Forest & Feedstocks for Energy Production	DNR (MDA)
AFW-7b	In-State Liquid Biodiesel Production	MEA (MDA)
AFW-8	Nutrient Trading with Carbon Benefits	MDE (MDA)

Lead State Agencies

MDE Maryland Department of the Environment
MDOT Maryland Department of Transportation
MEA Maryland Energy Admisinstration
PSC Public Service Commission
DHCD Department of Housing and Community Development
DHMH Department of Health and Mental Hygiene
MSDE Maryland State Department of Education
DBED Department of Business and Economic Development
DNR Department of Natural Resources
MDA Maryland Department of Agriculture

The remainder of this Chapter provides a summary of the mitigation policy options that the Commission is recommending be included in the ***Climate Action Plan***.

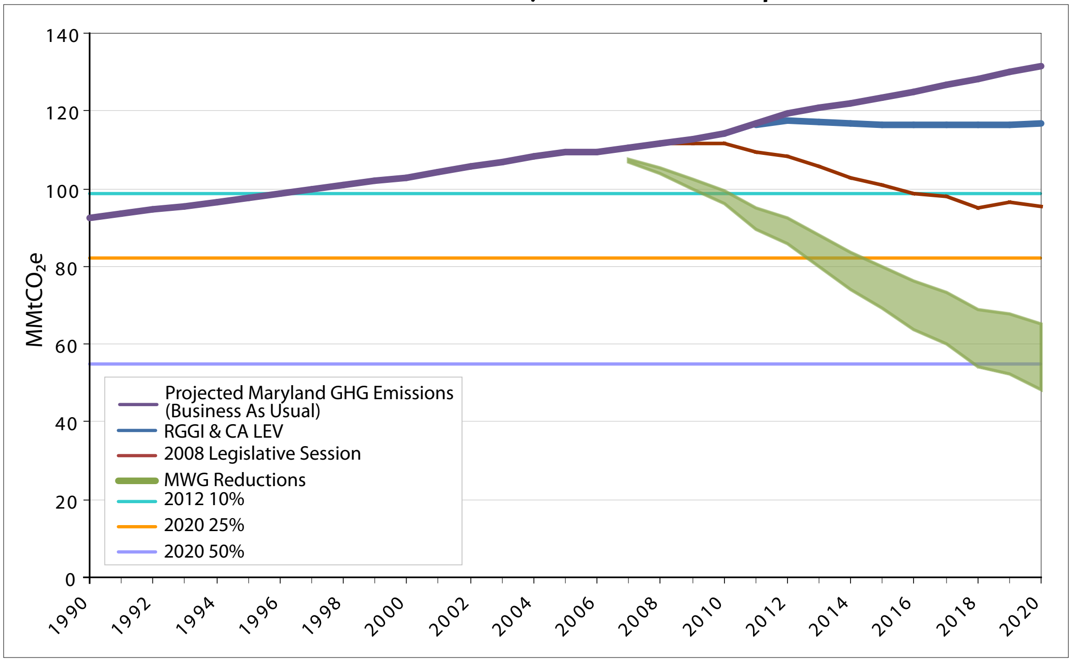
- The forty-two strategies combined result in reductions that are very consistent with the goals discussed earlier.
- The technical analysis that was performed to estimate reductions and cost-effectiveness for each policy option is the best possible analysis that could be completed in a six-month time frame. There will be additional analysis of many of the policy options conducted by MDE and other State agencies over the next several years.
- The analysis in this document and the results of these analyses are appropriate for setting the general policy direction the State of Maryland wants to pursue in reducing GHGs and addressing climate change. As implementation of the ***Plan*** begins, the inventory and the estimates of reductions and cost-effectiveness will be refined and updated.

The figure below, "GHG Reduction Potential from Maryland's Recent and Proposed Actions", shows the potential reductions that Maryland projects based on the full implementation of the forty-two measures included in the *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy*. The figure shows that by 2020, the ***Plan*** can achieve reductions that will be consistent with the goals established by the Commission. Because of the uncertainty in some of the analysis, the Commission expects the 2020 reduction levels to be between 40 and 55 per cent, approaching the higher-level target of a 50 per cent reduction by 2020.

Another key policy embodied in the ***Plan*** is that the current trend of continuing growth in GHG emissions should be reversed as quickly as possible. This figure shows that Maryland can start reducing that trend soon if the MWG policies are implemented.

The figure also shows that recent actions by Maryland, like the Regional Greenhouse Gas Initiative (RGGI) and the Clean Cars Program (CA LEV), and new programs adopted through legislation in 2008 will get the state close to the 25 per cent reduction target by 2020.

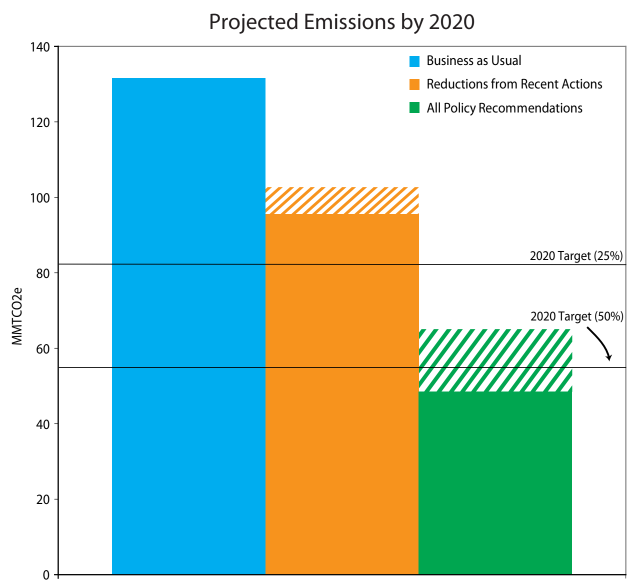
GHG Reduction Potential from Maryland's Recent and Proposed Actions

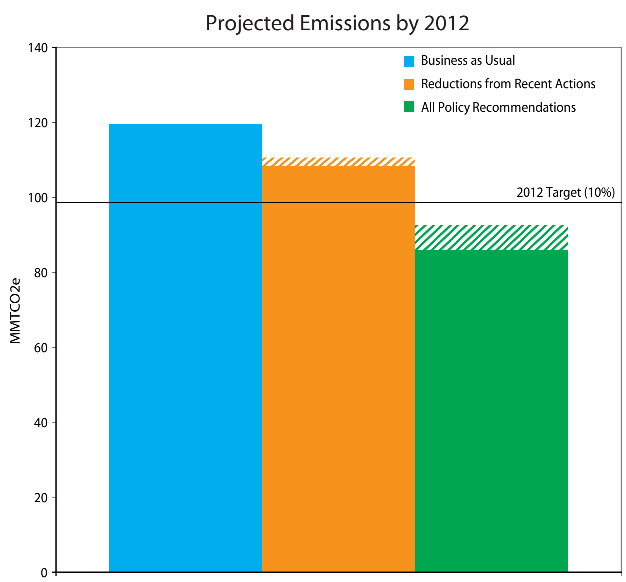


The next six figures show the potential emission reductions from recent actions and the Commission's quantified policy options (reduction strategies).

The two figures below, "Projected Emissions by 2020" and "Projected Emissions by 2012" show the annual benefits in 2020 and 2012. They illustrate that by 2020, the strategies are expected to achieve reductions that are consistent with the reduction goals set by the Commission. The Commission's 2020 goal is to achieve a 25 per cent to 50 per cent reduction from 2006 levels. The forty-two strategies are projected to achieve an approximate 40 per cent to 55 per cent reduction from 2006 levels by 2020. As discussed earlier, there is considerable uncertainty associated with calculating the aggregate benefits of the policy options. "Projected Emissions by 2020" also shows that early actions, already taken in Maryland, will achieve about 60 per cent to 70 per cent of the reductions needed to meet the 25 per cent reduction goal.

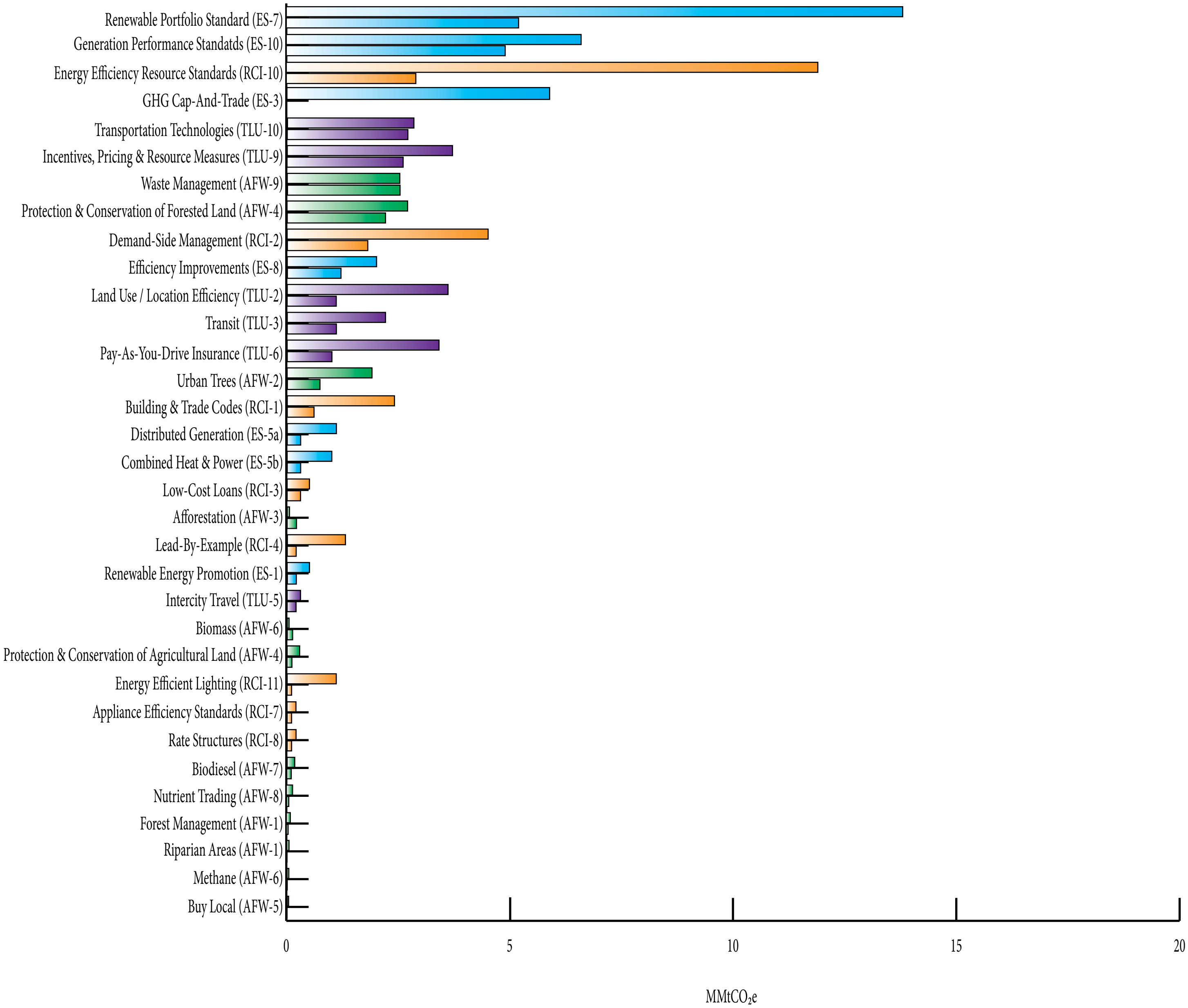
"Projected Emissions by 2012" shows the same information for 2012. 2012 is an important milestone as early reductions are critical. The science tells us that a ton of reduction in 2012 is much more effective than a ton of reduction in 2050. The reductions from the quantified policy options are expected to exceed the Commission's 2012 10 per cent reduction goal. They are projected to achieve an approximate 25 per cent to 30 per cent reduction from 2006 levels by 2012. Early actions also contribute significantly in 2012. Early actions are expected to achieve about 40 per cent to 50 per cent of the reductions needed to meet the 2012 goal.



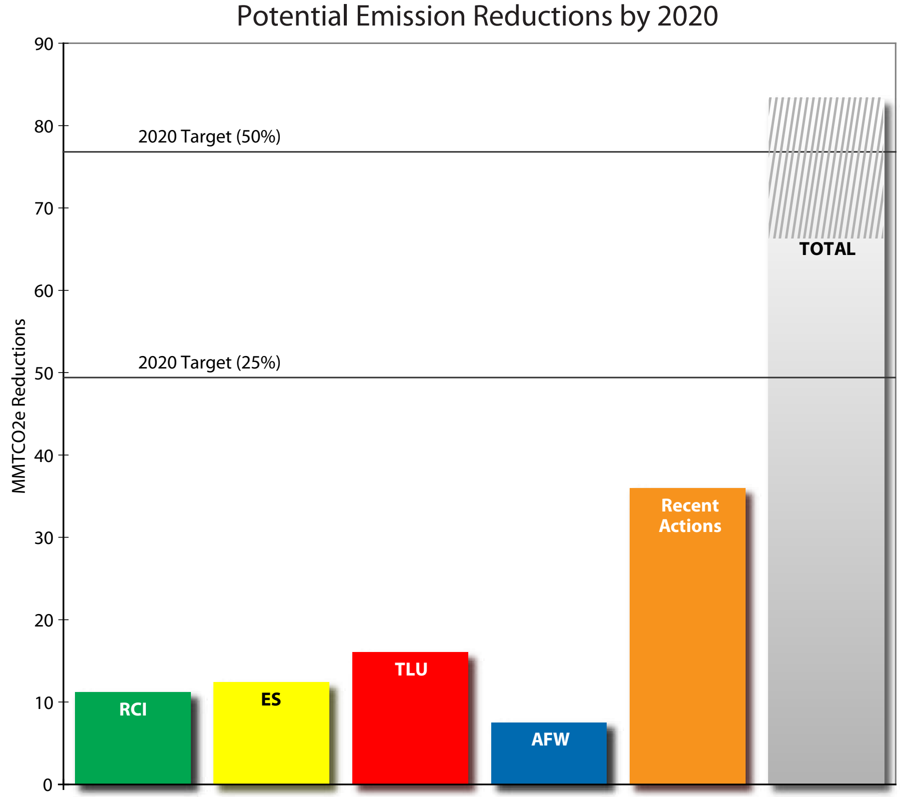


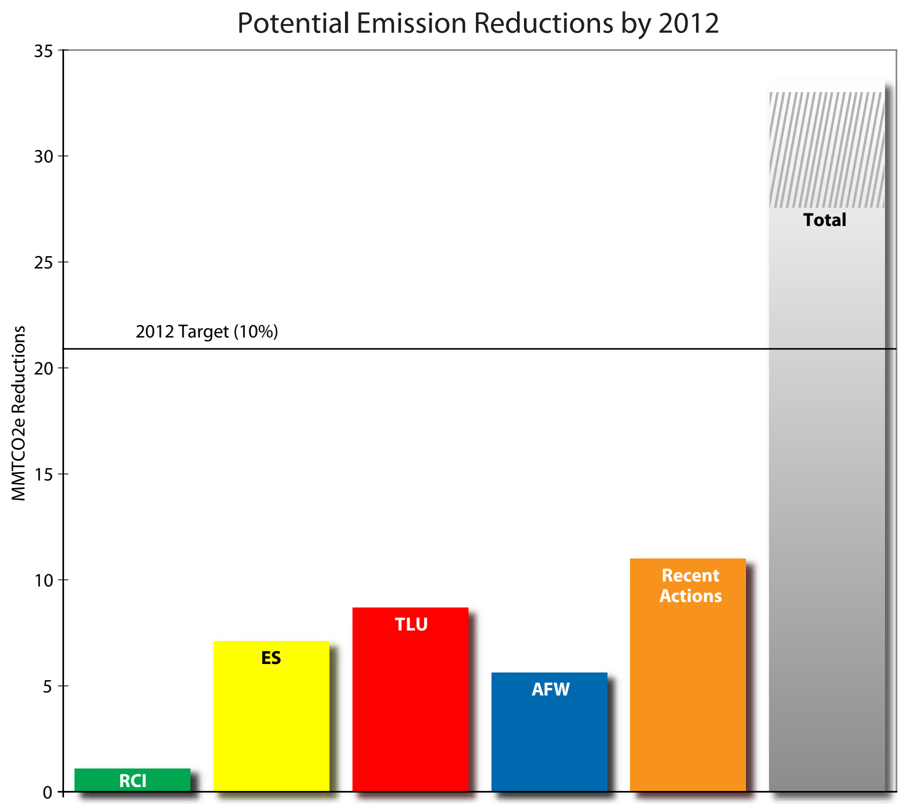
The figure below shows the individual reductions from each of the quantified policy options in 2020 and 2012.

Annual Greenhouse Gas Reduction Potential of Maryland Policy Options in 2020 and 2012 (The top bar in each pair represents 2020 emission reduction potential. The bottom bar in each pair represents 2012 emission reduction potential.)



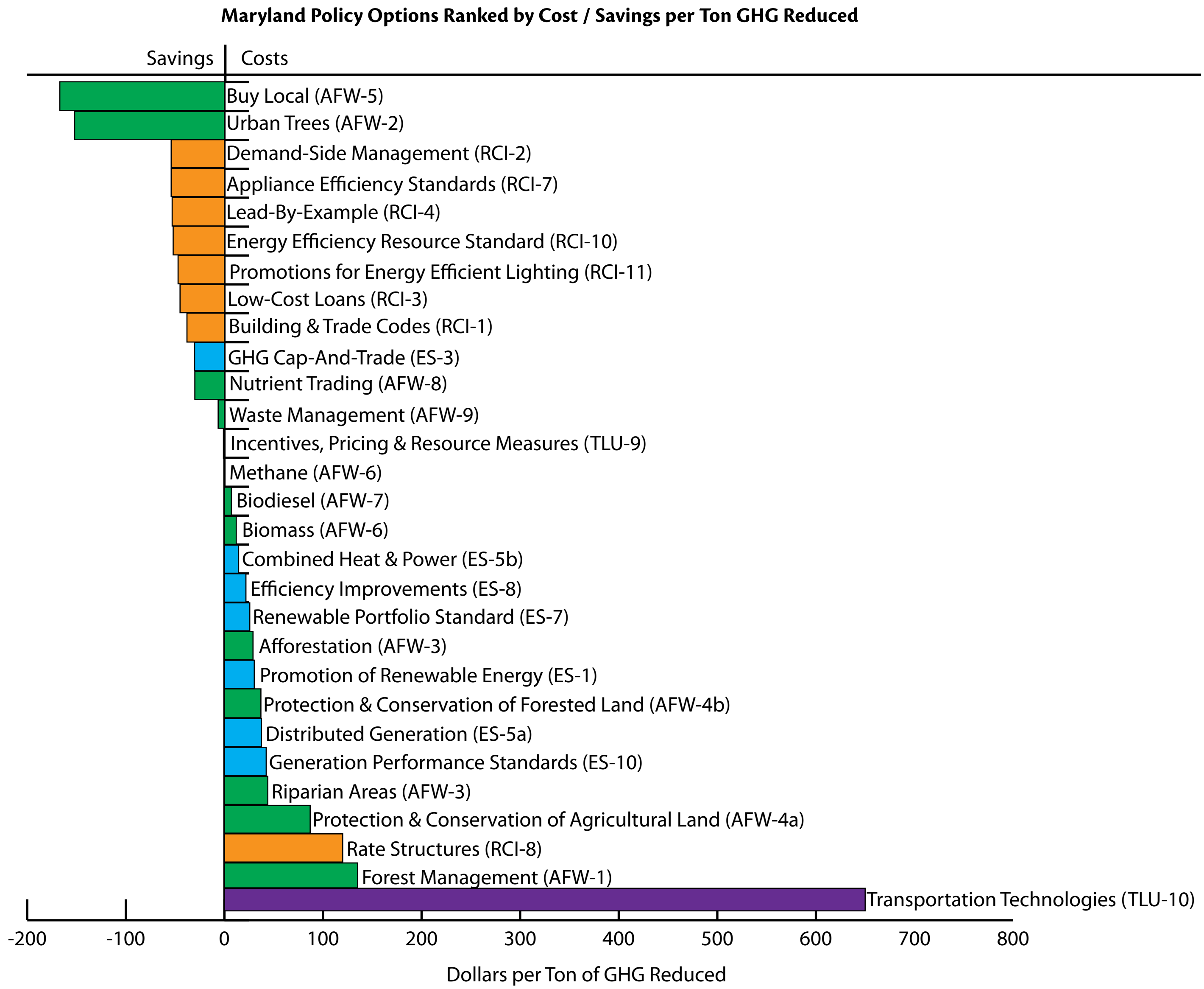
The next two figures, "Potential Emission Reductions by 2020" and "Potential Emission Reductions by 2012", summarize the estimated emission reductions from the four different sectors analyzed by the TWGs and recent actions for both 2020 and 2012. They also show the total reduction estimated from the ***Plan***, measured against the 2020 and 2012 targets.





In addition to the emissions benefits of these policy options, the Commission attempted to calculate the cost-effectiveness of the quantified policy options to see what economic impact they might have in Maryland. These cost estimates should be considered the "best available" and by no means should be reviewed as being completely accurate. As the State agency leads review and potentially implement the policy options, a much better estimate of the costs of the policies can be drawn.

The chart below shows the quantified policy options ranked by their cost-effectiveness. The measures to the left have a benefit to the State economy and the measures to the right have a direct cost to Maryland. In the aggregate, the policies yield a net economic benefit to Maryland, estimated to be approximately 2 billion dollars in 2020.



The charts in this Chapter are really illustrative in nature as quantifying emission reductions from GHG policies is a very complicated process. MDE has started to develop the resources necessary for a close review of GHG emission reduction potentials but the numbers generated by this process should be considered to be "based on the best available estimates" – they are in no way perfect.

A MORE SUSTAINABLE FUTURE

Selected Strategies that Provide Both Short- and Long-Term Benefits

Much of the Commission's effort in developing this initial *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy* and the rest of this Chapter focus on pushing for early reductions in the 2010 to 2015 timeframe and analyzing strategies to achieve deep, cost-effective reductions by 2020. These are both critical goals, driven by the science, to begin the process of reducing GHG emissions, reverse the current emissions growth trend, and to slow the build-up of GHGs in the atmosphere. Short-term reductions are an important component of a comprehensive GHG reduction strategy.

However, the Commission has also established longer term goals that are intended to push policy changes, technological advances and changes in behavior that will result in a dramatically more sustainable, carbon friendly future for Maryland in the 2030 to 2050 timeframe. The Commission's goal for 2050 is to set into motion a series of policy innovations that could reducce GHGs by up to 90 per cent (from a 2006 base) by 2050.

Many of the forty-two strategies that the Commission is recommending provide both short- and long-term benefits. The table on the next page summarizes the nine most important strategies that begin to push Maryland toward the more sustainable future needed to reverse global warming. These strategies will yield significant and lasting benefits in later years but they require long planning horizons and early implementation to achieve their full potential. Present policy decisions on transit and land use, building codes, strategic energy planning, technology initiatives, waste management, and forest, farmland and wetland stewardship will channel capital investments for the future, and help achieve the numerous aggressive goals identified in this ***Climate Action Plan***. The Commission recognizes that many of the longer-term policies are transitional and require dramatic changes in the way Maryland operates – these changes will not come easily and they will not come cheaply – but the Commission agrees that early actions now will lead us down a sustainable pathway.

To reach the Commission's 2050 goal, there will need to be major transitions in several areas that are fundamental to the lifestyles that Marylanders desire. These include: the way we use energy; the way we travel; and the way we, as consumers and environmental stewards, influence the markets that manufacture and sell products. These transitions are critical, as is the challenge to implement programs to bring about the desired changes. The transition will need to be cost-effective, consumer friendly and efficient.

As the implementation process for the forty-two strategies being recommended by the Commission begins, the process will continue to focus on reducing emissions in the 2012 to 2020 timeframe. However, starting next year, the Commission intends to also increase emphasis on the even more long-term changes that will be needed to move Maryland into that sustainable, carbon friendly, future needed to reverse global warming.

Strategies that are Critical to a More Sustainable Future

Strategy	Strategy Number	Lead & Supporting State Agencies
Land Use and Location Efficiency (Smart Growth)	TLU-2	MDOT (MDP, MDE)
Reducing Vehicle Miles Traveled (VMT)	TLU Area-1	MDOT (MDE, MDP)
Integrated Resource Planning	ES-6	PSC (MEA)
Technology Focused Initiatives	ES-2	MEA
Public Education and Outreach	CC-5	MDE (MSDE, MEA)
Afforest, Reforest, Restore Forests and Wetlands	AFW-3	DNR (MDA)
Protection of Agricultural / Forested Lands & Wetlands	AFW-4	MDA
Waste Management	AFW-9	MDE
Improving Building and Trade Codes	RCI-1	DHCD (MEA)

Southern Maryland Farm
Photo by Kathleen Perry

Overview of GHG Emissions

The agriculture, forestry and waste (AFW) sector contributes a small but important part of Maryland's overall GHG emissions profile. Significantly, agriculture and forest lands offer carbon sequestration opportunities that are not possible in other sectors. Through appropriate management, technology and energy conscious choices, these sequestration potentials can be maximized and the amount of GHG emissions from the AFW sector reduced.

Forests make up 44 per cent of Maryland land cover. In 2000, they absorbed an estimated 11.5 million metric tons more of carbon dioxide equivalents ($MMTCO_2e$) than they emitted. Urban forests added an additional savings of 2.4 $MMTCO_2e$. Science informs us that forest carbon sequestration will become less effective if we do not reduce our GHG emissions generally, due to the increasing dominance of pine trees and more frequent forest fires in a warmer Maryland climate. (See Chapter 2 of this ***Plan*** for greater detail on this subject.)

Agriculture and waste sectors were net emitters of GHGs, contributing 2.3 $MMTCO_2e$ (2 per cent of Maryland's total emissions), and 4.3 $MMTCO_2e$ (3 per cent of Maryland's total emissions) respectively. Both of these sectors are below the national average by 5 per cent and 1 per cent respectively. Even though these are a small per cent of Maryland's total, there are opportunities for decreasing energy use and reducing climate-affecting factors.

Agricultural emissions include methane (CH_4) and nitrous oxide (N_2O) emissions from enteric fermentation (digestion), manure management, agricultural soils, and agricultural residue burning. Emissions from agricultural soils account for the largest portions of agricultural emissions. The agricultural soils category includes N_2O emissions resulting from activities that increase nitrogen in the soil, such as fertilizer application (synthetic, organic, and livestock) and production of nitrogen-fixing crops.

The waste management sector includes both solid waste management and wastewater treatment. As organic waste decomposes in landfills, it generates methane. This methane was included as a potential energy source. Wastewater treatment plants produce both methane and nitrous oxide emissions; both gases are significantly more deleterious than an equal amount of carbon dioxide.

Opportunities for GHG mitigation in the AFW sector involve measures that reduce emissions across several sectors addressed in this ***Plan***. For example, production of liquid fuels from biomass can offset emissions discussed in the transportation sector, while biomass energy can replace fossil-fuel generated power and the associated emissions in the energy supply sector. Planting trees strategically reduces energy use in buildings as mentioned in the Residential, Commercial and Industrial (RCI) TWG Report later in this Chapter. Similarly, actions taken to increase waste recycling in the waste management sector can reduce emissions not only in the State (e.g., landfill methane) but also outside the State (e.g., emissions associated with the energy used to make products from virgin materials versus recycled materials).

Agriculture, forestry and waste GHG mitigation options most beneficial to Maryland were examined closely. (Individual policy options are summarized below; their full texts are in Appendix D-1). The following priority opportunities are:

- **Enhanced management of forests, wetlands, coastal shorelines and urban forests, including actions such as restoration, afforestation and reforestation.** Sustaining healthy, productive vegetation, as part of a thriving ecosystem, offers significant opportunities for carbon sequestration. Encouraging a full range of forest enhancing practices across public and private lands, in rural and urban settings, maximizes opportunities and positive impacts. Although the cost-effectiveness appears low in the quantifications of forest lands GHG reductions, note that natural services of healthy ecosystems has not been included as a savings. Urban forests provide very cost-effective GHG reduction opportunities, in part because their effect on energy use in buildings is readily quantifiable.
- **Protection and conservation of forest and agricultural lands, including riparian areas.** In addition to appropriate management, natural areas and agricultural lands need to be protected in balance with encroaching development to maintain sufficient acres of GHG "sponges".

- **Focus on local production and consumption of food and wood products.** Reduction of energy consumed in transporting goods contributes significantly to a smaller community carbon footprint while generating a plethora of social benefits. Farmer's markets prove to be very cost-effective in reducing GHG emissions.
- **Production of energy and biofuels from biomass (with targeted feedstocks).** Biomass as an energy source offers a range of exciting opportunities and noteworthy GHG emissions reductions. Conversely, biofuels can provide some relief from fossil fuel consumption but emerging science suggests that selection of feedstock figures prominently in actual GHG reductions and cause price perturbations in other markets. Concern over unintended consequences and embodied life-cycle energy lead to the exclusion of food and animal-feed as feedstocks in the biofuels policy recommendation.
- **Innovations such as nutrient trading.** Like a carbon market, sectors needing to use higher nutrient inputs (such as fertilizer) can purchase credits available from reduction of nutrient use by other producers, thus incentivizing reduced use of nutrients that release GHGs such as N_2O. Although the basic program is just being developed, its cost-effectiveness in reducing GHG emissions appears high.
- **Enhanced waste management and recycling.** The largest potential emission reductions in this sector come from enhancing recycling opportunities and technologies, and source reduction in waste streams across the State. Other options include using captured methane from municipal wastewater treatment and landfills as sources of energy. More work is necessary to specifically identify the best options.

Summary of Agriculture, Forestry and Waste Recommended Policy Options

The amount of carbon dioxide (CO_2) emissions reduced or sequestered in the policy options within the AFW sector overlaps with some of the quantified benefits and costs of policy options within other sectors. Those overlaps were identified and adjusted to eliminate double-counting as displayed in the chart at the end of this section.

For example, planting trees in urban settings helps to reduce energy use in buildings along with other benefits such as carbon sequestration. The RCI TWG also considered tree planting to improve the energy efficiency of buildings. Therefore the overlapping portion of the CO_2 reductions attributable to building energy savings in cities was removed from the AFW policy option quantifications. The related costs were then adjusted accordingly.

The availability of biomass in, and in proximity to, Maryland was determined. This added a constraint on the amount of energy and biofuels that could be produced. One of the AFW policy options recommends using biomass to produce energy. The Energy Supply (ES) TWG also considered biomass as an energy source. All emission reductions and costs associated with biomass to energy production are accounted for in the ES TWG's quantifications.

Both the AFW and Transportation and Land Use (TLU) TWGs eliminated food and animal feed sources as feedstocks for ethanol production. Current research suggests that the attendant life-cycle energy inputs are higher than outputs. Also, it appears that demand for competing uses and conversion of productive agricultural lands away from food production raises food prices thus making the inclusion of these feedstocks questionable as sound sustainable policy.

Background

The natural world offers abundant opportunities to increase the amount of carbon removed from the atmosphere and sequestered. Forests, grasslands, croplands, and wetlands all possess carbon-and energy-related benefits that are extensive, complex, and often beyond measure. Trees and plants remove carbon dioxide from the air and store carbon in their trunks and branches; absorb and filter nitrogen dioxide, sulfur dioxide, ozone, carbon monoxide, and particulate matter less than 10 microns in size; release oxygen and intercept rainwater and dust. The process of evapo-transpiration and shade from trees lowers summertime air and surface temperatures.

Shade and lower surface temperatures reduce the need for air conditioning in buildings thereby reducing the need for the production and transmission of electricity. Reduced energy production reduces emissions of GHGs and carbon from power plants. Shade and lower surface temperatures reduce maintenance needs of infrastructure which, in turn, reduces the conversion of raw materials to asphalt and concrete which reduces the production of GHGs from manufacturing plants, transportation and heavy equipment. Shade and lower surface temperatures reduce the evaporation of chemicals from car engines and reduces the need for air conditioning in cars. This reduces the amount of fuel burned and reduces the emissions from cars.

Sustainable forest and urban forest management is essential to healthy, productive forests and trees that maximize mitigation for GHGs and carbon sequestration. Additionally, these forests serve as the preferred land use for avoiding emissions. Increasing the amount and enhancing the condition of forests and trees is a critical component of mitigating climate change.

Baltimore City Urban Forest Project
www.bmore-ufp.org
Photo by Brett Gullborg

Forest Management for Enhanced Carbon Sequestration (AFW-1)

This policy option would promote sustainable forestry management practices in existing Maryland forests on public and private lands. The enhanced productivity of healthy, biodiverse and sustainable forests will yield increased rates of carbon dioxide (CO_2) sequestration in forest biomass, increased amounts of carbon stored in harvested, durable wood products, and increased availability of renewable biomass for energy production.

Policy Design: The recommended actions include a mix of legislative, programmatic, education/outreach and market measures. In addition to the General Assembly, various State agencies led by DNR (including Maryland Department of Agriculture (MDA), MDE, Maryland Department of Transportation (MDOT), and Maryland State Highway Administration (SHA)), as well as counties, private land owners, sawmill operators, artisans, and landscaping and nursery industries would be involved in implementing the following actions. Many of the agencies listed above are already implementing programs that are consistent with the goals of this policy option.

- Launch education/outreach for citizens and land managers on best forest management practices
- Proactively manage non-native pests and invasive species through:
  - *Outreach and education on control methods*
  - *Legislation restricting the sale of priority non-native, invasive species*
- Revise Forest Conservation Act (FCA) to achieve policy goals
- Use FCA offset funds to enhance forest management on private lands and reduce conversion to other land uses
- Support a Sustainable Forestry Act that encourages enhanced carbon storage in forests, use of durable wood products, and use of wood biomass for energy while maintaining healthy forest ecosystems
- Develop a certification program with the goal of certifying all State-owned forest lands as sustainably managed
- Include sustainable forest management in the RGGI offsets program
- Develop mechanisms to aggregate durable wood products from smaller land holdings to compete in meaningful markets.

Policy Goals:
Improve sustainable forest management on 25,000 acres of private land by 2020
Improve sustainable forest management on 100 per cent of State-owned resource lands by 2020

Implementation:
As lead agency, DNR's implementation plan is as follows:
Short-term (1-2 years)
- Recommend sustainable forest management be included in the RGGI offsets program
- Launch education/outreach for citizens and land managers on best forest management practices for carbon sequestration
  - *Species selection*
  - *Rotation length*
  - *Management intensity*
  - *Silvicultural system*
- Proactively manage non-native pests and invasive species through legislation restricting the sale of priority non-native, invasive species
- Contribute additional funds to the Maryland Agricultural Land Preservation Foundation (MALPF) specifically for the protection of forests to quickly implement an aggressive initiative to sequester carbon by avoiding deforestation and growing trees

- » *MALPF was created to preserve productive agricultural land and woodland to provide for the continued production of food and fiber*
- » *The majority of the funds have gone into the protection of agricultural lands, not forests.*

Medium-term (2-3 years)

- ➤ Proactively manage non-native pests and invasive species through outreach and education on control methods
- ➤ Develop mechanisms (e.g. Bay Bank, etc.) to aggregate durable wood products from smaller land holdings to compete in meaningful markets.
- ➤ Revise Forest Conservation Act (FCA) to achieve policy goals
  - » *Selection & management of retention areas*
  - » *Expand the use of funds for mitigation planting*
  - » *Promote community tree planting*
- ➤ Contribute funds to a Carbon Management Fund for improved land management
  - » *The Maryland Forest Service could use the Carbon Management Fund to enhance carbon sequestration through changes in management on State or private lands, such as: planting trees on barren lands (i.e. afforestation), changing tree rotation length, improving harvesting and regeneration techniques, selecting more productive native species, and improving silviculture techniques (such as implementing thinning regimes).*
  - » *Additional Forest Service staff will be required to implement, monitor and assess demonstration projects for their carbon sequestration value.*
  - » *The most productive techniques will be more widely implemented across the State. Private landowners would retain the carbon rights, stimulating the carbon market in the State.*

Long-term (3-5 years)

- ➤ Amend FCA to use offset funds to enhance forest management on private lands and reduce conversion to other land uses
- ➤ Support the introduction of a Sustainable Forestry Act that encourages enhanced carbon storage in forests, use of durable wood products, and use of wood biomass for energy while maintaining healthy forest ecosystems
- ➤ Participate in existing third-party forest certification programs (e.g. Forest Stewardship Council, Sustainable Forestry Initiative, etc.) with the goal of certifying all State-owned forest lands as sustainably managed
- ➤ Enroll 25,000 additional acres in forest stewardship plans by 2020. Will require a dedicated annual fund stream to increase technical service delivery of the DNR Forest Service.

Management strategies will need to be coordinated with the recommendations of the ARWG to address increasing salinity, soil saturation, and wetland migration.

Managing Urban Trees and Forests for Greenhouse Gas Benefits (AFW-2)

This policy option would maintain and improve the health and longevity of trees in urban areas and increase the urban tree canopy cover throughout the State. Trees in urban areas help absorb GHG emissions from power production, vehicles and the operation and maintenance of the built environment. Urban trees shield buildings from cold winds and lower ambient summertime temperatures, reducing heating and cooling costs and the demand for energy production. Reduced heat slows the formation of ground level ozone as well as the evaporation of fuel from motor vehicles.

This policy would be implemented through the following mix of education/outreach, legislation, funding, and planning measures:

- Provide outreach and education on the significance of trees and their role in the built environment and control methods for invasive species.
- Adopt legislation restricting the sale of invasive species
- Introduce an Urban Forest Canopy Act to add the urban tree canopy goals of this policy option
- Allocate a portion of Program Open Space (POS) funds to local governments to support urban tree canopy goals through comprehensive planning, planting, maintaining, expanding, monitoring and reporting of local street tree populations, and by developing incentives for wood recovery directed towards durable wood products
- The General Assembly, various State agencies led by DNR (including MDE, MDA, and SHA), as well as local governments, conservation organizations, private landowners, sawmills, the artisan community, arboreal industries and others would be involved in implementing this policy. Several of the agencies listed above are already implementing programs that are consistent with the goals of this policy option.

Policy Goals:

Establish an urban tree canopy in 50 per cent of Maryland's urban areas (averaged over all urban land use types) by 2020.

Implementation:

As lead agency, DNR's implementation plan is as follows:

Short-term (1-2 years)

- The General Assembly, DNR, MDE, MDA, and SHA, as well as local governments, conservation organizations, private landowners, sawmills, the artisan community, arboricultural industries and others would be involved in implementing this policy to define realistic canopy goals for GHG benefits and identify target areas and funding mechanisms.
- Provide outreach and education on the significance of trees and their role in the built environment and control methods for invasive species.

Medium-term (2-3 years)

- Adopt legislation restricting the sale of invasive species
- Introduce an Urban Forest Canopy Act to address the urban tree canopy goals of this policy option
- Contribute funds to a separate urban tree planting program (funded by FCA fee-in-lieu monies) to achieve avoidance and sequestration and to mitigate GHG emissions.
  - » *Trees planted under the former objective would be planted strategically to maximize emissions avoidance objectives; they would have to be planted on the portions of the site that would result in the greatest emissions avoidance.*
  - » *Trees planted under the latter objective could be planted anywhere, but sites and species should be selected to optimize biomass (large scale trees should be planted on sites with a minimum of constrictions on growing space).*

Long-term (3-5 years)

- Allocate a portion of Program Open Space (POS) funds to local governments to support urban tree canopy goals through comprehensive planning, planting, maintaining, expanding, monitoring and reporting of local street tree populations, and by developing incentives for wood recovery directed towards durable wood products.
- Establish an urban tree canopy in 50 per cent of Maryland's urban areas, subject to change as stakeholders are brought together and implementation is discussed (averaged over all urban land use types) by 2020.

Baltimore City Urban Forest Project
www.bmore-ufp.org

Afforestation, Reforestation and Restoration of Forests and Wetlands (AFW-3)

This policy option would promote forest and wetland carbon sequestration, both ecosystems being natural carbon "sinks". Healthy forests would be regenerated or established through afforestation (planting on lands that have not, in recent history, been forested) and reforestation where current beneficial practices are not displaced. To protect coastal wetlands from inundation due to sea level rise, this policy calls for acquiring adjacent lands to allow the wetlands to migrate landward. This strategy has significant adaptation co-benefits, since wetland protection is one of the best ways to save lives and prevent property damage in coastal areas. Riparian wetlands would be protected under this policy by increasing the acquisition of riparian buffers throughout the State.

Implementation strategies would include:

- Public outreach and education
- Green infrastructure planning
- Use of reforestation offsets under RGGI and allocation of RGGI allowances to forest management
- Tax incentives (Forest Conservation Management Act, property and inheritance tax), and incentives to encourage private landowners to produce non-traditional products and services
- Increasing fee-in-lieu payments under FCA to acquire easements
- Requiring utility company offsets for constructing transmission lines through forests
- Stepping up existing programs to protect wetlands, such as Maryland's no-net-wetland-loss goals / offsets, marshland creation as a shoreline erosion control measure, and acquisition of lands adjacent to coastal wetlands

The General Assembly, various State agencies led by DNR (including MDE, MDA, SHA, and the Maryland Port Authority), federal agencies including U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, Natural Resource Conservation Service, nonprofit conservation organizations, local governments, private landowners, Chesapeake Bay Foundation, and reservoir watershed management agencies would be involved in implementing this policy. Many of the agencies listed above are already implementing programs that are consistent with the goals of this policy option.

Policy Goals:

- ***Establish sufficient acreage in forests to offset loss of 900 acres each month to development, beginning in June 2008 and continuing through December 2020***
- ***Establish riparian buffers at a rate of 360 miles/year (50-foot width on either side of stream) to 2020, and continue until 70 per cent of all stream miles in the State are buffered***
- ***Increase wetland areas wherever feasible (non-quantified goal)***

Implementation:

As lead agency, DNR's implementation plan is as follows:

Short-term (1-2 years)

- Public outreach and education
- Green infrastructure planning
- Use of afforestation offsets under RGGI and allocation of RGGI allowances to forest management
- Step up existing programs to protect wetlands, such as Maryland's no-net-wetland-loss goals /offsets, marshland creation as a shoreline erosion control measure, and acquisition of lands adjacent to coastal wetlands

Medium-term (2-3 years)

- Tax incentives (Forest Conservation Management Act, property and inheritance tax), and incentives to encourage private landowners to produce non-traditional products and services

Long-term (3-5 years)

- Amend FCA to increase fee-in-lieu payments to acquire easements
- Require utility company offsets for constructing transmission lines through forests

Protection and Conservation of Agricultural Land, Coastal Wetlands and Forested Land (AFW-4)

Under this policy option, Maryland and its climate change partners would map, designate, prioritize and conserve existing forests, agricultural lands, and wetlands – all major carbon sinks – to sequester additional carbon and to avoid GHG emissions associated with development, degradation, and clearing. Deforestation and development now contribute up to a 25 per cent increase in GHG emissions. As noted in AFW-3, coastal wetlands, which protect lives and property from coastal storms, are at risk of inundation from sea level rise.

Green infrastructure planning tools would include land acquisition, conservation easements, purchase and transfer of development rights, tax incentives, and zoning. The toolbox would also include refining land use planning policies, dedicating proceeds from any future CO_2 budget trading program, authorizing local bond initiatives for GHG reduction programs, targeting POS funds, and creating other funding mechanisms to allow users of these tools — governments, nongovernmental organizations, and private citizens — to more effectively protect Maryland's existing green infrastructure network.

The General Assembly, MDA, DNR, MDE, and Maryland Department of Planning (MDP) would work in partnership with local governments, nonprofit organizations, foundations, and property owners to implement this policy option. Several of the agencies listed above are already implementing programs that are consistent with the goals of this policy option.

Policy Goals:

Decrease the conversion of agriculture land to developed land through the protection of 1.2 million acres of productive agricultural lands, to ensure no net loss by 2020.

Retain existing levels of forest cover (2.6 million acres) and protect an additional 250,000 acres of forest by 2020 through legal mechanisms, with more than half in areas of high value to water quality. In addition to existing programs, target upland forests.

Assess, then focus protection and restoration on wetland types with the greatest capacity for CO_2 sequestration.

Protect priority areas designated for coastal wetland retreat and coastal forest lands using nonstructural shore erosion controls (i.e. living shoreline) – keeping pace with wetland, forest and critical habitat loss due to sea level rise.

Implementation:

For those elements of this policy that cannot be implemented immediately, MDA, with the assistance of other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting.

"Buy Local" Programs for Sustainable Agriculture, Wood and Wood Products (AFW-5)

This policy option would promote the sustainable production and consumption of locally produced agricultural and forest goods, displacing the production and consumption of goods with higher life-cycle GHG emissions from high-energy production (e.g. plastic and steel products) and from transport from other states and countries. In addition to reduced transportation- and production-related emissions, GHG reductions would derive from carbon storage in durable wood products, and enhanced forest health (through increased product demand).

MDA, with assistance from DNR and the Maryland Department of Business and Economic Development (DBED), would work with local governments, farmers and farmer's market associations, lumber mills, furniture makers and other value-added producers and trade associations to implement this policy. Implementation strategies would include the following.

- Put leverage on local governments to ensure that zoning does not preclude intelligent, sustainable uses that support "buy local" enterprises, by unduly constraining local value-added mills or siting/participation in local markets.
- Encourage and develop LEED-type certification programs for Maryland wood products, organic produce and livestock to enable participating producers to offer consumers products that meet established standards for being raised and/or harvested sustainably, with net reductions in GHG emissions.
- Encourage the creation of value-added products from local woods in lieu of shipping raw materials from long distances.
- Provide education for producers in marketing techniques and effective local distribution.

Policy Goals:

Increase the number of local farmer's markets by 25 per cent by 2015 and 50 per cent by 2020

Require 80 per cent of goods consumed by Marylanders be grown or produced locally by 2050

Displace imported wood by locally grown and processed lumber by 20 per cent by 2015 and 50 per cent by 2050

Implementation:

For those elements of this policy that cannot be implemented immediately, MDA, with the assistance of DNR and DBED, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting.

Don Merritt, IAN Image Library (www.ian.umces.edu/imagelibrary/)

Expanded Use of Forest and Farm Feedstocks and By-Products for Energy Production (AFW-6)

This policy option would use local biomass from sustainable supplies of forestry and farming byproducts (chicken litter, methane, slash, switchgrass, corn stalks, food processing waste, etc.) for generation of electricity and thermal energy. Additionally, this option would reduce methane emissions by installing manure digesters and energy recovery projects. Energy from forest and farm feedstocks and by-products would offset fossil fuel-based energy production and associated GHG emissions. Shortfalls in supply could be met by local municipal solid waste such as paper, organics and yard waste.

All biomass products would be sustainably harvested without depriving soils of organic components essential for reducing erosion, maintaining soil nutrients and structure, conserving wildlife habitat and not jeopardizing future feedstocks in quantity and quality. Lifecycle energy costs and carbon emissions would be evaluated for each feedstock to ensure net energy and GHG reductions are achieved. Multi-facility manure digesters and energy recovery projects would be installed in confined animal feeding operations. Current laws could be amended to increase and/or equalize incentives for biomass energy production and use, and Fuels for Schools and biomass loan programs could be expanded. Maryland's energy policy could be adjusted to recognize thermal loads (40 per cent of the State's energy budget), and its Renewable Portfolio Standard (RPS) could be amended to include local biomass as a renewable energy source. Research, outreach and education are recommended to further these objectives.

The General Assembly and various State agencies led by DNR (including MDA, MEA, Maryland State Department of Education (MSDE), Maryland Department of General Services (DGS), and MDE, would implement this policy in cooperation with municipalities, power producers, local electric utilities and distributors, energy consumers in rural communities (hospitals, community colleges, and universities), and Soil Conservation Districts. Many of the agencies listed above are already implementing programs that are consistent with the goals of this policy option.

Policy Goals:

Use 10 per cent of available agricultural and 10 per cent of available forest residue biomass for electricity, steam, and heat generation by 2015, 25 per cent of available biomass in each sector by 2020.

Increase growth of energy crops and use 50 per cent of available energy crop biomass for electricity, steam, and heat generation by 2020

Utilize 50 per cent of available poultry litter and farm methane for renewable electricity, steam, and heat generation by 2020

Implementation:

As lead agency, DNR's implementation plan is as follows:

Short-term (1-2 years)

- Expand biomass loan programs
- Initiate research, outreach and education to further these objectives

Medium-term (2-3 years)

- Amend Maryland's Renewable Portfolio Standard (RPS) to include local biomass as a renewable energy source
- Amend current laws to increase and/or equalize incentives for biomass energy production and use
- Implement Fuels for Schools Program by providing funding to underwrite the conversion of boiler systems in Maryland's public institutions (e.g., schools and hospitals) to utilize the ample wood wastes available locally.

Long-term (3-5 years)

- Adjust Maryland's energy policy to recognize biomass opportunities for meeting thermal loads which constitute 40 per cent of the State's overall energy budget.

In-State Liquid Biofuels Production (AFW-7)

This policy option would promote sustainable in-state production and consumption of biodiesel from agriculture and/or agroforestry feedstocks to displace the use of fossil fuels. This would decrease the use of fossil fuel in the production of biodiesel, which will improve the GHG profile of in-state biodiesel production and consumption.

The ethanol portion of this policy option (AFW-7a), originally part of the AFW TWG's analysis, is not included in the Commission's suite of recommended actions. Further, the Commission has decided that this entire policy option (AFW-7a and 7b (biodiesel)) should not be included in the total GHG emission reductions or costs because of concern over food- and animal feed-based feedstocks. Using these feedstocks could be detrimental to consumers by raising food prices, to balanced and diverse crop production, and to embodied life-cycle GHG emissions. This option focuses on supply and is linked with TLU-4, "Low Greenhouse Gas Fuel Standard" (also removed from the Commission's recommendations). Dropping food-related biomass left marginal amounts available for in-state fuel production on a commercial scale. Local sustainable production of fuels should not be discouraged.

The full text of the AFW TWG's analysis of AFW-7a is included in Appendix D-1 for informational purposes.

The following strategies for increasing the production of biodiesel would be implemented by MEA, with assistance from MDA and other State agencies, all working in partnership with suppliers of feedstocks, distributors, communities adjacent to potential facilities, and environmental groups.

- Integrate State and regional strategies.
- Promote fractionalization of black liquor.
- Provide research and financial incentives for algal biofuels.
- Give bonuses to in-state production of biodiesel.
- Foster partnerships between users, suppliers, corporations, and adjacent communities.
- Provide incentives to communities that supply biomass for biodiesel.

Adrian Jones, IAN Image Library (www.ian.umces.edu/imagelibrary/)

Policy Goal:
Increase in-state biodiesel production from Maryland non-food feedstocks to offset diesel consumption in the State by 2 per cent in 2015, rising to 2.2 per cent in 2020.

Implementation:
Several State agencies are already implementing programs that are consistent with the goals of this policy option. For those elements of this policy that cannot be implemented immediately, MEA, working with MDA and other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. There is currently no in-state biodiesel production in Maryland. Facilities would come online if the production credit were increased. This would require legislative authorization. One to two years would be needed to construct new facilities.

Nutrient Trading With Carbon Benefits (AFW-8)

Originally designed as a market-based, cost-effective means of achieving water quality improvements through improved agricultural practices, nutrient trading can also provide significant GHG reduction benefits. Tradable nutrient credits are created through nutrient reduction – specifically nitrogen and phosphorus – achieved through practices that increase soil carbon sequestration and reduce use of nitrogen fertilizers that release nitrous oxide (N_2O), a GHG with 310 times the effect of one unit of CO_2.

Entities who need to apply or release more nutrients than are currently permitted under their nutrient management plans can obtain credits from sellers who have reduced their use. Carbon and enhanced nitrogen credits would be "stacked" onto existing nutrient credits as tradable commodities, adding more value to the total credit package, creating a robust nutrient trading market. Encouraging trade between non-point sources (e.g. agricultural operations) and point sources (e.g. wastewater treatment plants, industrial dischargers, highway contractors and developers) would create even more opportunities for GHG reductions, while also improving water quality, reducing fertilizer use and soil erosion, restoring wildlife habitat and wetlands, expanding economic opportunities for farmers and foresters, and promoting Smart Growth goals by preserving agricultural and forested lands.

Using EPA guidelines and grants from the U.S. Department of Agriculture, MDE, MDA and DNR are currently developing an intra- and interstate pilot cap and trade program for managing nutrient loads from point and non-point sources in the Upper Chesapeake Bay. Building on this, MDA and MDE, working with agricultural and urban non-point sources, municipal wastewater treatment plants, industrial and commercial dischargers, Soil Conservation Districts and other stakeholders, would develop guidelines that incorporate carbon credits and an enhanced value for nitrogen credits as tradable commodities. It is important for Maryland policy makers to understand how this program will work, what the currency of trade will be, etc., because Pennsylvania has already made a substantial commitment to participating in it.

Essential elements include:

- Allowance of credit stacking or credit nesting of carbon and enhanced-value nitrogen with regulated nutrients
- Flexibility to trade between point and non-point sources under a watershed-based general permit issued by MDE
- Mechanisms to ensure longevity of nutrient management plans (longer than 10 years)
- Reporting and certification protocol for trading entities
- A system for entering credits into a State registry
- Eligibility criteria for trading registered credits

Policy Goals:

Adopt a final trading policy in 2008.

By 2020, increase nitrogen fertilizer efficiency by 20 per cent through implementation of a nutrient trading scheme.

Implementation:

Several State agencies are already implementing programs that are consistent with the goals of this policy option. For those elements of this policy that cannot be implemented immediately, MDE, working with DNR, MDA and other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting.

Waste Management Through Source Reduction and Advanced Recycling (AFW-9)

This policy option would reduce the volume of waste from residential, commercial, and government sectors through programs that reduce the generation of wastes, expand recycling and upcycling (adding value to the re-manufactured product), and enhance reuse of product components and manufacturers' lifetime product responsibility. Increased recycling and reduced waste generation ("source reduction") would limit GHG emissions at landfills as well as in upstream production (i.e. energy used to extract and process raw materials and produce value-added commodities). This policy would also reduce landfill methane emissions by reducing and recycling the biodegradable fraction of landfill waste.

Implementation strategies include the following:

- Require or encourage State and local government agencies to preferentially purchase goods made from reused and recycled materials and goods from manufacturers who take "cradle to cradle" responsibility for their products.
- Identify incentives to reduce use of raw materials in manufacturing.
- Identify incentives for increased product quality to increase product life.
- Phase out subsidies that encourage wasteful manufacturing methods.
- Educate the public on the need for reducing Maryland's waste stream through better production and increased re-use and recycling.

The parties involved would be the General Assembly, MDE and all State and local government agencies, manufacturers, trade associations, consumers' associations, consumers, and retail outlets.

Policy Goals:

Reduce Maryland's waste stream by 15 per cent in 2012, 25 per cent by 2015, 35 per cent by 2020, and 80 per cent by 2050.

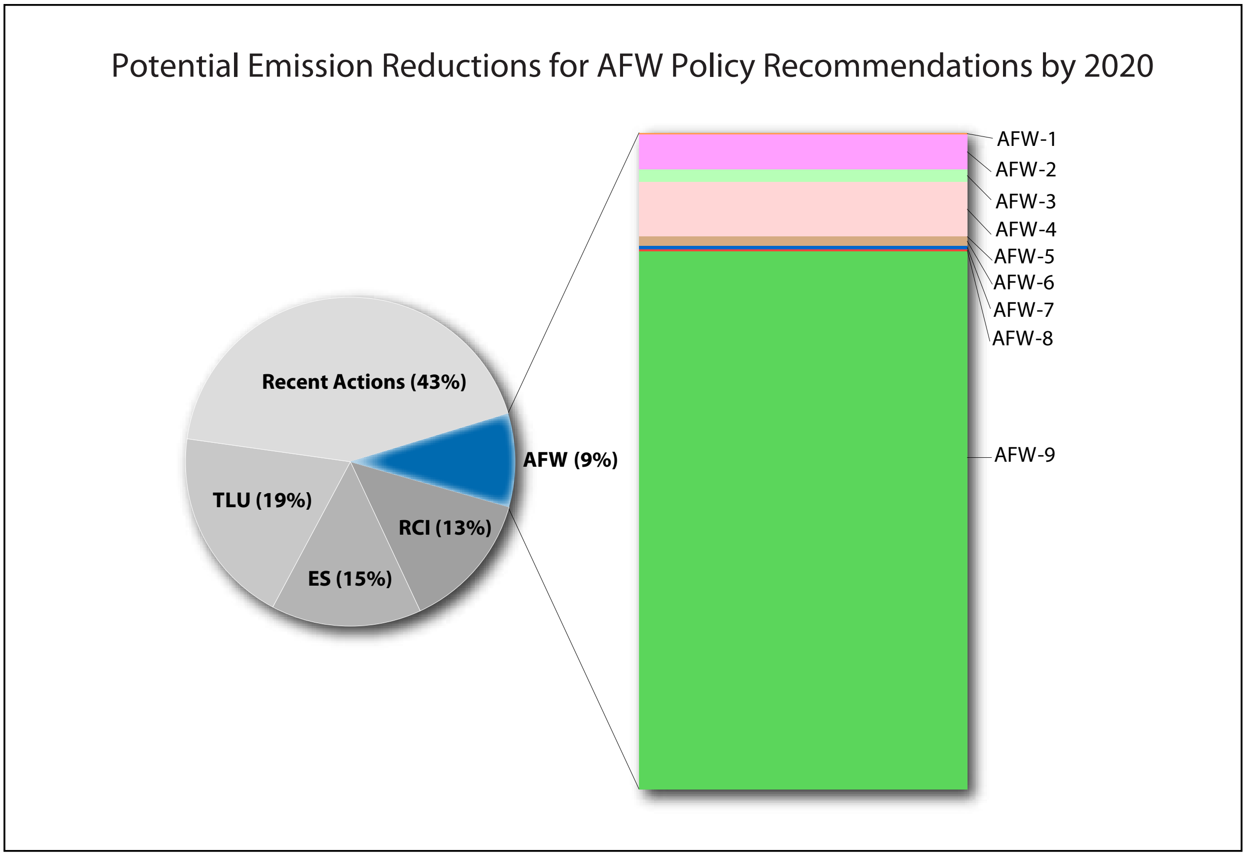
Increase Maryland's recycling stream by 10 per cent in 2012, 20 per cent by 2015, 30 per cent by 2020 and then show a gradual decrease to 10 per cent by 2050 as more products are reused and new source use is decreased.

Start in 2010 and ramp up to higher levels in 2012 and 2015, consistent with goals.

Implementation:

Several State agencies are already implementing programs that are consistent with the goals of this policy option. For those elements of this policy that cannot be implemented immediately, MDE, working with other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting.

Option No.	*Policy Option*	*GHG Reductions ($MMtCO_2e$)*			*Net Present Value 2008 - 2020 (Million $)*	*Cost Effectiveness ($\$/tCO_2e$)*
		2012	*2020*	*Total 2008 - 2020*		
AFW -1	Forest management for enhanced carbon sequestration	0.04	0.09	0.66	89.1	135
AFW-2	Managing urban trees and forestts	0.73	1.9	13.27	-2,017	-152
AFW-3	Afforestation, reforestration, & restoration of forests and wetlands					
	a. Afforestation	0.21	0.6	3.9	112.7	29
	b. Riperian areas	0.01	0.05	0.25	11	44
AFW-4	Protection & conservation of agricultural land, coastal wetlands and forested land					
	a. Agricultural land	0.11	0.28	1.93	168.6	87
	b. Coastal wetlands	NQ	NQ	NQ	NQ	NQ
	c. Forested land	2.2	2.7	30.5	1,128.7	37
AFW-5	Buy local programs					
	a. Farmers' market	0.01	0.03	0.2	-33.1	-167
	b. Local produce	NQ	NQ	NQ	NQ	NQ
	c. Locally grown & processed lumber	NQ	NQ	NQ	NQ	NQ
AFW-6	Expanded use of forest & farm feedstocks and by-products for energy production					
	Biomass	0.12	0.5	2.83	34.1	12
	Methane utilization from livestock manure & poultry litter	0.01	0.04	0.25	0.06	0.2
AFW-7	In-state liquid biofuels production					
	Ethanol	For Information Only - Further Study Needed				
	Biodiesel	0.1	0.17	1.41	10.5	7
AFW-8	Nutrient trading with carbon benefits	0.05	0.14	0.99	-29.7	-30
AFW-9	Waste management through source reduction & advanced recycling	8.8	29.27	184.00	-1,118	-6.0
	Sector Total	12.39	35.77	240.19	-1,643.04	-7
	Sector Total After Adjusting for Overlaps	5.62	7.53	83.48	-159.96	-2



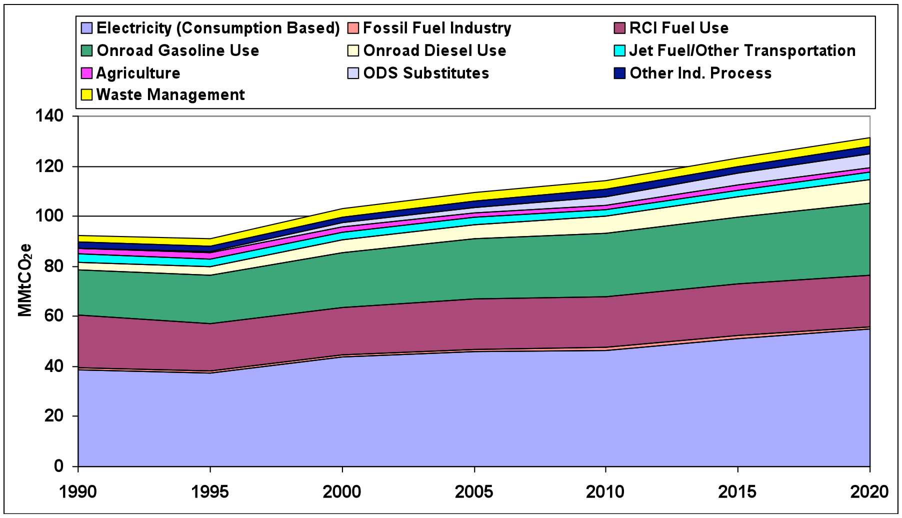
The pie chart above shows the potential emission reduction contribution to Maryland's goals from the AFW policies. The percentages are based on the total potential emission reductions from recent actions and all of the Commission's quantified policy options. Each AFW policy option's potential emissions reduction is graphically displayed on the right in the bar chart.

Southern Maryland Farm Land
Photo by Katy Perry

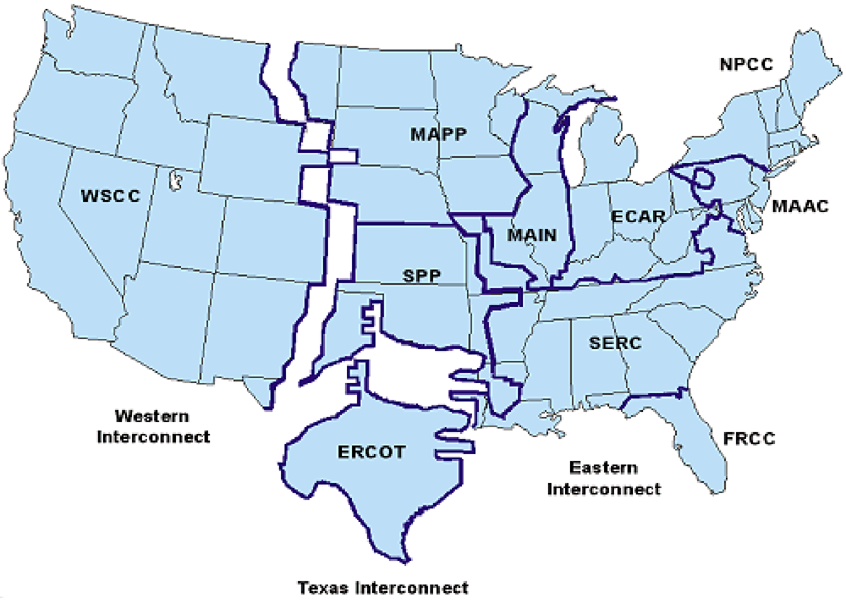
Coal Power Plant Along the Patapsco River, Baltimore
Joanna Woerner, IAN Image Library
(www.ian.umces.edu/imagelibrary/)

Overview of GHG Emissions

GHG emissions from the energy supply (ES) sector in Maryland include emissions from electricity generation and represent a substantial portion of the State's overall GHG emissions (approximately 42 per cent of gross emissions in 2005). On a production basis, a significant portion of Maryland's gross GHG emissions are associated with fossil fuel-fired electricity generation – roughly 85 per cent of the State's electricity-related fossil fuel emissions were associated with coal in 2005. On a consumption basis, Maryland imports a substantial amount of electricity generated out-of-state in the surrounding Mid-Atlantic Area Council (MAAC) region to meet retail electricity demand. The chart below shows the projected growth in Maryland's emissions and includes electricity consumption.



The Main Interconnections of the U.S. Electric Power Grid and the 10 North American Electric Reliability Council Regions



In the absence of State policies, such as RGGI, to curb emissions – the "Business-as-Usual" or Reference Scenario – the level of GHG emissions associated with meeting electricity demand in Maryland is expected to increase significantly.

Key Challenges and Opportunities

The Business-as-Usual scenario shows a growing reliance on imported power for the foreseeable future. Absent a major policy shift, these imports would likely have a carbon footprint comparable to the PJM average. However, the enactment of a strengthened RPS and the decision to join RGGI show that Maryland has chosen a dramatically different course. These policies require three strategies: first, reduce expected demand with energy efficiency; second, replace new coal imports with renewable generation, either Maryland-based or imported, and third, enforce these emissions limits through a regional cap under RGGI.

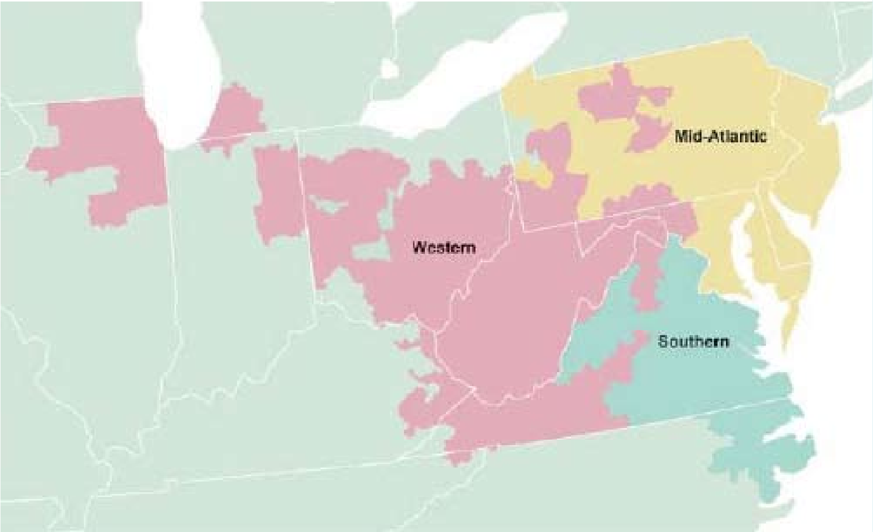
The RGGI modeling that has been performed indicates that Maryland has substantial "reserves" of GHG emissions reduction opportunities at negative or low cost. While power sector reductions are typically among the more expensive, under RGGI, Maryland will likely derive an economic benefit by reducing emissions beyond those required to meet the goal.

Opportunities for additional reductions have been identified through energy efficiency and biomass co-firing at existing fossil fuel power plants, promotion of renewable generation, clean distributed generation and combined heat and power, re-establishment of Integrated Resource Planning, further enhancement of the RPS, and enactment of a Generation Performance Standard.

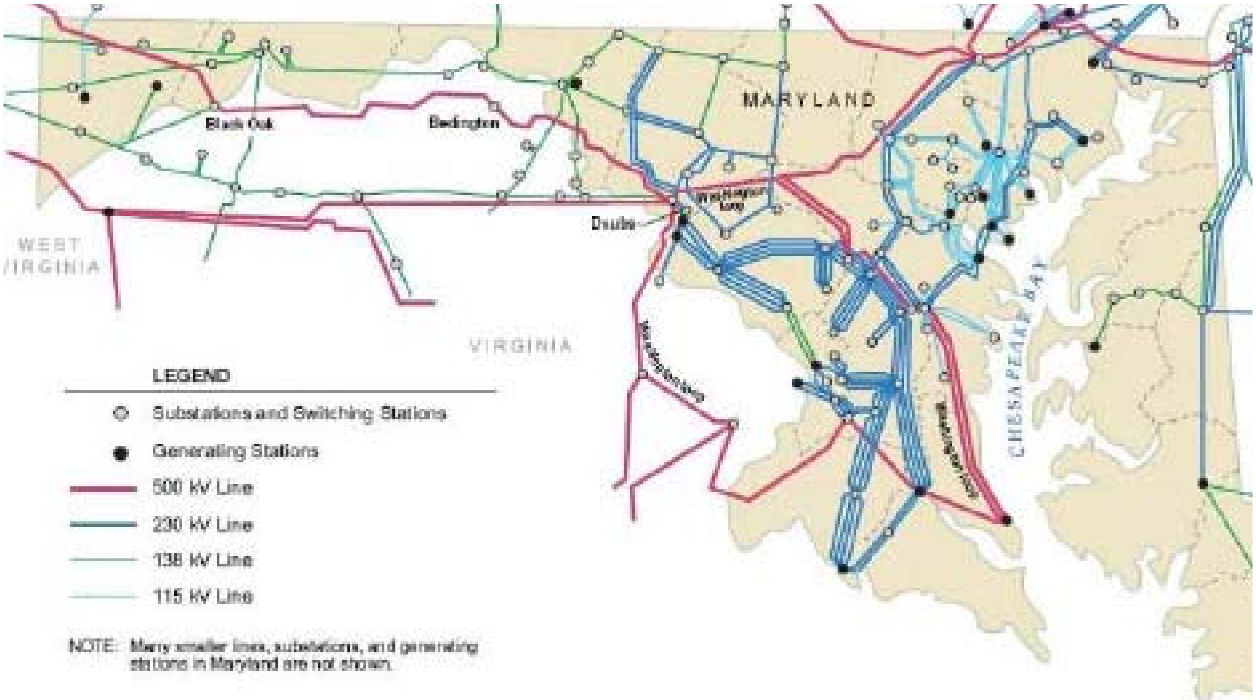
PJM Interconnection, a regional transmission organization, plays a vital role in the U.S. electric power system.

- **PJM ensures the reliability of the electric power supply system in 13 states and the District of Columbia.**
- **PJM operates an efficient, effective wholesale electricity market.**
- **PJM manages a long-term regional electric transmission planning process to maintain the reliability of the power supply system.**

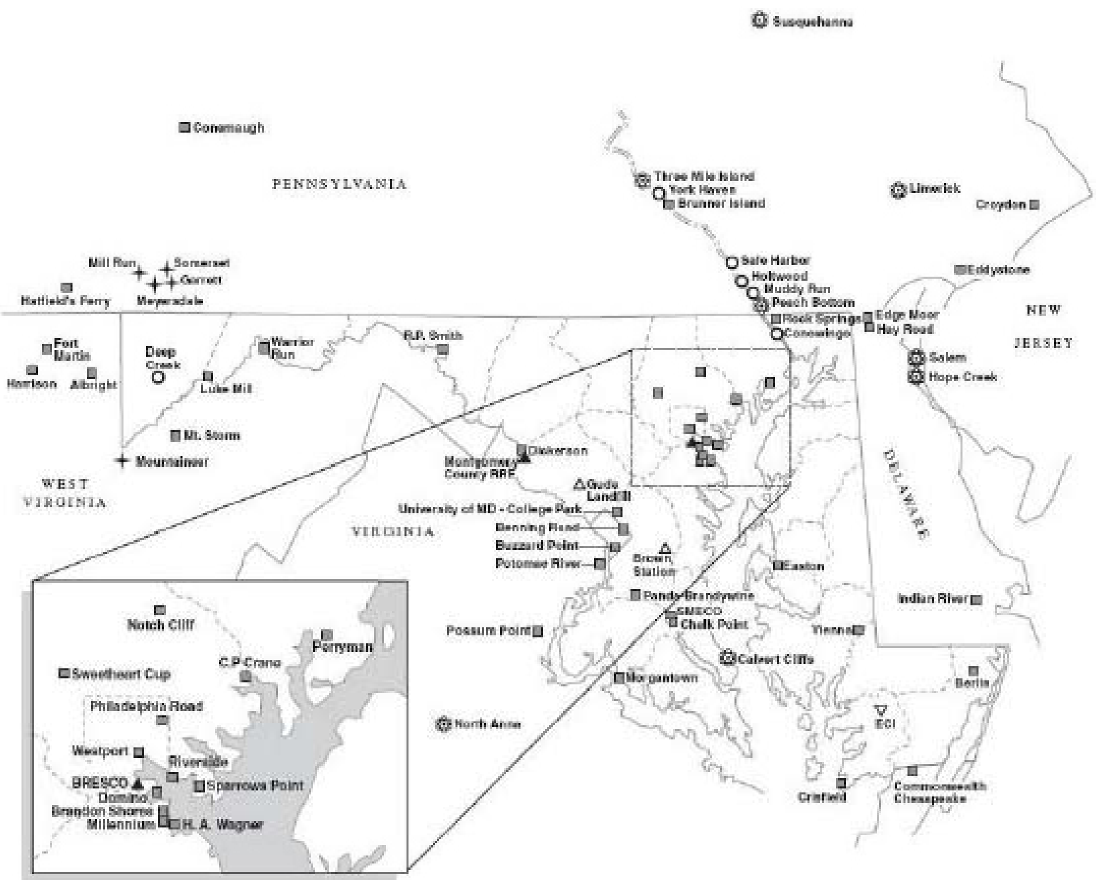
The PJM Region



Maryland Electricity Transmission Lines



Power Suppliers



GOVERNOR O'MALLEY COMMITS MARYLAND TO 20% RENEWABLE ENERGY

Governor O'Malley sponsored and signed into law in 2008 a bill that requires 20 per cent of the electricity used in the State to come from renewable resources by 2022. Increasing the amount of electricity coming from renewable resources will reduce greenhouse gas emissions and further spur development in new renewable electricity generation.

Promotion of Renewable Energy Resources (ES-1)

This policy option focuses on encouraging renewable energy development by removing regulatory and financial barriers to large-scale centralized facilities as well as on-site generation. Energy sources identified as Tier I in Maryland's Renewable Portfolio Standard (RPS) law would be targeted in the 2009-2020 timeframe, including wind, methane from landfills and wastewater treatment plants, biomass, solar, geothermal, ocean (energy from waves, tides, current and thermal differences), fuel cells and small hydro power.

The policy would be implemented primarily through the adoption and revision of State and local laws, regulations, programs and planning processes to:

- Streamline, encourage and modernize zoning and siting for renewable energy projects
- Ensure that any State resource planning process include consideration of renewable projects
- Develop a clean energy fund to provide for revolving loans (through bonds or other financing mechanisms)
- Make use of long-term contracts for offshore wind and other renewables
- Facilitate greater use of existing State authority for performance-based contracting of renewable energy projects

Parties involved would include the MEA, DBED, MDE, DNR, PSC, MDP and local governments, as well as members of the financial community, renewable energy developers, energy service companies, and the environmental community. Many of the agencies listed above are already implementing programs that are consistent with the goals of this policy option. Recent legislation, described in more detail in Chapter 7, will also be useful in implementing this effort.

In the 2007 Solar Decathlon, the University of Maryland's LEAFHouse took 2nd place overall and won the People's Choice award for the second time in a row. < http://solarteam.org/page.php?id=250>

Policy Goal:

This policy is an enabling mechanism for other climate-related policies. It would come into effect in 2009 and continue indefinitely. Policy quantification is based on an assumed increase of Tier 1 renewable energy alternatives at the rate of 0.1 per cent of total Maryland utility production each year from 2009 through 2020.

Implementation:

For those elements of this policy that cannot be implemented immediately, MEA, working with the PSC and other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. Contingent on RGGI revenues, promoting renewable energy could commence in January 2009. MEA currently administers several programs to promote renewable energy, including grants for wind, solar, E85 (ethanol blend gasoline) infrastructure, biodiesel infrastructure, and grants to local governments.

Technology-focused Initiatives for Electricity Supply (ES-2)

Technology and innovation play a critical role in energy production and use. This policy option is an umbrella covering several technology-related policies that would provide State government and other parties with resources and incentives for analysis, targeted research and development (R&D), market development, and adoption of GHG-reducing technologies not covered by other policies. It would especially target landfill gas combustion for power generation, use of biomass co-firing in existing fossil fuel fired units (complementing ES-8, "Efficiency Improvements and Repowering Existing Plants", below), energy storage and use of fuel cells.

The policy would be implemented by MEA, DBED, MDE, DNR and the PSC primarily through State funding and tax incentives for public and private R&D programs, as follows:

- Fund and conduct R&D to follow technology trends and identify critical technology pathways and opportunities for collaboration.
- Continue to fund the "Maryland Clean Energy Center" program created by the General Assembly in 2008 (HB 1337) to incubate and promote the development of the clean energy industry in Maryland.
- Provide grants and incentives to utilities and other applicants for targeted programs identified as priorities through public input. The California Public Interest Energy Research (PIER) program and the New York State Energy Research and Development Agency (NYSERDA) are program models.
- Provide a tax incentive to utilities, independent power producers, and manufacturers to invest in substantial R&D projects by allowing advantageous cost recovery for capital expenditures.
- Provide incentives for technological development in the manufacturing sector.

Policy Goals:

This policy is unquantified. It would take effect in 2008 and 2009 and continue indefinitely as an enabling mechanism for other climate-related policies. Its specific goals would be:

To position Maryland as a world leader in climate-related technology development and deployment

To achieve actual emission reductions from technology investments

To develop State industries with high in-state and export capability.

Implementation:

Several of the agencies listed above are already implementing programs that are consistent with the goals of this policy option. Recent legislation, described in more detail in Chapter 7, will also be useful in implementing this effort. For those elements of this policy that cannot be implemented immediately, MEA, working with other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. Technology-focused initiatives program development could possibly commence 6 months after the first RGGI auction, scheduled for September 2008. Certain initiatives may require authorization by the General Assembly.

Cap and Trade (ES-3)

Maryland, because of the Healthy Air Act of 2006, is already a partner in RGGI, a first of its kind cap-and-trade program for large electric power plants. This policy option would support continued active involvement in RGGI and encourages consideration of the expansion of RGGI to sectors beyond the power sector if the federal government fails to enact a credible national cap and trade program in 2009. For the purpose of this recommendation, a credible national program would require at least a 20 per cent reduction from current emission levels for covered sectors by 2020.

The cap-and-trade policy option is considered an existing action for the purpose of this report. Analysis of the GHG reduction benefits, costs and cost savings resulting from Maryland joining RGGI has been performed and confirms that the cap-and-trade program will result in greater emissions reductions and greater cost savings than would be likely without it. As for the potential of expanding the cap-and-trade beyond the power sector, this policy option recommends as the preferred strategy that the federal government enact a credible national program in 2009. An effective national cap-and-trade will be given precedence. Failing that, this policy advocates the expansion of the RGGI program to new sectors. Therefore this policy proposes advocacy and joint action with the other member states of RGGI. A key issue that surfaced during discussions of this policy was how to credit manufacturers for actions that indirectly reduce GHG emissions or reduce GHG emissions upstream or downstream of the manufacturing process. This is an important issue and will be discussed during the future stakeholder meetings described below.

Parties involved would be MDE, DNR, the PSC, MEA, the federal government, affected sector stakeholders, other RGGI states, and the environmental community.

Policy Goals:

The first goal of this policy is to continue Maryland's membership in the RGGI program at least for the balance of Phase 1 (2019). The second goal is to encourage the federal government to enact a national cap-and-trade program requiring at least a 20 per cent reduction from current emission levels for covered sectors by 2020. The third goal is to advocate the expansion of RGGI to additional sectors if the federal government does not enact a national program in 2009.

Implementation:

Maryland is already participating in RGGI. Therefore, much of this policy is already being implemented. For those elements of this policy that cannot be implemented immediately, like the expansion of RGGI to other sectors, MDE, with assistance from the PSC, DNR and MEA, has begun a stakeholder process. Some of the issues under consideration are summarized in stakeholder letters, attached to this ***Plan*** as Appendix F. MDE will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting.

Federal legislation on this issue is also being actively discussed. The best approach for expanding RGGI to other sectors is through federal legislation. RGGI will also be discussing changes to the RGGI program between 2009 and 2012. RGGI has already agreed to a 2012 review.

Clean Distributed Generation (renewables and combined heat and power) (ES-5)

This policy option encompasses a suite of financial incentives and other strategies to encourage investment in distributed renewable energy (e.g. solar, wind, geothermal) and combined heat and power (CHP). CHP is any system that generates electricity and uses the thermal energy thereby produced – and normally wasted – for space heating, water heating, air conditioning, industrial processes, etc. It is sometimes called "recycled energy" because the same energy is used twice. The end result is significantly increased efficiency over generating electric and thermal energy separately.

This policy could require the General Assembly to enact financial incentives such as: (1) direct subsidies, tax credits or exemptions for purchasing, selling or operating distributed renewable or CHP systems;** (2) tax credits for each kWh or BTU generated from a qualifying facility; and (3) feed-in tariffs. Additional incentives for renewable technologies would include R&D funding; net metering; cost recovery for regulated utilities that make reasonable and prudent investments in utility-owned or customer-owned distributed renewable energy resources; and a clean energy grants program. Other strategies for both distributed renewables and CHP would include: (1) improved interconnection policies; (2) improved rates and fees policies, (3) streamlined permitting; (4) financing packages and bonding programs; (5) power procurement policies, and (6) education and outreach on the emission reduction value provided by these systems. MEA, MDE, the PSC and the Maryland Clean Energy Center (MCEC) would develop and administer the financial incentives programs, technical assistance, regulatory policies and codes and standards.

*****The Solar and Geothermal Tax Incentive and Grant Program (SB 207/HB 377), passed by the General Assembly in its 2008 Session, accomplishes part of this recommendation by increasing grant awards and tax incentives for purchasers of solar and geothermal systems.***

Policy Goals:

Achieve 1 per cent of all electricity sales in the State from distributed renewable generation by 2020, with a phase-in beginning in 2010.

Achieve 15 per cent of in-state CHP technical potential at commercial and industrial facilities by 2020, with a phase-in beginning in 2010.

Implementation:

Several of the agencies listed above are already implementing programs that are consistent with the goals of this policy option. Recent legislation, described in more detail in Chapter 7, will also be useful in implementing this effort. For those elements of this policy that cannot be implemented immediately, MEA, working with the PSC and other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. MEA currently facilitates wind and solar distributed generation with grants as financial incentives. An increase in market penetration would require additional funds from the RGGI auctions.

Integrated Resource Planning (ES-6)

Critical comprehensive planning is necessary to meet Maryland's future electricity demands. Integrated Resource Planning (IRP) is a regulatory and planning process that evaluates meeting future electricity demands and selects the optimal mix of resources that minimizes the cost of electricity supply while meeting reliability needs, aligning environmental and energy supply policies, and other objectives. Under this policy option, an objective review of energy supply options from both conventional and renewable energy sources as well as energy efficiency options would be considered prior to approving utility expansions of electricity generation or transmission. IRP would better align GHG emissions reduction and other environmental goals and energy supply policies by requiring consideration of more options than under current law and a longer time horizon in making resource decisions.

The Commission recommends that Maryland enact regulatory or legislative changes as needed to implement an IRP process consistent with the policy design described here.

This policy is very consistent with Maryland's Strategic Electricity Plan. Over the next few years, the PSC and MEA will analyze and define the State's energy needs and then implement a plan to achieve those goals. New or amended PSC laws and / or regulations may be needed to implement an IRP process consistent with this policy option.

Policy Goals:

This policy option is unquantified. It would take effect in 2009 and continue as a mechanism for meeting future electricity demands. The specific goals are as follows:

- ***Develop a comprehensive plan that supports and balances reliability, environmental, and economic policies of the State, effective 2009.***
- ***Evaluate all options, on both supply and demand sides, in a fair and consistent manner.***
- ***Minimize risks of cost increases to all stakeholders, including evaluation of:***
  - ***The risk of cost increases associated with future regulation of GHG emissions, conventional pollutants and hazardous pollutants when evaluating both supply-side and demand-side resource options;***
  - ***A broad range of possible fuel costs and risks of fuel price increases and volatility; and***
  - ***The risk mitigation benefits of energy efficiency and renewable energy.***
- ***Consider environmental impacts, including GHG emissions from both in-state and out-of-state generation sources serving Maryland customers.***
- ***Create a flexible plan that allows for uncertainty and permits adjustment in response to changed circumstances.***

Implementation:

Several State agencies are already implementing programs that are consistent with the goals of this policy option. For those elements of the policy that cannot be implemented immediately, the PSC, working with MEA, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting.

Renewable Portfolio Standard (ES-7)

A renewable portfolio standard (RPS) is a policy requiring retail electricity suppliers and power importers to supply a certain percentage of retail electricity from renewable energy sources by a stipulated date. Utilities can satisfy the RPS requirement by generating renewable energy themselves or by purchasing renewable energy credits from a renewable energy generator. Maryland has had an historic RPS and in 2008 enacted an enhanced RPS (Renewable Portfolio Standard Percentage Reqirements – Acceleration (SB 209/HB 375)). The RPS proposed in this policy option goes slightly beyond the new RPS legislation enacted in 2008, although much of what is recommended is included in the new legislation.

The principal difference between the RPS adopted by the General Assembly in the 2008 Session and the RPS proposed here is the timing of meeting the 20 per cent Tier 1 standard. The current Maryland law specifies the 20 per cent goal be met by 2022, while this policy option sets the date as 2020. Thus, this policy recommends strengthening the existing RPS to achieve 20 per cent renewable energy by 2020, ramping up from a start date of 2008. No changes are recommended to the Tier 2 timeline or percentages. The RPS requirement would apply to electricity supplied to Maryland customers. Parties involved include the PSC, MEA and MDE, and all load serving entities (LSEs) providing electricity over utility distribution lines in Maryland.

Policy Goal:
Most of this policy's goals have been adopted through the enactment of the Renewable Portfolio Standard Percentage Requirements – Acceleration legislation in 2008.

Implementation:
The PSC is already working to implement the Renewable Portfolio Standard Percentage Requirements - Acceleration Act of 2008. No change to the PSC's regulations would be needed should the General Assembly so act, and such an increase in acceleration would have no substantial impact on the PSC's current tracking and enforcement activities. PSC would be able to implement an increasingly accelerated RPS standard as soon as it took effect. At this time, PSC is considering the implementation of an online compliance filing system, which will enhance the PSC staff's ability to receive and analyze RPS information.

The PSC notes that it would be undesirable for a further increase in the acceleration of RPS requirements to interfere with existing contracts for electricity supply under standard offer service ("SOS"). Therefore, prior to the enactment of legislation to implement this policy option, consideration should be given to timing so as not to interfere with existing contracts and their dates of expiration.

Efficiency Improvements and Repowering Existing Plants (ES-8)

This policy option would promote the identification and pursuit of cost-effective GHG emissions reduction opportunities from existing generating units through improving their operating efficiency or adding biomass. It would, in time, result in the identification of a portfolio of technological options for reducing emissions and allow Maryland utilities to share the opportunities they have identified. It complements ES-10, "Generation Portfolio Standard" (GPS), which covers new generating units, and ES-3, "Cap-and-Trade", by ensuring that utilities pursue cost-effective actual emission reductions rather than simply purchasing emission allowances.

Key implementation strategies would include: (a) requiring utilities to evaluate their existing generating units for opportunities to improve their GHG emissions profile through efficiency improvements or the addition of biomass. This evaluation would be part of an overall plan identifying cost-effective options for reducing system emissions on a short-term and long-term basis; b) requiring utilities to pursue cost-effective options identified above; and c) creating financial incentives that reward such emissions reductions. The term "cost-effective" would be defined by some objective measure, such as cost per ton of carbon equivalent.

The planning and emission reduction requirements would be implemented through planning processes already initiated by the PSC, in cooperation with DNR, MEA and MDE.

Policy Goal:
Co-fire biomass at existing coal-fired generating units at a maximum state-wide average rate of 8 per cent of total energy input by 2015. The policy would initiate in 2010 and reach the 8 per cent goal in 2014.

Implementation:
For those elements of this policy that cannot be implemented immediately, MEA, working with the PSC and other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. Implementation will likely be a long process. GHG savings would not be likely to occur before 2010.

Coal power plant on the banks of the Patapsco River, Baltimore.
Route 95 is in the right bottom corner.
Joanna Woerner, IAN Image Library (www.ian.umces.edu/imagelibrary/)

Generation Performance Standard (ES-10)

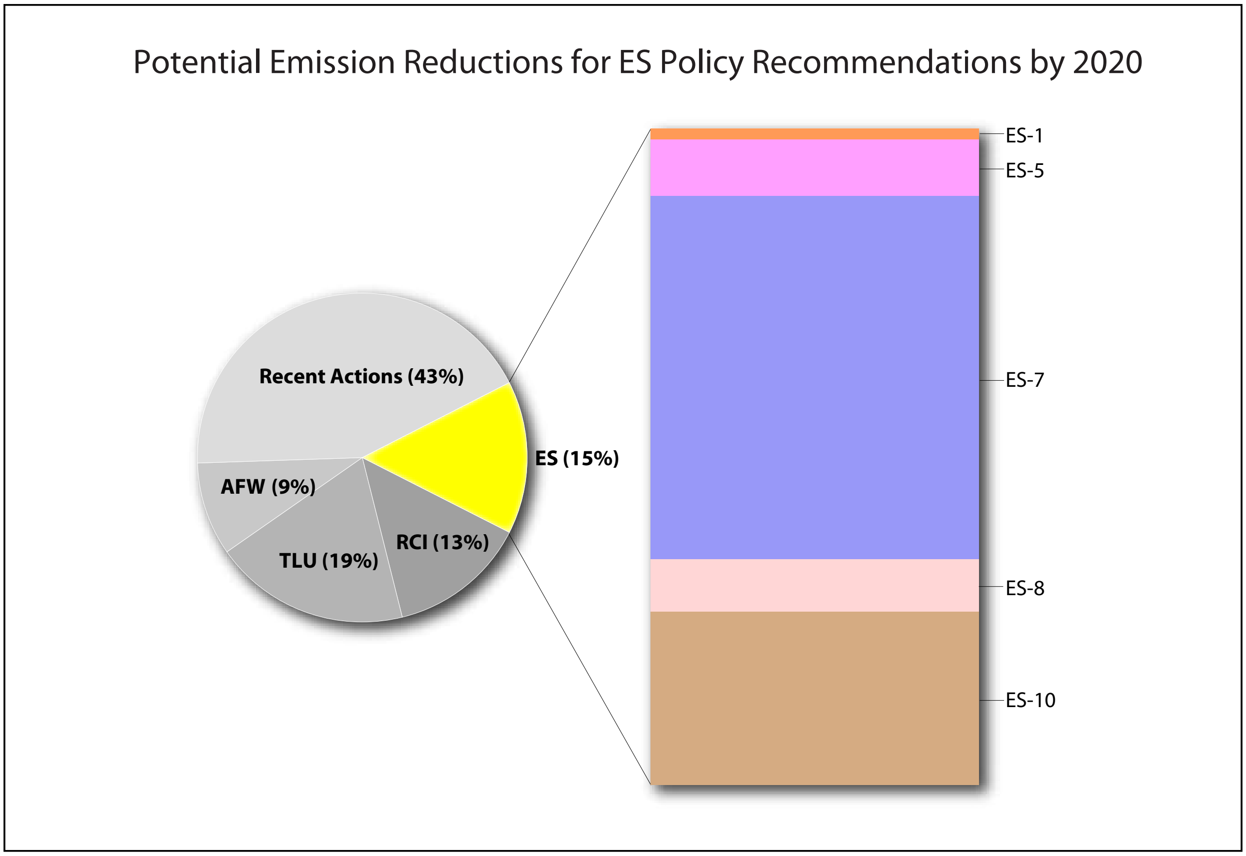
A generation performance standard (GPS) is a mandate that requires Load Serving Entities (LSEs) to acquire electricity on an average portfolio basis, with the portfolio meeting a per-unit GHG emission rate below a specified standard. This policy option would promote the purchase of energy and capacity from low-carbon or renewable technologies. This policy is complemented by ES-8, "Efficiency Improvements and Repowering Existing Plants", which is directed at reducing GHG emissions from existing plants.

The GPS portfolio would require that 100 per cent of an LSE's energy portfolio emit an average of no more than a specified number of pounds of CO_2 per megawatt-hour. The GPS would be modeled after Maryland's existing RPS with the exception that the GPS may rely on a more diverse mix of replacements for coal-fired electricity than the RPS. This would encourage renewable energy sources and would also fit well with any State resource planning process for new generation. Any LSE selling energy to retail consumers in Maryland would be required to meet the GPS. GPS is best done at the federal level, but until this occurs, a Maryland GPS is a good way to control leakage and imports of high-carbon intensity electricity from out-of-state. Implementation would be through MDE in coordination with the PSC and MEA. These agencies are already implementing programs that are consistent with the goals of this policy option.

Policy Goal:
Enact a GPS of 1,125 pounds of GHGs per MWh by 2013.

Implementation:
MDE, working with MEA and the PSC, will be setting up a stakeholder process in 2008. A more detailed implementation plan will be drafted for the Commission to consider in its Spring 2009 meeting. New legislation will be needed to implement this policy. Therefore, the Commission will be considering whether to push forward with a legislative proposal at its Fall meeting. The benefits from this strategy are greatly reduced if effective federal legislation is passed.

Option No.	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008 - 2020 (Million $)	Cost Effectiveness ($\$/tCO_2e$)
		2012	2020	Total 2008 - 2020		
ES -1	Promotion of Renewable Energy	0.2	0.5	3.3	89	27
ES-2	Technology-Foccused Initiatives	U	U	U	U	U
ES-3	GHG cap-and-trade					
	ES-3a Account for all reductions under an auction-based cap-and-trade					
	ES-3b Account for only capped level of reduction	U	6.95	U	-253	-36.4
ES-4	CCSR incentives	For Information Only - Further Study Needed				
ES-5	Clean Distributed Generation					
	ES-5a Distributed Generation	0.3	1.1	6.7	250	37.5
	ES-5b Combined Heat and Power	0.3	1	6.3	90	14.4
ES-6	Integrated Resource Planning	U	U	U	U	U
ES-7	Renewable Portfolio Standard	5.2	13.8	100.7	2,589	25.7
ES-8	Efficiency Improvements and Repowering Existing Plants					
	ES-8a Biomass component	1.2	2	17.9	389	21.8
	ES-8b Repowering component	For Information Only - Further Study Needed				
ES-9	Carbon tax	For Information Only - Further Study Needed				
ES-10	Generation Performance Standards	4.9	6.6	62.6	2,659	42.4
	Sector Total After Adjusting for Overlaps	*11.9*	25	194.2	5,933	30.6
	Reductions from Recent Actions	4.8	17.2	88	2,076	23.6
	Sector Total Plus Recent Actions	*16.7*	44.2	282	8,009	28.4



The pie chart above shows the potential emission reduction contribution to Maryland's goals from the ES policies. The percentages are based on the total potential emission reductions from recent actions and all of the Commission's quantified policy options. Each ES policy option's potential emissions reduction is graphically displayed on the right in the bar chart.

Montgomery Park
Photo by Mary Jane Rutkowski

Back River, Baltimore
Jane Thomas, IAN Image Library (www.ian.umces/edu/imagelibrary/)

Key Challenges and Opportunities

The principal means to reduce emissions in the Residential, Commercial and Industrial (RCI) sector include improving building and operations energy efficiency, substituting electricity and direct fuel use with lower-emission energy resources (such as solar water heating and geothermal heat pumps), and various strategies to decrease the emissions associated with electricity production (see Report of the Energy Supply TWG, above). Although Maryland has pursued energy efficiency in the past, these were not sustained or were unevenly pursued. This lack of sustained commitment left many highly cost-effective opportunities on the table, such as measures to improve the efficiency of buildings, appliances, and industrial practices. These opportunities can help the State achieve substantial progress in meeting its GHG emissions reduction goals.

Maryland has already taken important steps in this direction. Three recently passed pieces of legislation are particularly relevant for the RCI sector: HB 374, SB 268, and SB 208. The ***EmPOWER Maryland*** goal, set by Governor O'Malley in July 2007 and codified in HB 374 in April 2008, establishes a statewide goal to reduce by 2015 per capita electricity consumption and per capita peak electricity demand by 15 per cent. SB 268 established the Maryland Strategic Energy Investment Program and Fund, which enables RGGI auction proceeds to be used to decrease energy demand and increase clean energy supply. SB 208, "High Performance Buildings Act", requires new or renovated State buildings and new schools to be high performance, energy efficient buildings. The Green Building Task Force was created in 2006 by the Maryland General Assembly (via House Bill 1211). In its December 2007 final report (see <http://www.mdp.state.md.us/pdf/Final_Report_GBTF.pdf>), the Task Force provided recommendations to the Governor and the General Assembly for facilitating green building efforts within the residential and commercial building sectors.

There are significant opportunities to reduce GHG emissions growth attributable to the RCI sectors in Maryland. An overview and summary of policy options follows.

Overview of Policy Recommendations and Estimated Impacts

The Commission recommends a suite of eight policies for the RCI sector that offers the potential for significant and cost-effective GHG emission reductions in Maryland. The State is already implementing programs that are consistent with the goals of this policy option. Recent legislation, described in more detail in Chapter 7, will also be useful in implementing this effort.
If implemented early and aggressively, these policies could collectively reduce emissions below the reference case or "business as usual" scenario, at a net savings to the State and its citizens, as follows: **

- Over 11 $MMtCO_2e$ per year by 2020 (annual reductions); and
- Cumulative savings of roughly 54 $MMtCO_2e$ from 2008 through 2020 (cumulative reductions).
- Net cost savings of over $5.4 billion through the year 2020 on a net present value (NPV) basis. The weighted average cost of these policies is a net savings of $48 per $MMtCO_2e$.

** RCI-8 is included in these calculations, which were prepared prior to the Commission removing it as a recommended option. The numbers will require minor adjustment to reflect its removal.

All of the recommended policies focus on demand side management (DSM), but they are distinguished by their different approaches, their focus on varied types of energy use, or the specific energy users they target. RCI-2 implements general DSM programs on a widespread basis, and RCI-10 engages utilities in planning and market-based procurement of efficiency services for electricity and natural gas. Together, they are the chief tools for implementing the ***EmPOWER Maryland*** program. RCI-4 targets State and local government buildings, and RCI-3 focuses on small businesses and residences, particularly low-income energy users, which are often difficult to reach, or have issues like split incentives for rental properties that have frustrated previous efforts to reduce energy demand in this sector. RCI-1 covers the residential and commercial sectors but focuses on incorporating energy efficiency into the design of new and renovated buildings. RCI-7 and RCI-11 target specific end-uses of electricity and natural gas – appliances and lighting – but cover all sectors. RCI-5 (jointly considered with the Cross-Cutting Issues TWG) seeks to affect choices by students, their families, and consumers in general.

Policies RCI-2, 3, 5, 10, and 11 are all structured to provide incentives for energy efficiency or other measures to reduce GHG emissions. RCI-1 (building codes), RCI-4 (energy efficiency of government buildings and operations), and RCI-7 (appliance standards) involve implementation of mandatory measures to reduce energy consumption.

There is overlap in the expected emissions reductions and costs or cost savings among several policies. Some (such as RCI-2) are defined by their usage reduction goals, while others are defined by addressing a specific type of energy use. Overlaps are expected to occur where policies have the same target audience and implement the same measures. RCI-3, for example, involves the creation of revolving low-interest loan fund(s) for small-scale residential and commercial energy efficiency projects and implementation of individual measures that are usually included within more comprehensive energy efficiency programs such as RCI-2 and RCI-10 (the ***EmPOWER Maryland*** tools). DSM programs addressing the residential and commercial sectors in RCI-2 and RCI-10 would include appliance and lighting upgrade programs, which would overlap with the results for RCI-7 and RCI-11. By design, RCI-2 and RCI-10 are mutually exclusive. RCI-2 focuses on DSM programs funded by RGGI revenues and implemented by MEA, while RCI-10 DSM measures would be implemented by utilities. Finally, RCI-1 (focused on new construction within the residential and commercial sectors) and RCI-4 (focused on government and school buildings) partially overlap with RCI-2 and RCI-10, which are designed to drive a comprehensive response across all sectors.

The RCI policy suite impacts the efficacy of some policies in other sectors as well. By decreasing overall electricity demand, RCI policies would reduce the impact of a Renewable Portfolio Standard (ES-7), which is designed to generate a certain per centage of electricity from renewable sources. Similarly, the reduction in demand would decrease the impact of efficiency improvement in power plants (ES-8a and ES-10), as these plants would be producing less power. Overlaps also occur between AFW and RCI sectors. Trees that are strategically placed to reduce building heating (by providing wind breaks during the winter) and cooling loads (by shading buildings during the summer) in AFW-2 would reduce the operation of high-efficiency HVAC systems or HVAC system components recommended under RCI-1, RCI-2, RCI-4, RCI-7, and RCI-10.

The policy recommendations described briefly below and in more detail in Appendix D-3, result not only in significant emissions and costs savings, but offer a host of additional benefits as well. These benefits include: reduction in spending on energy by homeowners and businesses; reduced risk of power shortages, energy price increases, and price volatility; improved public health as a result of reduced pollutant emissions by power plants; reducing dependence on imported fuel sources; and green collar employment expansion and economic development. In addition, several of these policies have water conservation benefits, not only through reduced cooling demands for power plant operation, but also by reducing water consumption by the end users (e.g., RCI-1 and RCI-7). As part of the effort to implement the Policy Options within the Residential, Commercial, and Industrial Strategies section, State agencies also will refer to the Final Report of the Green Building Task Force (see <http://www.mdp.state.md.us/pdf/Final_Report_GBTF.pdf>) for guidance.

REDUCING GREENHOUSE GAS EMISSIONS WITH SOLAR

Maryland commits to reducing greenhouse gas emissions by increasing incentives to replace traditional electricity generation with solar power. Maryland increased its grant to $2,500 per kilowatt installed for up to 4 kilowatts. These small systems are ideal for homes and small businesses. In addition, solar equipment is exempt from sales and property tax. Combined with the solar requirement in the Renewable Energy Portfolio Standard, Maryland now has a comprehensive set of incentives that promote solar in all settings, from homes to large commercial buildings.

Improved Building and Trade Codes & Beyond – Code Building Design and Construction in the Private Sector (RCI-1)

This policy option would reduce energy consumption in new or renovated residential and commercial buildings through improvement and enforcement of building and trade codes, updated periodically to reflect state-of-the-art practices. Builders and owners would also be encouraged to go beyond code standards and improve building performance through construction design and, thereafter, through maintenance practices, by using Leadership in Energy and Environmental Design (LEED) Certification for New and Existing Buildings or other similar protocols.

The Maryland Department of Housing and Community Development (DHCD), working in partnership with MEA, MDE, the PSC, MPD, DBED, Maryland Departments of General Services (DGS) and Labor, Licensing, and Regulation (DLLR), the Maryland Green Building Council, local government building code agencies, and builders and trade associations, would:

- Periodically review and update building, trade and energy codes to improve energy efficiency in new construction and renovations.
- Develop a training and certification program and technical assistance for code officials and contractors on energy efficiency and related Green Building and trade codes.
- Formulate a system to ensure enforcement of a uniform building permit program.
- Identify and encourage owners and contractors to go beyond code standards and construct and maintain buildings using high performance building practices such as LEED or similar standards through tax rebates and other incentive programs.
- Establish a state-wide threshold for mandatory compliance with the adopted building/energy codes.
- Provide incentives such as permitting and fee advantages, tax credits, and "green mortgages" to encourage retrofit of existing residential and commercial buildings and energy efficient new home construction.
- Seek assistance from utility companies and regional energy efficiency partners for conducting energy audits and incorporating other energy efficiency practices into building design, renovation, and maintenance.

Many of the agencies listed above are already implementing programs that are consistent with the goals of this policy option.

Policy Goal:

Reduce energy consumption per square foot of floor space by 15 per cent by 2010, and 50 per cent by 2020.

Implementation:

For those elements of this policy that cannot be implemented immediately, DHCD, working with MEA and other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. DHCD will continue its ongoing efforts relating to improving the energy efficiency of buildings through its Codes Administration unit and Single Family Housing and Multifamily Housing Programs, partnerships with other State agencies, and active participation on the Green Building Council. In addition , DHCD will assemble a panel of building code experts, including the International Code Council experts, State and local building code authorities and governments, State and local planning agencies and boards, architects and engineers, building materials manufacturers, trade associations, federal government agencies, State agencies, and other stakeholders.

1-2 yrs: The panel will submit its final report to the General Assembly no later than October 1, 2010, with recommendations for designing and implementing enhanced building codes.

2-3 yrs: Adopted recommendations (which may include new legislation, materials, guidelines, code documents, and technical assistance units) will be in place and implementation will have begun or been completed.

3-5 yrs: Full implementation of all recommendations is expected along with a process to ensure ongoing updates of enhanced building codes, including integration into the existing statewide process for code adoption in Maryland.

Demand-Side Management (DSM)/Energy Efficiency Programs, Funds, or Goals for Electricity and Natural Gas (Including Expansion of Existing Programs and Peak Load Reduction) (RCI-2)

This policy option focuses on increasing investment in electricity and natural gas demand-side management (DSM) strategies through programs run by the MEA, energy service companies (ESCOs), utilities, or others, in order to meet the goals of overall reduction in energy consumption and peak load demands. It is intended to achieve the incremental difference between the energy efficiency gains from RCI-10, "Energy Efficiency Resource Standard" (EERS), and statewide application of the Governor's EmPOWER Maryland goals (15 per cent reduction in per capita electricity and natural gas use and peak load demand by 2015). The "Regional Greenhouse Gas Initiative – Maryland Strategic Energy Investment Program" legislation (SB268/HB 368) in the 2008 General Assembly Session accomplished an important part of this policy by creating a public benefit fund using RGGI auction revenues.

MEA and its State partner agencies, MDE, DHCD, the PSC, MDP, DBED, DGS, DLLR, and the Maryland Green Building Council, would adopt and revise programs and planning processes to:

- Implement a public benefit fund using revenues from RGGI allowance auctions with the goal of increasing the funding, scope, coverage and marketing of energy efficiency programs.
- Develop an administrative framework for coordination and oversight of energy efficiency programs, including a procurement process for energy service companies and other providers.
- Establish ongoing, high-level statewide resource planning in coordination with the PSC.
- Scale-up training and education in energy efficiency measures
- Expand energy audit programs and establish recycling/scrapping programs for old appliances.
- Use tax policy or other incentives to facilitate implementation of energy efficiency measures.
- Review efficiency best practices for specific industries and conduct training on these practices.

Much of this policy option is now required as part of the 2008 legislation referenced above and described in detail in Chapter 7.

Policy Goals:

Together with RCI-10, achieve a 15 per cent reduction in per capita electricity and natural gas use by 2015, starting in 2008.

Capture 100 per cent of achievable cost-effective energy efficiency by 2025, starting in 2008.

Implementation:

For those elements of this policy that cannot be implemented immediately, MEA, working with the PSC and other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. The implementation plan will build from the recently enacted Strategic Energy Investment Fund legislation and the full recommendation in Appendix D-3, but may also include additional analysis and appropriate modification by the State implementation team.

Low-Cost Loans for Energy Efficiency (RCI-3)

This policy option would create a revolving loan fund to enable residents and businesses to purchase energy efficient equipment such as appliances, furnaces, boilers, hot water heater upgrades, and to support structural efficiency upgrades. This policy is intended to complement RCI-2 (Demand Side Management) and RCI-10 (Energy Efficiency Resource Standard), the chief tools for implementing the EmPOWER Maryland program.

The MEA, in cooperation with private sector lending firms, would oversee a revolving loan fund. Fund revenues would come from auctioned RGGI allowances and private sector capital. MEA would establish criteria for eligibility to ensure benefits reach low-income homes and would delineate loan purposes and repayment terms. A Pay-As-You-Save program or other mechanism may be required to demonstrate energy efficiency has been achieved. MEA would also coordinate with other State agencies and the real estate industry to establish guidelines and regulations to help achieve energy efficiency in rental properties in Maryland.

Policy Goals:

Establish loan funds in sufficient amounts to begin making loans by 2009 and continue indefinitely.

Achieve government funding at the minimum level of $15 million ($10 million for the residential sector and $5 million for the commercial sector) and leverage with private capital at the minimum level of $60 million ($40 million for the residential sector and $20 million for the commercial sector).

Implementation:

MEA is already implementing programs that are consistent with the goals of this policy option. It currently administers the Jane E. Lawton Loan Program, passed in the 2008 Session of the General Assembly (SB 885/HB 1301), and the State Agency Loan Program. These programs target State buildings, other government buildings, and small businesses for low-interest energy efficiency loans. Contingent on RGGI revenue and approval by the General Assembly, additional loan programs targeting the residential sector could begin in Spring 2009.

Government Lead-by-Example: Improve Design, Construction, Appliances, and Lighting in New and Existing State and Local Buildings, Facilities and Operations (RCI-4)

Under this policy option, State and local governments would adopt practices beyond established building codes, such as LEED-NC for construction and LEED-EB for operation, to obtain high performance and energy efficient buildings.

Policy Design:

- DGS and other capital improvement authorities within the State system would construct new buildings and renovate existing ones to meet the LEED-NC silver standard. This would conform with the High Performance Buildings Act of 2008 (SB 208) which mandates LEED silver rating in new and renovated State buildings.
- DGS would analyze options to enhance the High Performance Buildings Act of 2008 to:
  - *Require new construction and major renovations for which permits are requested between 2013 and 2020 to meet LEED Platinum ratings or a comparable standard.*
  - *Require buildings undergoing major renovations for which permits are requested between 2009 and 2013 to meet LEED Gold ratings or a comparable standard.*
- All State agencies led by MEA would:
  - *Commission State buildings to ensure building systems are installed and are performing as designed to meet high performance criteria.*
  - *Collect data on energy use in government buildings and maintain it in a database to measure improvements over time.*
  - *Benchmark State buildings to compare efficiency among similar buildings to set priorities for improvement.*
  - *As soon as possible provide meter, energy accounting systems, and trained staff to measure and verify energy consumption and account for improvements and implementation of energy efficiency programs.*
  - *Require architects and engineers to design buildings to meet a climate-neutral requirement and ensure that buildings will meet sustainable building guidelines.*

Policy Goal:

Reduce per-unit-floor-area consumption of carbon-based electricity by 15 per cent by 2010, 50 per cent by 2020 and become 100 per cent carbon neutral by 2030 within all government owned and leased buildings.

Implementation:

Many State agencies are already implementing programs that are consistent with the goals of this policy option. For those elements of this policy that cannot be implemented immediately, MDE, with support from DGS, MEA, MDP, DHCD and other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. This policy will require regulation changes to ensure that all government buildings meet improved efficiency standards. MDE will likely need to chair a team to include the supporting agencies, among others, that will need to develop a formal implementation strategy. It is likely that this measure will need at least two years for full implementation.

More Stringent Appliance/Equipment Efficiency Standards (State-level, or Advocate for Regional or Federal-level Standards) (RCI-7)

For appliances which do not have energy efficiency levels established by federal or Maryland laws, this policy option would call for the General Assembly to adopt legislation establishing energy efficiency standards recommended by the Appliance Standard Awareness Program.

MEA, in cooperation with the PSC and MDE, would:

- Analyze options, including State legislation, to implement this option.
- Periodically review appliance ratings by the Appliance Standard Awareness Program and seek legislation updating the standards accordingly for appliances not covered by existing laws.
- Continue to work with federal authorities and energy officials from other states to advocate for a national energy efficiency appliance standard.
- Continue to work with consumer groups to promote purchases of energy efficient appliances.

The agencies listed above are already implementing programs that are consistent with the goals of this policy option. The Energy Independence and Security Act of 2007 (EISA), enacted in 2007 by Congress, establishes new efficiency standards for certain residential and commercial appliances.

Policy Goal:

Adopt Maryland legislation in 2009 to establish energy efficiency standards for appliances which are not covered by federal laws or existing State legislation. Efficiency ratings would conform to recommendations by the Appliance Standard Awareness Program.

Implementation:

This policy option will require action by the General Assembly. Implementing regulations will take 6-9 months to develop once authority is granted to MEA.

Energy Efficiency Resource Standard (EERS) (RCI-10)

An EERS is a standard established by law which requires utilities to generate, transmit and use electricity and natural gas more efficiently. It includes energy savings programs for consumers, and may also include efficiency improvements in the distribution grid, combined heat and power (CHP) systems and other clean distributed generation systems such as solar collectors and windmills. This policy option is intended to complement RCI-2, (Demand Side Management), to achieve the EmPOWER Maryland goal of a statewide 15 per cent reduction in per capita electricity use and peak load demand by 2015. The legislation recommended in this policy has been accomplished by the passage of the EmPOWER Maryland Energy Efficiency Act of 2008 (HB 374), which codified Governor Martin O'Malley's EmPOWER Maryland goal.

This policy requires setting a mandatory, measurable energy efficiency standard for utilities to meet by a certain date, with oversight by MEA, the PSC and MDE. Design features include the following:

- Utilities submit plans for efficiency programs to the PSC for approval.
- The plan must include a diverse portfolio of programs, including home energy assessments, energy efficiency rebates, commercial and industrial programs, training for contractors and facility managers, and demand response programs.
- PSC evaluates the plan based on cost-effectiveness, ability to capture opportunities for energy efficiency that would otherwise be lost, and fair distribution of funds and programs geographically and among sectors.
- After PSC approves plans, utilities issue requests for proposals (RFPs) for service companies to perform the work identified in the portfolio.

Policy Goals:

Together with RCI-2, require utilities to achieve EmPOWER Maryland energy savings goal of 15 per cent of electricity per capita demand by 2015.

Mandate electricity and natural gas reduction targets for utilities of 0.5 per cent of demand in 2009, ramping up to 2 per cent in 2014-2015.

Implementation:

With the enactment of the ***EmPOWER Maryland*** legislation, the legislative recommendation in this policy option has been largely accomplished. However, since the legislation only covers electricity, there is an opportunity to implement a similar policy for natural gas. This will require action by the General Assembly.

Promotion and Incentives for Energy Efficiency Lighting (RCI-11)

The Energy Independence and Security Act of 2007 (EISA) establishes new federal minimum efficiency standards for common light bulbs, requiring them to use about 20-30 per cent less energy than present incandescent bulbs by 2012-2014. This policy option would support the new federal standards by phasing out the sale or use of energy-inefficient incandescent light bulbs in Maryland, through education and incentives for voluntary replacements of inefficient incandescent light bulbs with energy efficient compact fluorescent light (CFL) bulbs or other energy efficient light bulbs.

Policy Design:

- MEA would design and implement a public awareness campaign to encourage residential customers to purchase CFL or other energy efficient bulbs such as light emitting diodes (LEDs) instead of incandescent light bulbs.
- MEA would explore incentive programs to further encourage the transition from incandescent bulbs to CFLs.
- MDE would explore current disposal problems associated with CFLs, such as minute mercury content within the bulbs, and ensure that appropriate disposal/recycling facilities are available to protect the environment from contamination.

MEA and MDE are already implementing programs that are consistent with the goals of this policy option.

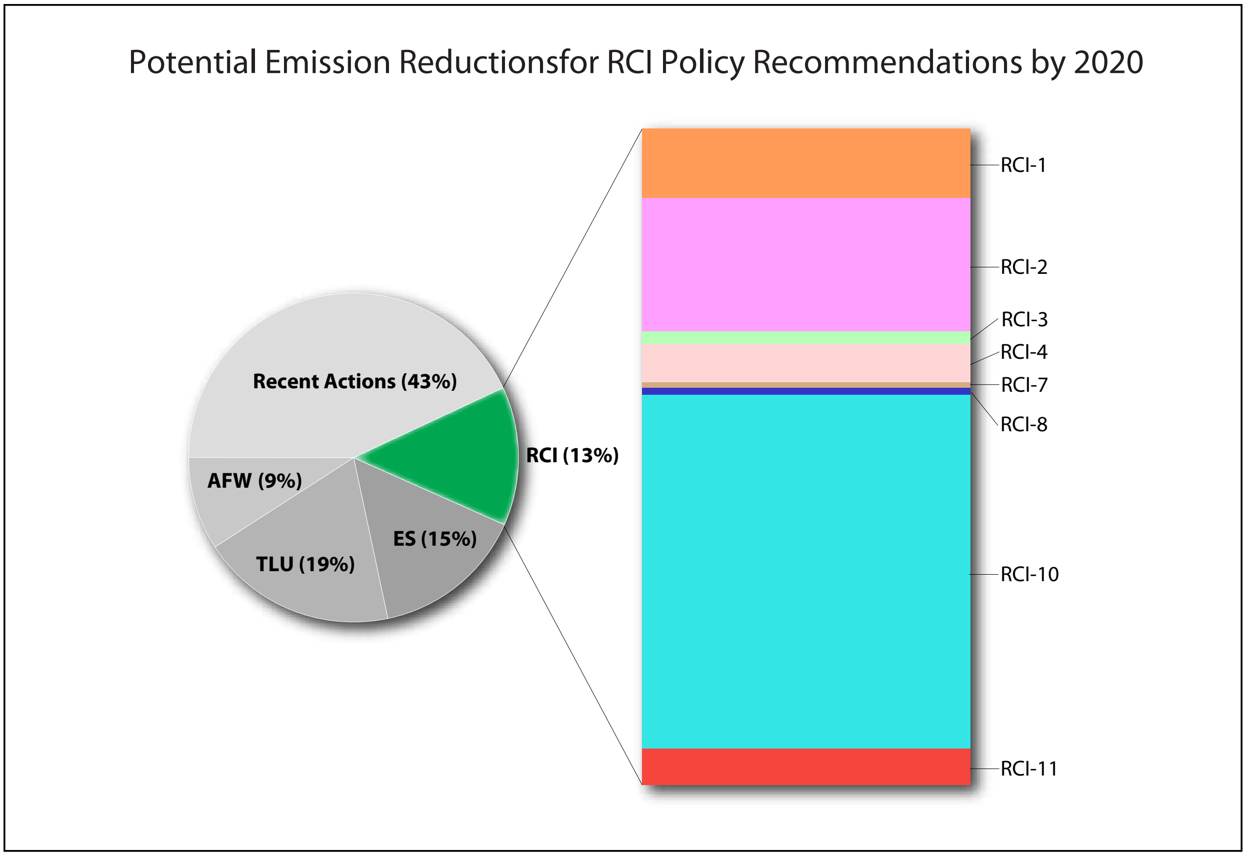
Policy Goal:

By 2014, have screw-in compact fluorescent bulbs make up 95 per cent of residential light bulb sales in Maryland.

Implementation:

Initial programs are underway by MEA. A full suite of programs will be developed over the summer of 2008. Contingent on RGGI funding and budget approval by the General Assembly, MEA will ramp up to full implementation by Spring 2009.

Option No.	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008 - 2020 (Million $)	Cost Effectiveness ($\$/tCO_2e$)
		2012	2020	Total 2008 - 2020		
RCI -1	Improved Building and Trade Codes	0.6	2.4	13.8	-527	-38
RCI-2	Demand-Side-Management	1.8	4.5	35.0	-1,898	-54
RCI-3	Low-Cost Loans for Energy Efficiency	0.3	0.5	4.1	-187	-45
RCI-4	Improved Design, Construction, Appliances and Lighting	0.2	1.3	6.4	-337	-53
RCI-5	Energy Efficiency and Environmental Awareness	Jointly considered with the Cross-Cutting TWG, Policy CC-5				
RCI-7	More Stringent Appliance / Equipment Efficiency Standards	0.1	0.2	1.2	-63	-54
RCI-8	Rate Structures and Technologies	For Information Only - Further Study Needed				
		0.1	0.2	2.0	246	120
RCI-10	Energy Efficiency Resource Standard (EERS)	2.9	11.9	71.0	-3,670	-52
RCI-11	Promotion and Incentives for Energy Efficiency Lighting	0.1	1.1	7.7	-362	-47
	Sector Total After Adjusting for Overlaps	*101*	*11.2*	*54.1*	*-5,450*	*-48*
	Reductions from Recent Actions	*4.3*	*9.0*	*71.5*	*Not Quantified*	
	Sector Total Plus Recent Actions	*5.4*	*20.2*	*125.5*		



The pie chart above shows the potential emission reduction contribution to Maryland's goals from the RCI policies. The percentages are based on the total potential emission reductions from recent actions and all of the Commissions's quantified policy options. Each RCI policy option's potential emissions reduction is graphically displayed on the right in the bar chart.

Adaptive Land Use in Baltimore City
Source: U.S. Environmental Protection Agency

Bike to Work Day
Photo by Don Mauldin

Overview of GHG Emissions

GHG emissions from transportation are tied to carbon-based fuel consumption. In Maryland, the transportation sector accounted for approximately 32 per cent of gross GHG emissions in 2005 (about 32.5 million metric tons of carbon dioxide equivalent, or $MMtCO_2e$). From 1990 through 2005, transportation-related GHG emissions in Maryland increased by 8.3 $MMtCO_2e$, comprising 22 per cent of the State's net growth in gross GHG emissions during this period and reflecting a 2 per cent average annual rate increase in emissions due to transportation fuels.

As a result of Maryland's population and economic growth and a 40 per cent increase in total vehicle miles traveled (VMT), on-road gasoline vehicle use grew 36 per cent between 1990 and 2005. Meanwhile, on-road diesel vehicle use rose 91 per cent during that period, suggesting rapid growth in freight movement within or across the State. In 2005, on-road gasoline vehicles accounted for about 74 per cent of transportation GHG emissions, on-road diesel vehicles contributed 18 per cent, and aviation, marine vessels, and rail made up most of the remaining 8 per cent.

Under a business-as-usual (BAU) scenario, Maryland and the nation are projected to have rapid future growth in transportation GHG emissions. Historic growth for diesel fuel has been stronger than for gasoline. This trend is expected to continue for the 2005–2020 period, with gasoline and diesel fuel consumption projected to increase by 13 per cent and 58 per cent, respectively. Jet fuel, aviation gasoline and marine vessel fuel consumption could increase by almost 10 per cent between 2005 and 2020.

GHG Emission Reduction Goals

Recognizing the problem, the State has already taken a significant step to reduce GHG emissions from the transportation sector by enacting a program based on California's strict vehicle emissions standards (CA LEV). The Maryland Clean Cars Act was signed into law by Governor O'Malley in April of 2007 and regulations were adopted in November of 2007. These standards will become effective in Maryland for model year 2011 vehicles. Currently, the Clean Cars Program represents the only transportation program that directly regulates CO_2 emissions.

Numerous other State programs are currently serving to reduce GHG emissions. Such initiatives seek to reduce VMT and congestion through ridesharing and telecommuting; to increase transit usage by ensuring a "Guaranteed Ride Home" for transit users; to reduce gasoline consumption through biofuel use by State fleets; and to reduce congestion and improve system efficiencies through intelligent transportation systems like CHART (Coordinated Highways Action Response Team) and traffic signal synchronization, which cut idling and reduce emissions.

Maryland strives to maximize GHG emission reductions in a responsible manner, addressing, among other factors, the economic, social, health, and mobility needs of the State.

Reflecting the urgency and importance of reducing climate change, the Transportation and Land Use (TLU) TWG set aggressive goals and recommended a package of strategies to achieve these targets. Some of the policy options offered for consideration are new concepts and have not been widely tested; others will vary in their effectiveness depending on when and how they are implemented, the level of participation across the transportation sector, volatility in carbon-based fuel prices, future federal legislative and regulatory action, the pace of technological innovation and adoption of new fuels and vehicles, among other factors. For example, the targets sought by the TWG for VMT reduction in Maryland reach beyond what is largely considered to be viable by the national transportation policy community, i.e, reductions in the rate of VMT growth.

Maryland has set goals for reducing Maryland's GHG emissions in all sectors. The goals for total GHG emissions reductions are:

- 10 per cent below 2006 GHG emissions levels by 2012
- 15 per cent below 2006 GHG emissions levels by 2015
- 25-50 per cent below 2006 GHG emissions levels by 2020
- 90 per cent below 2006 GHG emissions by 2050

There is no intent or requirement to target emissions reductions for each sector commensurate with the current or projected contribution of the sector to total emissions. Effectiveness, cost, ease of implementation and timing may in fact be better considerations than respective contribution to emissions in the final implementation of solutions statewide. Nevertheless, the TWG did assign a corresponding reduction to transportation for use as a benchmark against which to compare estimated reductions from the policy options.

Using the TWG methodology, if each sector is expected to contribute to the reduction efforts in proportion to its contribution, a 25-50 per cent reduction below 2006 GHG emissions levels would be expected from the transportation sector in 2020. If all of the TLU policy options were implemented, they are estimated to achieve a reduction of approximately 47 per cent from 2020 BAU emissions.

The recommended implementation strategy for the transportation sector is to start up a multi-member working group, led by the Maryland Department of Transportation, to analyze the relationship among the policies and identify steps for moving forward. The overall success in reducing GHG emissions from transportation will follow from the development of a comprehensive and achievable set of strategies with broad-based participation and support from businesses and individuals across the State.

Key Challenges and Opportunities

The solution to reducing transportation-related GHG emissions lies in restructuring our system to offer low GHG options, improving land use to better link existing and future development with transit and walkable communities, and educating individuals to make better transportation choices.

Transportation GHG emissions are generated from three areas: VMT, vehicle technologies, and the carbon intensity of the fuels used in our vehicles. Consumers have direct control over two of these areas: vehicles and VMT. The implementation of State and federal vehicle fuel efficiency standards provides potential for substantial reductions in GHG emissions. Early gains are made when consumers embrace new technologies such as hybrids and fuel cell vehicles. Other immediate benefits are realized when individuals reduce their VMT by carpooling, teleworking or taking transit, by living closer to their place of employment, and by combining their incidental travel and patronizing local businesses and services. Maryland has taken steps to increase transit options and encourage sustainable land use patterns to help citizens make better choices.

The next challenge will be to develop an implementation strategy that takes into account all of the relevant external, interstate and market influences and variables, to help us make real and meaningful progress toward the aspirational goals. The Commission, State and local government transportation and land use agencies, and others with influence on the transportation sector will need to work cooperatively to develop, implement and foster policies that will reduce mobile source GHG emissions and VMT growth, balancing a variety of needs for Maryland's citizens and businesses. Strategies will need to be frequently evaluated for their effect on GHG reduction as well as their impact on communities, on economic development, housing, and quality of life. The Commission recognizes that implementing statewide Smart Growth, transit-oriented development and VMT goals in the context of land use and zoning decisions made by local governments will remain a significant challenge.

Many of the transportation policy options will require further study in order to develop sound time frames and processes for future implementation. The TLU policy options illustrate programs and benefits designed to help achieve the statewide GHG emissions reduction targets. Implementation of the policy options presents a unique set of challenges including identifying key stakeholders, strategies, processes, and measurement and evaluation methods in order to meet the policy goals.

LESSONS LEARNED FROM THE CLEAN AIR ACT

Using the Transportation Conformity Process to Address Greenhouse Gases

Maryland has been successfully implementing the Transportation Conformity provisions of the Clean Air Act for over 20 years. In simple terms, the Transportation Conformity requirement insures that the State's transportation plans will not result in increased emissions that are inconsistent with the State's air quality plan. This process seems to be ideal for addressing greenhouse gases as well.

The cornerstone of the Transportation Conformity Program is the "Interagency Consultation" process, which brings together State and local air quality and transportation planners and public stakeholders in a partnership designed to insure that the State's transportation and air quality goals are met. The Interagency Consultation process has already built a strong technical approach for analyzing and modeling how emissions change as transportation plans are updated, as well as an effective system for stakeholder input.

Maryland will be investigating and potentially implementing a pilot program to blend greenhouse gas controls into the Transportation Conformity process. The Maryland Departments of the Environment and Transportation will be working with local governments in the Baltimore, Washington and Philadelphia areas to explore how this kind of a process could be started. The Metropolitan Washington Council of Governments Climate Change Steering Committee is also considering a similar effort.

Overview of Policy Recommendations and Estimated Impacts

The Commission originally recommended eleven transportation and land use strategies for implementation in the ***Interim Report*** submitted to the Governor and the General Assembly in January of 2008. Following further study, the Commission has combined TLU-7, "VMT Reductions" with TLU-2, "Land Use and Location Efficiency". The Commission has also consolidated TLU-1, Carbon Fuel Tax Fund" with TLU-9, " Incentives, Pricing and Resource Measures". TLU-4, "Low Greenhouse Gas Fuel Standard", needs further analysis and technological development before it can be implemented and has been removed from the recommended actions. There are now eight revised policy options recommended for implementation in the TLU sector.

The policy options represent a set of tools and associated targets designed to demonstrate how the transportation sector can significantly reduce GHG emissions while achieving other State transportation goals.

The Transportation and Land Use strategies are organized into three groups:

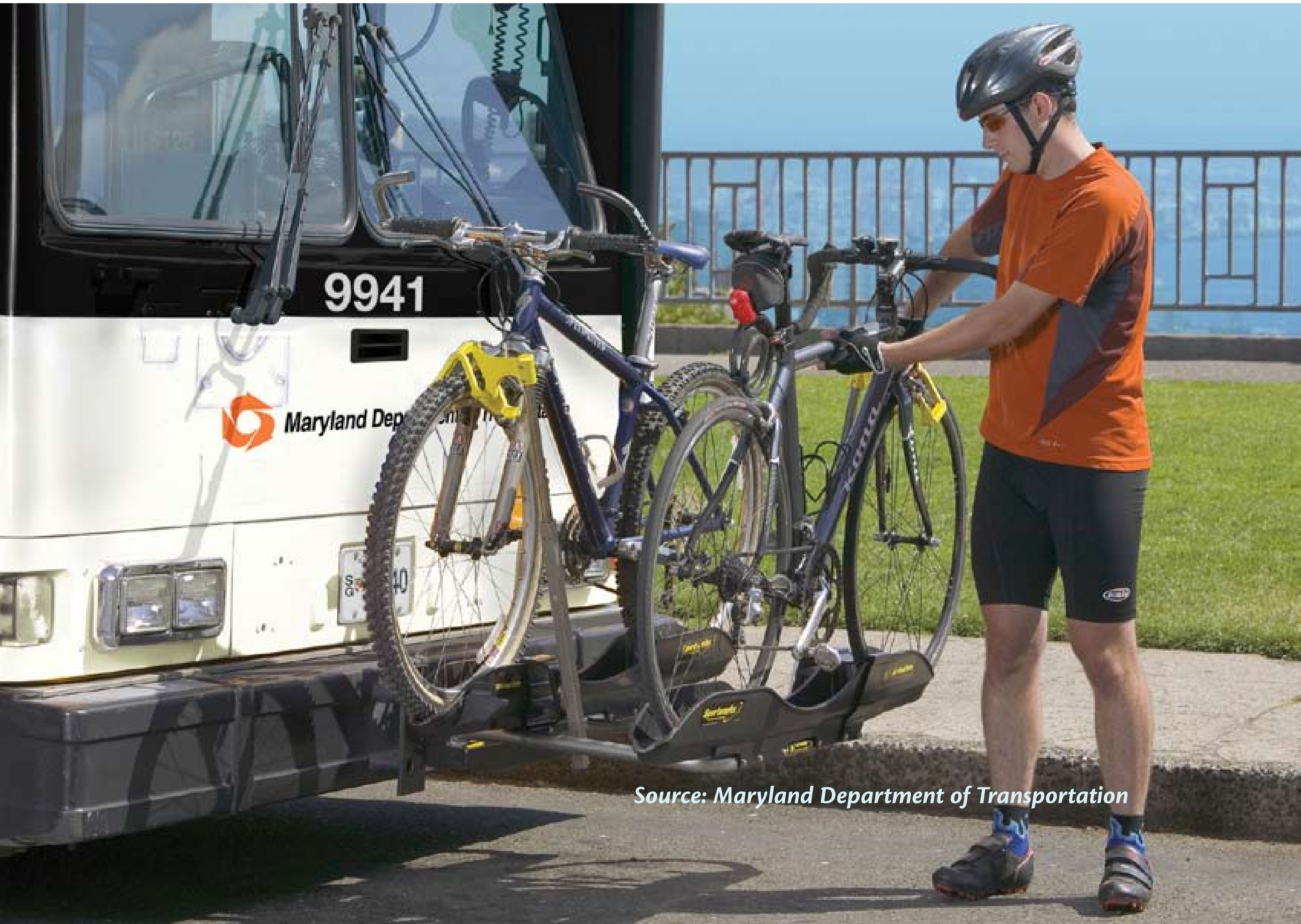
- TLU Area 1: Reduce the number of miles driven (VMT).
- TLU Area 2: Reduce carbon per unit of fuel (cleaner fuels).
- TLU Area 3: Reduce carbon per mile and/or per hour (improved vehicle efficiency).

Because the Clean Cars Act of 2007 was already in place, TLU Area 3 starts from a baseline which already includes the Clean Cars Program.

Executed together, and with consideration of the critical timing and implementation issues discussed in the key challenges and opportunities section, this suite of TLU policy recommendations has the potential to substantially reduce Maryland's transportation GHG emissions.

Commission Recommendations from Transportation

- The Commission recommends that the Governor convene an implementation working group of key stakeholders to include: MDOT (as the lead agency), MDE, MIA, MDP, MEA, DHCD, DBED, Metropolitan Planning Organizations (MPOs) and local governments. The working group would evaluate the TLU policy options and develop specific implementation strategies for selected policies.
- The State goal is to reduce GHG emissions. Transportation policies and strategies which are designed to support the State's overall goal should maintain the focus on GHG reduction through efforts to reduce VMT and fuel carbon intensity, and support vehicle technologies and efficiencies and other methods to achieve the overall GHG goals.
- Transportation-related policies should not be implemented to the extent that a detrimental impact on the future of Maryland's economy and the quality of life for its residents would be greater than the benefits of climate action. Socio-economic, environmental justice and competitiveness impacts must be considered.
- The linkage of the transportation policy options should be examined. Recommended strategies will likely work best when they are implemented in relation to other policies (for example, pricing or land use changes implemented together with transit expansion), and with consideration for appropriate order and phasing.
- Implementation strategies for each policy option should be reviewed with the objective of determining the level of responsibility for implementation, whether State, local, regional, multi-state or federal, or some combination thereof.



Source: Maryland Department of Transportation

TLU Area 1: Reduce VMT's Contribution to GHG Emissions

TLU Area 1 is a suite of policy options aimed at reducing vehicle miles traveled (VMT), as a means of reducing the GHG emissions associated with transportation. Aggressive implementation of all of the policy options in Area 1 would result in GHG reductions between 25 per cent and 50 per cent compared with current transportation sector emissions. Less aggressive implementation would reduce VMT by 20 per cent, contributing to meeting the lower end of the State's 25-50 per cent GHG reduction goal. Because of the interrelationships between policy options, the Commission recommends implementation of Area 1 policies as a package. The different elements of the package are often complementary and depend on mutual implementation for their success. For example, options that encourage alternatives to automobile use, such as TLU-6, "Pay-as-You-Drive Insurance", may be ineffective if alternatives such as mass transit (TLU-3) are not available. Within Area 1, the important variable is the strength of implementation of the individual policies. Taken together, these policies have substantial power to reduce GHGs.

MDOT will lead an implementation working group comprised of various stakeholders, including, MDE, Maryland Insurance Administration (MIA), MDP, the Office of Smart Growth and other State agencies, local government, and MPOs. The working group will evaluate the suite of policy options in Area 1 to assess the best approach and phasing for implementation. It will begin coordinating to achieve near-term implementation of the entire policy suite. Immediate action is especially important for options that require longer lead times, such as increasing transit capabilities (TLU-3), changes to land-use planning (TLU-2), and changes in the insurance industry (TLU-6).

Policy Goal:

Reduce the emissions associated with VMT by between 25 and 50 per cent of 2006 levels in 2020 by implementing the suite of policy options in TLU Area 1. Interim reduction goals are 10 per cent and 15 per cent reductions by 2012 and 2015, respectively.

Following are summaries of individual policy options within TLU Area 1: TLU-2, TLU-3, TLU-5, TLU-6, TLU-8, TLU-9 AND TLU-11.

Integrated Planning for Land Use and Location Efficiency (TLU-2)

This policy option calls for the implementation of integrated land use planning, transportation and development strategies that encourage people to drive fewer miles while ensuring a competitive economy, affordable housing opportunities, and community-based public schools and services for Maryland residents.

This policy could be implemented through legislation, integrated planning process reforms, investment incentives, pricing and other strategies to promote compact, transit-oriented development, community-based public schools and public services, and other growth management objectives. The Maryland Transit Administration – Transit-Oriented Development (HB 373/SB 204) legislation, enacted in the General Assembly's 2008 Session, furthers this policy by promoting integrated planning and incentives for transit-oriented development throughout the State. State and local governments should locate public schools, libraries, and government offices in areas that can be accessed by transit, walking or bicycling.

Policy Goal:

Return statewide VMT to 2000 per capita levels by 2020 and ensure continuing reductions in per capita VMT (excluding vehicles over 10,000 pounds engaged in commercial freight activity) of 30 per cent by 2035 and 50 per cent by 2050 from a 2020 baseline.

Transit (TLU-3)

This policy option seeks to shift passenger mode choice to transit and carpooling. This option is necessary to ensure that the mode-shift created by the other recommended policies away from single-occupant car use can be effectively accommodated.

State funds would be dedicated to implement this policy option. MDOT, MDE, MTA, SHA, MDP and MPOs would be directed to implement policies at the State and local levels that:

- Improve transit service and expand transit infrastructure (rail, bus) through increased funding, planning, and improved coordination of Rideshare, Transit, Park and Ride, Bike-Pedestrian, and the interstate transportation infrastructure.
- Focus new development and growth on transit-served corridors.
- Expand transit marketing and promotion.

Many of the agencies listed above are already implementing programs that are consistent with the goals of this policy option. The Maryland Transit Administration – Transit-Oriented Development (HB 373/SB 204) legislation, enacted in the General Assembly's 2008 Session, furthers this policy by promoting integrated planning and incentives for transit-oriented development throughout the State.

Policy Goal:
Double transit ridership statewide by 2020.

Three Types of Land Use – Suburbs, Agriculture & Wetlands
Emily Nauman, IAN IMage Library (www.ian.umces.edu/imagelibrary/)

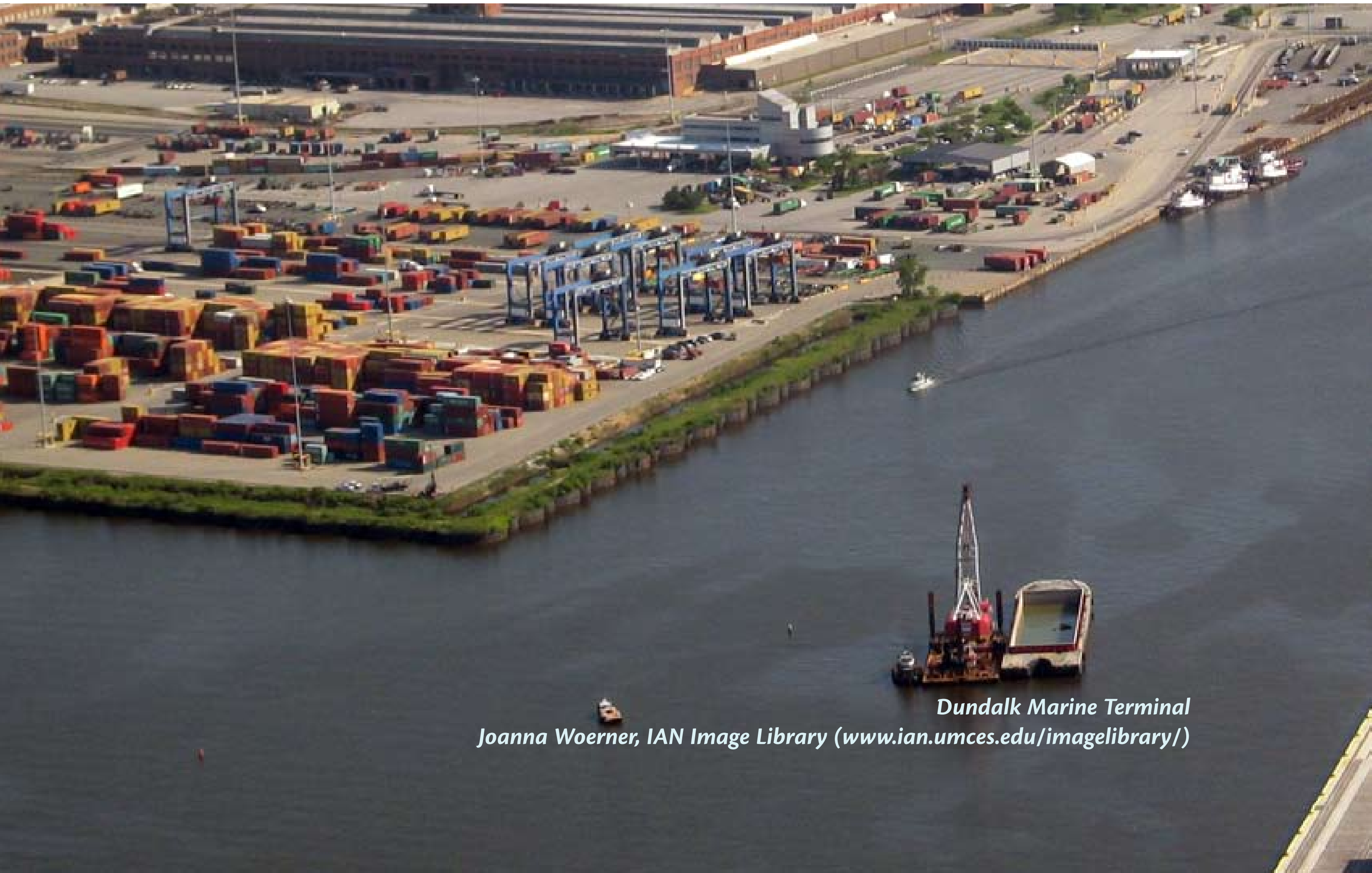
Intercity Travel: Aviation, Rail, Bus and Freight (TLU-5)

This policy option seeks to enhance connectivity of non-automobile transportation modes between cities through infrastructure and technology investments. An expansion of rail is especially encouraged to shift passenger trips away from short-range air travel and to increase rail freight transportation.

MDOT, MDE, MDP, Office of Smart Growth, SHA, and MPOs would work with passenger and freight rail providers to develop a plan with short-, medium-, and long-term projects directed toward achieving this policy's goals. The plan would incorporate existing plans developed by MDOT and proposals by outside groups such as the Mid-Atlantic Rail Operations (MAROPS) study and the National Association of Rail Passengers. Appropriate funding needs to be committed to insure rapid progress on the near-term goals.

Policy Goals:
Make passenger and freight rail more accessible, efficient, and available to help meet the 2020 GHG reduction goals by:
1. ***Building capacity of express rail and bus by expanding and/or improving current passenger and freight rail as needed.***
2. ***Marketing new and/or improved/expanded services.***
3. ***Shifting short- and mid-distance air travel to modern rail.***
4. ***Supporting auto-free tourism development in Maryland.***

Many of the agencies listed above are already implementing programs that are consistent with the goals of this policy option.



Dundalk Marine Terminal
Joanna Woerner, IAN Image Library (www.ian.umces.edu/imagelibrary/)

Pay-as-You-Drive Insurance (TLU-6)

This policy option would tie consumer insurance costs to actual motor vehicle travel use, so premiums would be directly related to hours or miles driven. This would provide price signals to consumers encouraging a reduction in miles driven, while allowing insurance companies to make premiums more actuarially accurate.

The Maryland Insurance Administration (MIA) would lead a work group including MDOT, MDE, the insurance industry, consumer advocacy groups and other stakeholders, to develop recommendations for implementation.

The Commission recommends that the MIA work with the insurance industry to explore pilot programs for implementation and marketing.

Policy Goal:

Make PAYD coverage available to all Maryland drivers as early as possible and push for adoption by Maryland drivers by the 2012 time frame.

Jane Thomas, IAN Image Library (www.ian.umces.edu/imagelibrary/)

Bike and Pedestrian Infrastructure (TLU-8)

This policy option seeks to improve, add, and promote sidewalks and bikeways to increase pedestrian and bicycle travel, thus reducing automobile use.

State agencies led by MDE, MDOT, SHA and MTA, working in partnership with local governments and private stakeholder interests, could develop the following infrastructure planning and designing tools/concepts. Some of the agencies listed above are already implementing programs that are consistent with the goals of this policy option.

- A state-wide "Complete Streets" policy, requiring new and renovated streets to be designed to accommodate all users. State transportation grants to localities could be made contingent on consistency with this policy.
- A rewrite of the Highway Design Manual, requiring all new engineering and construction to accommodate safe, convenient movement of bicycles and pedestrians along and, where possible, across all non-limited corridors.
- Installation of shower and bike storage facilities in new buildings, transit stations, and places of employment through a mix of incentives and, where possible, requirements.

State government could provide financial incentives to local governments such as:

- Grants to identify gaps in local bicycle and pedestrian infrastructures and to develop plans and policies to encourage biking and walking.
- Funding to install low-cost safety solutions that improve conditions for bicycling and walking.
- Grants and funding to improve pedestrian and bicycle infrastructure that provides more effective and safer pedestrian and bicycle access to and from public schools.
- New taxing authority and more flexibility with gas tax revenues to finance local improvements, including public education, safety, engineering, and revisions to local land use policies (requires legislative action).

Policy Goal:

Increase the bicycle and walking mode share of all trips in Maryland urbanized areas by 15 per cent from the current levels by 2020. The quantification of this policy's GHG emissions reduction potential and cost-effectiveness is included in TLU-3, "Transit".

Incentives, Pricing and Resource Measures (TLU-9)

Pricing and incentives encourage wise stewardship when consumers make transportation choices. Updating Maryland's current pricing and incentives and developing new incentives would reflect the true environmental and social costs of our transportation choices. This would amplify efforts to reduce GHG emissions through Smart Growth incentives and transit investments.

MDOT, MDE and MDP could implement a set of incentives, pricing, and resource measures, that together use (1) market signals to help Maryland agencies and citizens manage travel using better information about costs and benefits; and (2) a restructured transportation pricing system to fund investments in the system that accepts growth and maintains quality of life without increasing GHG emissions.

Commuter incentives and reforms in how pricing and incentives are considered in the State planning process should be developed. The Commission discussed a carbon fuel tax but decided not to move forward with a specific recommendation at this time. Some of the agencies listed above are already implementing programs that are consistent with the goals of this policy option.

Policy Goals:

By 2020, establish the following pricing measures throughout the State:

Appropriate GHG emission-based road user fees, with revenues used to fund transportation improvements and systems operations that advance State emission reduction goals.

Time-of-day emission-based cordon pricing in appropriate central areas as a local option to finance improved public transportation.

Incremental fees based on the carbon-intensity of fuels.

Parking pricing policies that ensure an effective use of urban street space for the highest and best uses – giving greater priority to low-carbon modes of transportation such as walking, cycling, and public transportation.

Bike to Work Day
Photo by Don Mauldin

Evaluate the GHG Emissions from Major Projects (TLU-11)

This policy option would require State agencies to conduct an evaluation of the resulting transportation and land use GHG emissions related to State and local major capital projects such as major road construction or modifications, and State capital investments in new buildings including public school construction projects.

The Commission recommends that this requirement be established by executive order in 2008, with a directive to MDE, MDOT, the Office of Smart Growth, MDP, DGS and the Interagency Committee on School Construction to develop guidance for State agencies and other large capital project sponsors to use in evaluating the GHG impact of major capital projects. These agencies would seek federal guidance for models and best practices and to ensure compatibility with anticipated federal requirements. If needed, State legislation should be considered. Several of the agencies listed above are already implementing programs that are consistent with the goals of this policy option.

Policy Goals:

This is an enabling goal with no quantification of GHG emission reductions or cost-effectiveness. It would require State agencies and sponsors of other large capital projects, including public school construction projects, to:

- ***Understand the impacts of new capital projects on the Governor's GHG commitment by performing a GHG impacts analysis on all major capital projects.***
- ***Where appropriate, include the analysis of potential alternatives, such as transit-oriented land use and investment; adding toll lanes and express buses; adding high occupancy toll (HOT) lanes; adding hybrid transit-oriented HOT lanes; adding rail and express bus alternatives; and an analysis of alternative public building and public school sites including no-build, renovation/addition, and re-use of existing buildings for GHG emissions and reduction strategies.***

TLU Area 3: Reduce Carbon per Mile and/or per Hour

This policy option seeks to reduce GHG emissions from both on-road vehicles and off-road engine vehicles (including marine, rail and other off-road engine and vehicles such as construction equipment) through deploying technology designed to cut GHG emission rates per unit of travel activity. This option constitutes TLU Area 3, "Reduce Carbon Intensity per Mile and/or per Hour".

Transportation Technologies (TLU-10)

This policy would require State regulatory action, led by MDOT and MDE, and legislative action to promote transportation options with reduced emissions and to improve transportation system management policies to reduce emissions. Implementation mechanisms that relate to engines/vehicles would include the following:

- Provide incentives to increase purchases of fuel-efficient or low GHG vehicles.
- Increase the use of alternate fuels or low sulfur diesel to reduce GHG emissions.
- Reduce idling time (i.e. long-haul trucking, locomotives, and construction equipment).
- Initiate marketing and education campaigns to operators of off-road vehicles.
- Adopt "Green Port Strategy" for Baltimore area port facilities.
- Adopt State contracting and fleet standards for low GHG equipment procurements.

State-level transportation system management implementation mechanisms would include:

- Traffic management center(s)
- Traffic signal synchronization
- Managed lanes and dynamic roadway and full corridor pricing
- Smart parking systems
- Bus signal priority

Policy Goals:

- ***Reduce emissions from on-road engines / vehicles by an additional 7.5 per cent by 2020 from the current baseline.***
- ***Reduce emissions from off-road transportation sources by 15 per cent by 2020.***

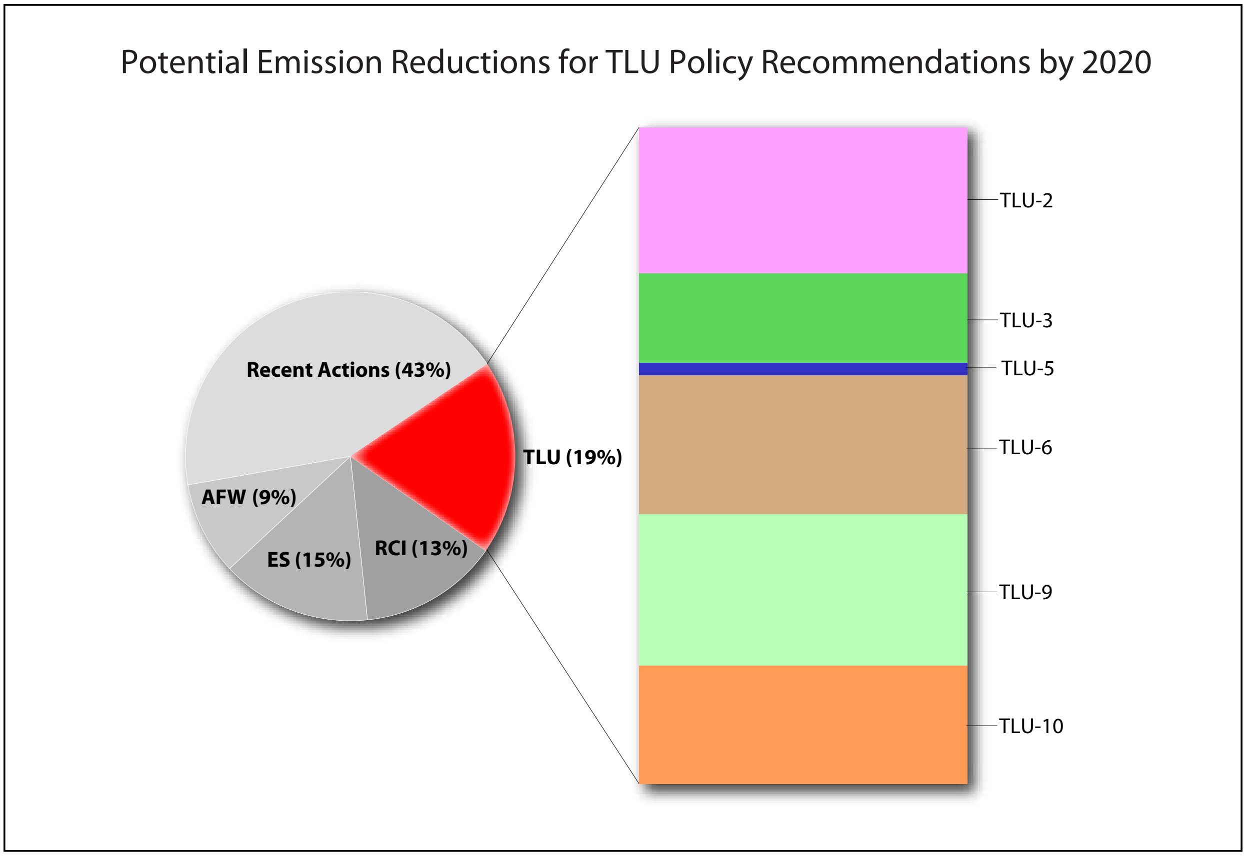
Implementation:

Several State agencies are already implementing programs that are consistent with the goals of this policy option. For other elements of this policy that cannot be implemented immediately, MDOT, working with MDE and other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. MDE is already implementing the Clean Cars Program. This program includes a technology-forcing provision called the Zero Emission Vehicle (ZEV) requirement.

Woodrow Wilson Bridge Construction
Source: <http://www.Roadstothefuture .com>

Option No.	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008 - 2020 (Million $)	Cost Effectiveness ($\$/tCO_2e$)
		2012	2020	Total 2008 - 2020		
TLU Area 1: Reduce VMT's contributions						
TLU-2	Land Use and Location Efficiency	1.1	4.6	27.6	Large Net Savings	
TLU-3	Transit	1.1	2.8	20.3	Net Savings	
TLU-5	Intercity Travel	0.2	0.3	2.4	TBD	
TLU-6	Pay-As-You-Drive Insurance	1	4.3	27.2	Net Savings	
TLU-8	Bike and Pedestrian Infrastructure	Included in TLU-3				
TLU-9	Incentives, Pricing and Resource Measures	2.7	4.7	37.4	Net Savings	
TLU-11	Evaluate GHG from Major Projects	NA	NA	NA	NA	NA
TLU Area 1: Total of Individual Options		6.1	16.7	114.9		
TLU Area 2: Reduce Carbon per Unit of Fuel - For Information Only - Further Study Needed						
TLU-4	Low GHG Fuel Standard (For Information Only)	0.7*	1.9*	12.8*	501.7*	30 - 90*
TLU Area 3: Reduce Carbon per Mile and or per Hour						
TLU-10	Transportation Technologies	0.40	0.44	4.17	610.3	-200 - +1,500
TLU Area 3: Total of Individual Options		0.40	0.44	4.17	610.3	-200 -1,500
	Sector Total Before Adjusting for Overlaps, Using Only the Area Totals	*7.2*	*19.04*	*131.87*		
	Reductions from Recent Actions	*0.08*	*0.11*	*1.13*		
	Sector Total Plus Recent Actions	*7.28*	*19.5*	*133.0*		

*The sector totals include the quantified reductions from TLU-4. These calculations were made prior to the Commission's decision to remove TLU-4 as a recommendation pending further analysis and technological innovation.



The pie chart above shows the potential emission reduction contribution to Maryland's goals from the TLU policies. The percentages are based on the total potential emission reductions from recent actions and all of the Commission's quantified policy options. Each TLU policy option's potential emissions reduction is graphically displayed on the right in the bar chart.

Carroll Park
Photo by Mary Jane Rutkowski

Cross-Cutting

Overview

Some issues relating to climate policy cut across multiple or all sectors. The MWG addressed such issues explicitly in a separate TWG as "cross-cutting" issues rather than assigning them to any individual sector. Cross-cutting recommendations typically encourage, enable, or otherwise support emissions mitigation activities and/or other climate actions. The types of policies considered for this sector are not readily quantifiable in terms of GHG reductions and cost-effectiveness. Nonetheless, if successfully implemented, they would likely contribute to GHG emission reductions and enhance the economic benefits described for each of the other policy recommendations that were quantified.

The Cross-Cutting Issues (CC) TWG developed recommendations for each of ten policies that were then reviewed, revised, and ultimately adopted by the Commission. All of the CC policy options are focused on supporting the quantified policy options recommendations developed by the other TWGs.

The "Statewide Goals and Targets" recommendation (CC-3) is the over-arching Commission recommendation, and it is based on the goals established in the Commission's ***Interim Report***. These goals are designed to reduce Maryland's GHG emissions by 25 per cent to 50 per cent below 2006 levels by 2020 and 90 per cent below 2006 levels by 2050. The goals include interim reduction targets of 10 per cent reductions by 2012 and 15 per cent reductions by 2015, again using the 2006 baseline.

The quantified policy options in Commission's ***Climate Action Plan*** are projected to achieve these levels of reductions. The full text of each policy recommendation is in Appendices D-1 through D-5.

Key Challenges and Opportunities

One of the key challenges facing Maryland and other states is the lack of clear federal climate change goals, policies and programs. Recent enactment of the Federal Energy Independence and Security Act of 2007 (EISA) will provide some direction on auto mileage and energy efficiency requirements, but there are many other facets of the climate change problem that will need to wait a year or more for federal policy to become more apparent.

In the meantime, Maryland's participation in important regional ventures such as RGGI offers the State the clear opportunity to help develop regional and collaborative initiatives that will have broader applicability than just within Maryland borders.

The State has begun to implement a number of activities recognized in the Lead-by-Example policy option (CC-4). It will need to build on these efforts and take such initiatives to the next level. Additionally, the State will need to organize efforts across State agency boundaries in order to realize some of the reductions anticipated from State government.

Although in the aggregate, the policy recommendations in the ***Climate Action Plan*** are projected to result in a net cost savings to Maryland, implementation of some of the individual policies may entail additional costs to State government that the State will need to determine how to finance. Determining how to finance implementation of the ***Plan*** will remain an ongoing challenge.

A key opportunity for the State is in the arena of building more business and economic development opportunities and developing substantial numbers of additional green jobs associated with reducing GHG emissions. The ***Plan*** calls for the creation of a special task force to promote such efforts.

GHG Inventories and Forecasting (CC-1)

GHG emissions inventories and forecasts are essential for understanding the magnitude of all emission sources and sinks (both anthropogenic and natural), the relative contribution of various types of emission sources and sinks to total emissions, and the factors that affect trends over time. Inventories and forecasts inform State leaders and the public on statewide trends, opportunities for mitigating emissions or enhancing sinks, and verifying GHG reductions associated with implementation of Climate Action Plan initiatives.

This policy option would be implemented by MDE, with assistance from DNR, MEA, PSC, MDOT, and MDA. Its essential elements include a statewide GHG inventory and forecast and implementation of GHG reporting by emission sources and sinks as soon as possible, as allowed by current funding and supplemented with budget amendments.

Policy Goals:

Develop a consistent and complete inventory of emission sources and sinks
- ***Include a production-based inventory for all man-made and natural emissions generated within Maryland***
- ***Include a consumption-based inventory for all emissions associated with energy imported and consumed in Maryland***

Develop a protocol for preparing the statewide emission and sink inventory

Develop a consistent and complete forecast of future GHG emissions
- ***5 and 10 year increments extending at least 20 years in the future***
- ***Include projected growth***

Develop a standardized protocol for periodic forecasting of statewide GHG emissions

Refine the inventory for manufacturers - This is particularly important if an expanded cap-and-trade program is considered.

Implementation:

MDE has already begun to implement this recommendation. For those elements of this policy that cannot be implemented immediately, MDE, with assistance from DNR, MEA, PSC, MDOT and MDA, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. This policy speaks to the necessity for Maryland to establish the necessary framework to implement an accurate and accountable climate change program. It is more of a measure that is required as part of an overarching climate change and GHG reduction plan and program. Provided there is adequate staffing, this policy could be implemented immediately and would be necessary to meet the overall goals of the Commission. This policy would require constant attention so the staffing needs would be permanent but necessary for the implementation of the entire ***Climate Action Plan.***

GHG Reporting and Registry (CC-2)

This policy option focuses on reporting GHGs and establishing a GHG registry. GHG reporting, including measuring GHG emissions in order to support the management of emissions, would, among other benefits, help sources reduce their emissions, prepare for possible GHG reduction mandates, and support the construction of GHG inventories. A GHG registry would enable the recording of GHG emissions reductions in a central repository, and could provide a mechanism for regional and cross-border cooperation and a foundation for trading programs.

Led by MDE, the State government would oversee a common GHG emissions reporting system including building the GHG emission reduction requirements into air permits, developing protocols for reporting, and allowing for calculation of GHG emissions where MDE determined that was appropriate. MDE and participants benefiting from the registry would share the costs of developing and managing the system. The system would:

- Provide an accurate, complete, consistent, transparent, and verified set of GHG emissions data from reporting entities;
- Report emissions annually for all six traditional GHGs, and, to the extent possible, for black carbon;
- Require reporting of direct emissions and phase in power- and heat-related emissions;
- Maximize consistency with other GHG reporting programs;
- Allow flexibility as GHG mitigation approaches evolve; and
- Provide guidance to assist participants.

Policy Goal:
Implement a GHG registry for Maryland sources as soon as possible.

Implementation:
Much of this strategy is already being implemented as MDE has joined the effort to develop a national GHG registry by joining The Climate Registry. For those elements of this policy that cannot be implemented immediately, MDE will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. This policy speaks to the necessity for Maryland to establish the necessary framework to implement an accurate and accountable climate change program. It is more of a measure that is required as part of an overarching climate change and GHG reduction plan and program. Provided there is adequate staffing, this policy could be implemented immediately and would be necessary to meet the overall goals of the Commission. This policy would require constant attention so the staffing needs would be permanent but necessary for the implementation of the entire ***Climate Action Plan***.

Statewide GHG Reduction Goals and Targets (CC-3)

Governor O'Malley's Commission on Climate Change concluded in the Interim Report that it is necessary to adopt science-based goals for reducing Maryland's GHG emissions. Reductions occurring earlier in time have more mitigation value than reductions later in time. Reductions in the 25 per cent to 50 per cent range by 2020 (2006 year base) appear to be needed to avoid the IPCC's most catastrophic forecasts. Specific targets for reduction by 2012/1015 are essential to provide a framework for Maryland's reduction efforts.

The goals should be adopted as part of the ***Climate Action Plan***. A report should be issued to the public periodically, beginning in 2010, to summarize Maryland's programs and progress in meeting target goals.

Policy Goals:
10 per cent GHG emission reductions below 2006 levels by 2012 (consumption based)
15 per cent GHG emission reductions below 2006 levels by 2015
25-50 per cent GHG emission reductions below 2006 levels by 2020
- ***25 per cent goal to be enforceable, a regulatory driver***
- ***50 per cent goal to be science-based, non-regulatory reduction goal with programs to reward market-based reductions above 25 per cent***

90 per cent GHG emission reductions below 2006 levels by 2050 (science-based regulatory goal to drive research and development of climate neutral technology/ programs/innovations)
Science-based review of goals every four years starting in 2012
Include progress from 1990 levels

Implementation:
The Commission has already adopted goals and has developed this *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy* to meet these goals. There may be a need to adopt regulations, an executive order or legislation to formalize these goals. MDE will be setting up a stakeholder group to discuss this process. To the extent legislation is desired, the Commission will be discussing new legislation at its meeting in the Fall of 2008.

State and Local Governmental GHG Emissions (Lead-by-Example) (CC-4)

This policy option would promote energy efficiencies and GHG reductions that can be achieved through State and local governmental procurement and purchasing processes. Taken together with policy option RCI-4, "Government Lead-by-Example", which promotes energy efficiency standards in new State-funded and other government buildings, facilities, and operations, these measures would result in significant reductions of GHG emissions by governmental entities. Additionally, and perhaps of a greater benefit, the example set by government would stimulate public and private organizations to adopt similar practices. The massive purchasing power of government to select efficient goods from companies that practice energy reduction and sequestration of carbon dioxide would also be a powerful market stimulant for green businesses and jobs.

This policy would require all agencies of State government to commit to a series of steps to reduce their carbon footprint and to encourage local governments and private business to do likewise. It would be initiated by executive order of the Governor. State and local governments would promote:

- Establishment of clear standards for government in the purchase of goods from firms that practice energy use reduction and conservation of resources.
- Evaluation of GHG emission reduction along the entire supply chain to increase the efficiency of operations throughout purchasing and end-of-life disposal.
- Establishment of policies for purchasing only energy efficient products and services by specifying ENERGY STAR certified or similar equipment and appliances for State/municipal consideration.
- Encouragement of business/private sector acceptance to follow government's lead by outreach/ education programs demonstrating the savings in resources, costs and improvement of health benefits.

Policy Goals:

Together with the efficiency measures recommended in RCI-4 and other strategies in this Climate Action Plan, reduce the carbon footprint of government and increase efficient use of resources.

Lessen public interest in consumption and promote use of materials that favor conservation and that are compostable, recyclable and reusable.

Encourage State and local government agencies and by extension private industry to consider at the purchase stage, the end-of-life disposal stage of equipment and goods.

Implement procedures for State-owned or leased facilities life-cycle costing in the selection and building designs for both new and renovated space.

Implementation:

Most State and local agencies are already implementing programs that are consistent with the goals of this policy option. For those elements of this policy that cannot be implemented immediately, all State agencies led by MDE will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. This policy would likely require significant State action, which could be championed by an effort led by MDE. An implementation team, led by MDE using possibly the Commission as its base would need to meet and agree on what State actions could be taken and by what means (regulation, legislation, executive order). This team would likely need to meet for approximately one year to develop its timeline/ schedule/ implementation plan and it would likely take 3-5 years to fully implement all the selected measures.

DNR LEADS BY EXAMPLE

The Maryland Department of Natural Resources (DNR) has initiated a forest carbon sequestration demonstration project to reduce emissions and offset a portion of DNR's carbon footprint. This project is a key recommendation set forth by ARWG in the Interim Report.

DNR has begun to conduct a carbon footprint analysis for all of the Department's lands, facilities, and managerial practices. A robust methodology is being developed and will be third-party certified to ensure that the final results are valid. The results of the project will provide a baseline that DNR can use to set GHG emission reduction benchmarks and determine what carbon sequestration demonstration projects should be implemented. Components of DNR's carbon footprint project include:

- Assess the agency's direct and indirect emissions, including but not limited to electricity use, heating and cooling, and transportation fleet.
- Develop methodology, borrowing from GHG protocols recommended by inventory experts.
- Publish results and detailed methodology in a final report.
- Create a tool and manual to streamline the carbon footprint analysis for other agencies.

The ARWG has identified the need for carbon sequestration through a variety of land use management practices including agriculture, wetlands and forestry. It is in the best interest of DNR to demonstrate innovative carbon techniques and programs. The components of the carbon sequestration demonstration program include:

- Identify potential funding sources and partners for the demonstration project
- Identify an afforestation site and determine the most appropriate forest management practices for capturing the carbon
- Ensure that the proposed sequestration project is real, quantifiable, permanent, monitored and additional to what would have happened but for the action taken
- Evaluate and select appropriate industry standards and registration protocols for both voluntary offsets and/or market-driven carbon credit sales to provide for future alternative options down the road

Demonstrate how long-term carbon sequestration can be achieved by using long-term forest rotations and executing product use agreements with building and furniture industries.

Public Education and Outreach (CC-5)

State-sponsored public education and outreach combined with community actions, economic incentives and disincentives provided by other State climate change policies, form the foundation for behavioral and life style changes necessary to reduce GHG emissions. This policy is designed to encourage continuation of existing efforts and to promote new actions.

The State would build upon current educational efforts and action campaigns of State agencies such as MDE, DNR, the Maryland State Department of Education (MSDE), and University System of Maryland, utilities (BGE, SMECO), non-profit organizations, faith communities, and others. The combination of efforts would insure that scientifically based factual information is made available through public education and outreach efforts and reaches all segments of the public.

Policy Goals:

Educate and coordinate legislature and agencies on climate change, conservation, and energy efficiency for government facilities, operations, and transportation.

Develop Maryland-specific lessons on climate change, energy conservation, and energy efficiency aligned with the Voluntary State Curriculum and Core Learning Goals, and integrate into K-12 curriculum.

Implement the Governor's Regional Environmental Education Network (GREEN).

Support on-going efforts by higher education institutions to include climate change as part of their overall educational and facilities-management practices.

Organize an annual one-day conference for regional public media representatives on: the state of climate change mitigation in Maryland and the level of attainment of State GHG goals; latest climate science and observations; climate change impacts on public health, regional environment, the Chesapeake Bay, and the economy; and applications of climate-friendly technologies.

Collaborate with county departments of environment and utilities to educate and stimulate commercial organizations and homeowners to adopt climate friendly measures and promote climate friendly products.

Develop/distribute guidelines to encourage farmers and forestry operators to practice climate friendly measures. Develop a website to host voluntary experts to answer climate-related questions from this target audience.

Implementation:

Many of the agencies listed above are already implementing programs that are consisent with the goals of this policy option. For those elements of this policy that cannot be implemented immediately, MDE, with assistance from MSDE, DNR, MEA, the University System of Maryland (USM), and the Commission's Outreach/Education work group, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. This policy speaks to the necessity for Maryland to establish the necessary framework to implement an accurate and accountable climate change program. It is more of a measure that is required as part of an overarching climate change and GHG reduction plan and program. Provided there is adequate staffing, this policy could be implemented immediately and would be necessary to meet the overall goals of the Commission. This policy would require constant attention so the staffing needs would be permanent but necessary for the implementation of the entire ***Climate Action Plan.***

Review Institutional Capacity to Address Climate Change Issues Including Seeking Funding for Implementation of Climate Action Panel Recommendations (CC-7)

Addressing climate change will be a long-term project for the State and will cross into all sectors of State government. This policy option would call for the State to develop the governance, organizational capacity and funding to execute GHG mitigation and adaptation policies, implement programs, monitor and analyze results, and modify and update policies and programs over time.

The Governor's Office, General Assembly, MDE, and other executive departments and agencies would be involved in implementing this policy, which would require engagement at the highest levels of the Executive Branch. Essential elements include:

- Assignment of a member of the Governor's staff as liaison for GHG policies, a sub-cabinet committee to coordinate GHG programs across the government, and a department assigned as lead agency for implementing key GHG mitigation programs and acting as a coordinating point for GHG programs in other departments.
- Assignment of responsibility to all departments to consider GHG consequences when making decisions about departmental policies, programs, and activities.
- Full funding for the lead agency and all departments to carry out GHG responsibilities.
- Innovative State funding mechanisms to stimulate investment in cost-effective climate change solutions.
- Creation of institutional capacity and R&D efforts that remain in place to carry through to achievement of the 2050 goals

Policy Goal:

Establish organizational, staffing and funding capacity in the State government in 2008-2009 to oversee and carry out comprehensive GHG mitigation and adaptation programs and activities.

Implementation:

For those elements of this policy that cannot be implemented immediately, MDE will work with other State agencies to develop a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. One of the most significant policy decisions that the Commission considered dealt with the need to ensure Maryland has the institutional capacity to manage and implement an aggressive climate change program. Led by MDE, this policy option will require all the member agencies of the Commission to consider the staffing resources and physical structure needed to implement the ***Climate Action Plan***. Implementation will need to be further discussed by the Commission and likely will require at least 6 months to one year of review and discussion before a formal implementation plan for the Governor is available. In Chapter 7, "Legislative Update and Next Steps", the Commission makes specific recommendations for the first steps toward building institutional capacity.

Participate in Regional, Multi-State and National GHG Reduction Efforts (CC-8)

This policy option focuses on establishing and expanding regional approaches for controlling GHG emissions. Regional approaches such as RGGI can offer broader and more efficient means of controlling GHG emissions than in-state approaches alone. In addition, global warming is a problem requiring national and international action, and Maryland needs to help shape the national initiatives. This policy option calls for the Governor and the General Assembly to push for federal action to reduce GHGs.

This policy is already being implemented. Under this policy, Maryland would continue to develop aggressive GHG reduction programs and thus lead by example. Maryland should encourage regional programs, like RGGI, as well. Maryland's leadership should also work with Congress and the federal government to significantly reduce GHG emissions nationally and internationally. This effort, to lead by example while pushing for a strong federal and international effort, is absolutely critical.

Policy Goal:
Influence the national and international debate over reducing GHGs.

In Chapter 6 of this ***Plan***, "Building a Federal-State Partnership", the Commission makes specific recommendations for a federal regulatory program that would work in partnership with climate programs developed by Maryland and other leadership states.

RGGI States

Promote Economic Development Opportunities Associated with Reducing GHG Emissions in Maryland (CC-9)

This policy option focuses on promoting the economic and business opportunities associated with climate protection and growing Maryland businesses while achieving state-wide GHG reduction goals. The State would work with public and private entities to promote "green industry" by promoting the consumption of local goods and services and providing job opportunities related to green building, energy efficiency, public transportation, renewable energy sources, and research and development of new practices and technologies. The Maryland Clean Energy Center and Technology Incubator Program, created by the General Assembly in its 2008 Session (HB 1337), will provide significant support for this policy by promoting the development of clean energy industries and jobs in Maryland.

Maryland Department of Business and Economic Development (DBED) would:

- Establish a work group to identify and promote green industry opportunities, markets, and financing mechanisms.
- Work with labor unions and technical schools to promote green collar job training
- Identify new financing mechanisms to stimulate and incubate green business development
- Promote in-state R&D and establishment of green industries.

Policy Goals:

Implement task force recommendations and deliver training programs, financing mechanisms and loans to stimulate targeted businesses in 2009 and 2010

Create 2,500 new jobs in Maryland tied to green industry and energy efficiency by 2012

Implementation:

For those elements of this policy that cannot be implemented immediately, DBED, with assistance from MEA, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting.

Create Capacity to Address Climate Change in an After Peak Oil" Context (CC-10)

Oil will become expensive after the "peak" of oil production. The increased cost per barrel will lead to higher environmental risks and health costs of extracting oil from non-traditional sources and burning a higher per centage of coal. Under this policy option, Maryland would take a strategically proactive stance by establishing an "After Peak Oil" work group of experts and stakeholders under the umbrella of the Commission to review and evaluate all proposed climate change and energy-related policies and legislation for appropriateness and sensibility in the context of shrinking supplies of affordable oil.

A work group to analyze this issue would be established in 2008.

Policy Goal: By 2010, the work group would develop operating protocols and commence reviewing and evaluating proposed climate change and energy-related policies and legislation, and its recommendations would be considered and concerns addressed before the proposed measures move forward.

Implementation:

MEA, with assistance from MDE, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting.

Evaluate Climate Change Policy Options to Determine Projected Public Health Risks/ Costs/ Benefits (CC-11)

Both the potential health risks from climate change and the health benefits of certain mitigation and adaptation strategies are significant. Under this policy option, a State Climate Change Environmental Health and Protection Work Group would be established under the umbrella of the Commission to systematically review the health risks, costs, and benefits of all proposed climate change and energy-related policies and legislation before they move forward. Careful attention would be given to impacts of policies on vulnerable populations in Maryland.

The Governor would appoint a core group of Work Group members representing major stakeholders, content experts and others. The State would recruit additional Work Group members through a non-political process. Parties involved would include all State agencies led by DHMH, energy producers, consumers, environmentalists, and health professionals.

Policy Goal:

By 2010, the work group would commence reviewing and evaluating all proposed climate change and energy-related policies and legislation, and its recommendations would be considered and concerns addressed before the proposed measures move forward.

Implementation:

For those elements of this policy that cannot be implemented immediately, DHMH, with assistance from MDE, DNR and other State agencies, will be developing a more detailed implementation plan for the Commission to consider in its Spring 2009 meeting. Because this policy has significant cross-over with some of the recommendations of the Commission's Adaptation and Response Working Group (ARWG), the plan will focus on both the mitigation and adaptation policy goals. This policy speaks to the necessity for Maryland to establish the necessary framework to implement an accurate and accountable climate change program. It is more of a measure that is required as part of an overarching GHG reduction and climate change adaptation plan and program. Provided there is adequate staffing, this policy could be implemented immediately and would be necessary to meet the overall goals of the Commission. This policy would require constant attention so the staffing needs would be permanent but necessary for the implementation of the entire ***Climate Action Plan***.

Option No.	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008 - 2020 (Million $)	Cost Effectiveness ($\$/tCO_2e$)
		2012	2020	Total 2008 - 2020		
CC -1	GHG Inventories and Forecasting	Not Quantified				
CC-2	GHG Reporting and Registry	Not Quantified				
CC-3	Statewide GHG Reduction Goals and Targets	Not Quantified				
CC-4	State and Local Government GHG Emissions (Lead by Example)	Not Quantified				
CC-5	Public Education and Outreach	Not Quantified				
CC-6	Tax and Cap Policies	Not Quantified				
CC-7	Review Institutional Capacity	Not Quantified				
CC-8	Participate in Regional, Multi-State, and National Efforts	Not Quantified				
CC-9	Promote Economic Development Opportunities	Not Quantified				
CC-10	Create Capacity for "After Peak Oil"	Not Quantified				
CC-11	Evaluate Policy Options to Determine Public Health Risks	Not Quantified				

CONCLUSION

The Commission's forty-two recommended GHG mitigation strategies have evolved in the course of a rigorous, comprehensive, ten-month long stakeholder process which drew upon the expertise and commitment of MWG and TWG participants representing broad and diverse interests. While the work of these dedicated individuals is complete, the actual work of implementing the ***Climate Action Plan*** and getting Maryland on a sustainable trajectory to the 2020 and 2050 reduction goals just begins now, building on early initiatives such as RGGI, the Clean Cars and ***EmPOWER Maryland*** programs, and Maryland's RPS. For those engaged in moving this work forward – ultimately all Maryland citizens – the Commission leaves these three take-away messages:

- **Early actions are key.**
- **Shrinking Maryland's GHG footprint will grow Maryland's economy.**
- **What we do in Maryland matters in Maryland, for us, our children, and theirs.**

Deep Creek Rainbow
Photo by Margie Wise

CHAPTER FIVE

Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change

Phase I: Sea-level rise and coastal storms




REPORT OF THE MARYLAND COMMISSION ON CLIMATE CHANGE
ADAPTATION AND RESPONSE WORKING GROUP

ADAPTATION AND RESPONSE WORKING GROUP

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Co-Chair: Don Halligan (Asst. Secretary), Maryland Department of Planning)
Working Group Coordinator: Zoë Johnson (Maryland Department of Natural Resources)

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MARYLAND DEPARTMENT OF NATURAL RESOURCES

Integration & Application Network

Science communication by Jane Thomas, Integration and Application Network, University of Maryland Center for Environmental Science.

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CHAPTER FIVE

Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change

REPORT OF THE MARYLAND COMMISSION ON CLIMATE CHANGE
ADAPTATION AND RESPONSE WORKING GROUP

JULY 2008

Maryland Department of Natural Resources

MDE

MDP Maryland Department of Planning

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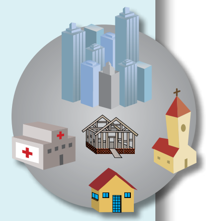
Jane Hawkey.

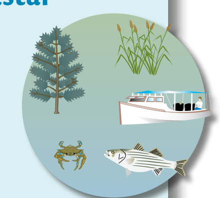
KEY RECOMMENDATIONS



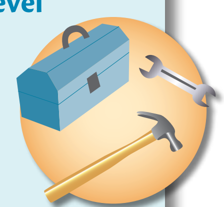
- **Take action now to protect human habitat and infrastructure from future risks.**
  Require the integration of coastal erosion, coastal storm, and sea-level rise adaptation and response planning strategies into existing state and local policies and programs. ***Develop*** and ***implement*** state and local adaptation policies (i.e., protect, retreat, abandon) for vulnerable public and private sector infrastructure. ***Strengthen*** building codes and construction techniques for new infrastructure and buildings in vulnerable coastal areas.

- **Minimize risks and shift to sustainable economies and investments.**
  Develop and ***implement*** long-range plans to minimize the economic impacts of sea-level rise to natural resource-based industries. ***Establish*** an independent Blue Ribbon Advisory Committee to advise the state of the risks that climate change poses to the availability and affordability of insurance. ***Develop*** a *Maryland Sea-Level Rise Disclosure and Advisory Statement* to inform prospective coastal property purchasers of the potential impacts that climate change and sea-level rise may pose to a particular piece of property. ***Recruit, foster,*** and ***promote*** market opportunities related to climate change adaptation and response.

- **Guarantee the safety and well-being of Maryland's citizens in times of foreseen and unforeseen risk .**
  Strengthen coordination and management across agencies responsible for human health and safety. ***Conduct*** health impact assessments to evaluate the public health consequences of climate change and projects and/or policies related to sea-level rise. ***Develop*** a coordinated plan to assure adequacy of vector-borne surveillance and control programs.



- **Retain and expand forests, wetlands, and beaches to protect us from coastal flooding.**
  Identify high priority protection areas and strategically and cost-effectively direct protection and restoration actions. ***Develop*** and ***implement*** a package of appropriate regulations, financial incentives, and educational, outreach, and enforcement approaches to retain and expand forests and wetlands in areas suitable for long-term survival. ***Promote*** and ***support*** sustainable shoreline and buffer area management practices.



- **Give state and local governments the right tools to anticipate and plan for sea-level rise and climate change.**
  Strengthen federal, state, local, and regional observation systems to improve the detection of biological, physical, and chemical responses to climate change and sea-level rise. ***Update*** and ***maintain*** state-wide sea-level rise mapping, modeling, and monitoring products. ***Utilize*** new and existing educational, outreach, training and capacity building programs to disseminate information and resources related to climate change and sea-level rise.

- **State and local governments must commit resources and time to assure progress.**
  Develop state-wide sea-level rise planning guidance to advise adaptation and response planning at the local level. ***Develop*** and ***implement*** a system of performance measures to track Maryland's success at reducing its vulnerability to climate change and sea-level rise. ***Pursue*** the development of adaptation strategies to reduce climate change vulnerability among affected sectors, including agriculture, forestry, water resources, aquatic and terrestrial ecosystems, and human health.

VISION FOR THE FUTURE

Climate change, sea-level rise, and associated coastal storms are putting Maryland's people, property, natural resources, and public investments at risk. To protect Maryland's future economic well-being, environmental heritage, and public safety, and to guide the fundamental intent of the Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change, the Adaptation and Response Working Group recommends that legislative and policy actions be instituted by the Governor and the Maryland General Assembly to:

- ***Promote*** programs and policies aimed at the avoidance and/or reduction of impact to the existing-built environment, as well as to future growth and development in vulnerable coastal areas.
- ***Shift*** to sustainable economies and investments and ***avoid*** assumption of the financial risk of development and redevelopment in highly hazardous coastal areas.
- ***Enhance*** preparedness and planning efforts to protect human health, safety, and welfare.
- ***Protect*** and ***restore*** Maryland's natural shoreline and its resources, including its tidal wetlands and marshes, vegetated buffers, and Bay islands, that inherently shield Maryland's shoreline and interior.

INTRODUCTION

We must take action now to plan for the impacts of climate change

Climate change is among the most daunting environmental problems faced by the world today. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) shows that no country or region of the world will be unaffected, and in many countries the consequences for human activities will be profound.[1] The IPCC defines *adaptive capacity* as the ability of a system to adjust to climate change, including climate variability and extremes, to reduce potential damages, take advantage of opportunities, and cope with the consequences.[2] The prospect of long-term climate change is now leading decision-makers to do some hard thinking about how this process of adaptation can fit within and serve the broad goals of sustainable development in a country, region, or state.

Adaptation and response planning is crucial to Maryland's ability to achieve sustainability. A 'do-nothing' approach will lead to unwise decisions and increased risk over time. Planners and legislators must realize that the implementation of measures to mitigate climate change and sea-level rise impacts associated with erosion, flooding, and inundation of low-lying lands is imperative to sustainable management, as well as protection of Maryland's coastal resources and communities.

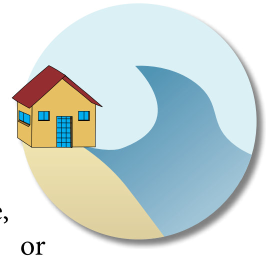
The Adaptation and Response Working Group (ARWG) of the Maryland Commission on Climate Change (MCCC) was charged with developing the *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change*. The Executive Order calls for the Strategy to outline specific policy recommendations for reducing the vulnerability of the state's natural and cultural resources and communities to the impacts of climate change, with an initial focus on sea-level rise and coastal hazards, including shore erosion and coastal flooding.

Adaptation and response planning is crucial to Maryland's ability to achieve sustainability

This report lays out the specific priority policy recommendations of the ARWG to address short-and long-term adaptation and response measures, planning and policy integration, education and outreach, performance measurement, and, where necessary, new legislation and/or modifications to existing laws. For the purposes of this report, the priority policy recommendations have been condensed and a select number of implementation targets identified. Full versions of the priority policy recommendations, which include a detailed discussion of implementation mechanisms, related policies and programs in place, qualitative benefits, and cost assessments and feasibility issues, are contained in Appendix E.

MARYLAND'S VULNERABILITY TO SEA-LEVEL RISE AND COASTAL STORMS

Maryland's people, property, natural resources, and public investments are at risk



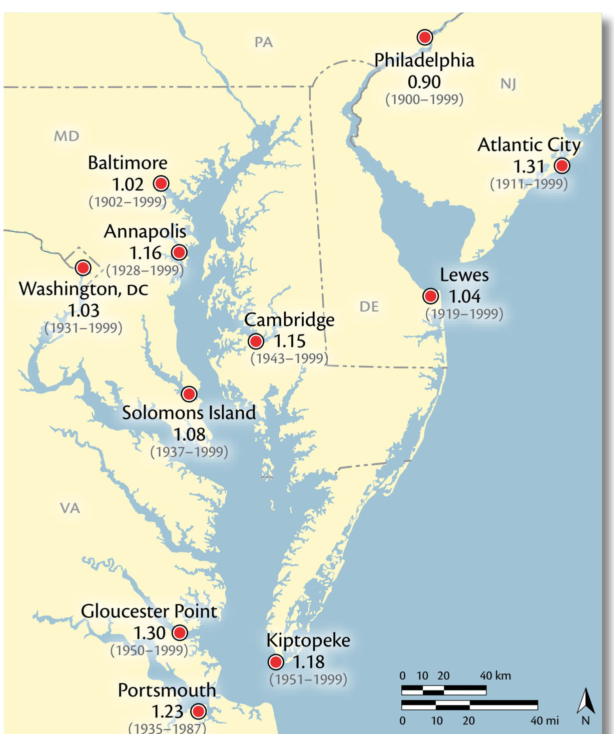
The IPCC defines *vulnerability* as the degree to which a system is susceptible to or unable to cope with adverse effects of climate change, including climate variability or extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.[2] With over 3,000 miles of coastline, Maryland is poised in a very precarious position when it comes to the impacts of climate change. Maryland's coast is particularly vulnerable to both episodic storm events, such as hurricanes and nor'easters, and chronic hazards associated with shore erosion, coastal flooding, storm surge, and inundation. These coastal hazards are both driven and exacerbated by climate change and sea-level rise.

> Maryland is poised in a very precarious position when it comes to the impacts of climate change
> —Governor Martin J. O'Malley

Rising sea levels over the last 20,000 years formed the Chesapeake Bay that we know today. While the rapid rate of sea-level rise that occurred over the past 5,000 years has slowed, historic tide-gauge records show that levels are still rising and have increased by one foot within Maryland's coastal waters in the last 100 years (Figure 1). Such a rate of rise is nearly twice that of the global average over the same time period. Maryland is experiencing more of a rise in sea level than other parts of the world, due to naturally occurring regional land subsidence (Figure 2).

Measurement of sea level at any particular location is *relative*. Relative sea-level rise is the sum of global (eustatic) sea level change plus changes in vertical land movement at a particular location (Figure 3). In support of this report, the MCCC Scientific and

Rates of sea-level rise (feet per century)



NOAA Tides and Currents (www.tidesandcurrents.noaa.gov).

Figure 1. Rates of sea-level rise in Chesapeake and Delaware Bays region. Data are from tide gauges and the period of time they cover is in parentheses.

Land subsidence (feet per century)

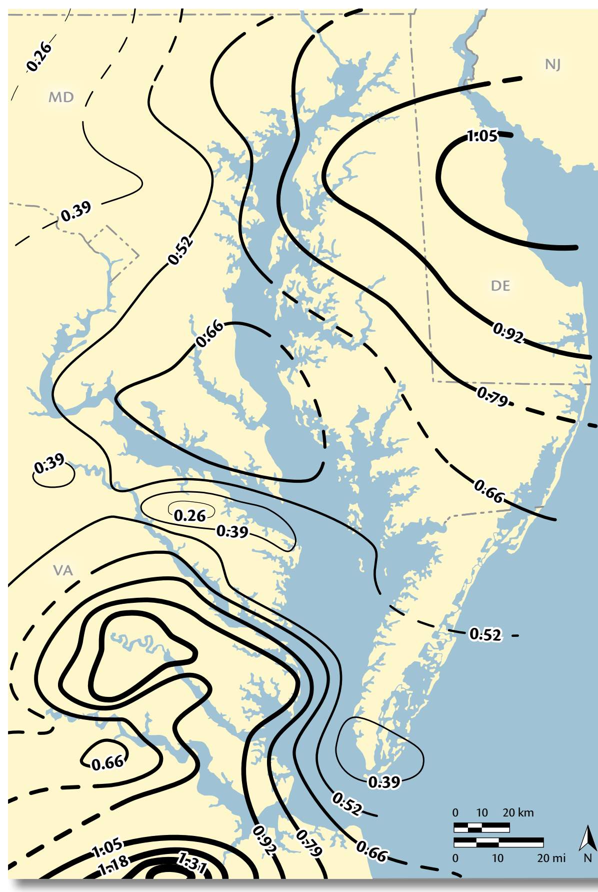


Figure 2. Rates of land subsidence in the Chesapeake Bay region.[4] Subsidence in this region is mostly a result of postglacial rebound or readjustment (sinking) of land elevations since the retreat of the glaciers at the end of the last ice age. Lines are dashed where values are inferred.

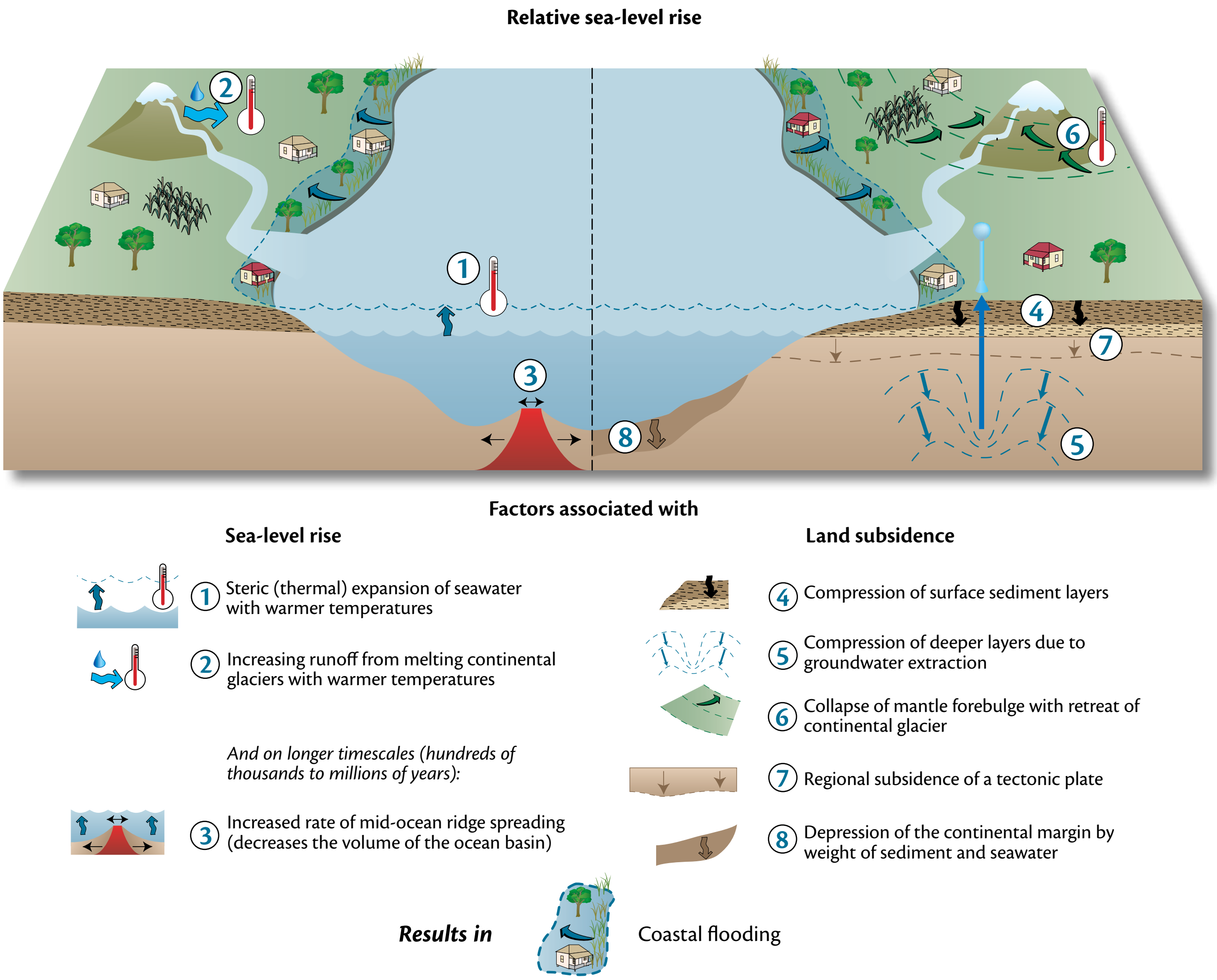


Figure 3. Relative sea-level rise is a result of a combination of factors. Sea-level rise is the combination of the increase in volume of water as a result of global warming and decrease in size of the ocean basins due to mid-ocean ridge spreading. Land subsidence is a consequence of various factors which result in the land surface sinking, reducing elevation. Sea-level rise and land subsidence combine to result in relative sea-level rise.

Technical Working Group (STWG) assessed the 2007 IPCC global sea-level rise projections, along with regional land subsidence variables, and provided a conservative estimate that by the end of this century, Maryland may experience a relative sea-level rise of 2.7 feet under a lower-emission scenario, and as much as 3.4 feet under the higher-emission scenario (Figure 4).

Due to its geography and geology, the Chesapeake Bay region is considered the third most vulnerable to sea-level rise, behind Louisiana and southern Florida. See Figure 5 for a graphical illustration of low-lying land areas in Maryland that may likely be subject to sea-level rise inundation and coastal flooding over the next 100 years. In fact, sea-level rise impacts are already being detected all along Maryland's coast.

Shore erosion. Erosion is a significant problem currently facing Maryland's diverse coastal

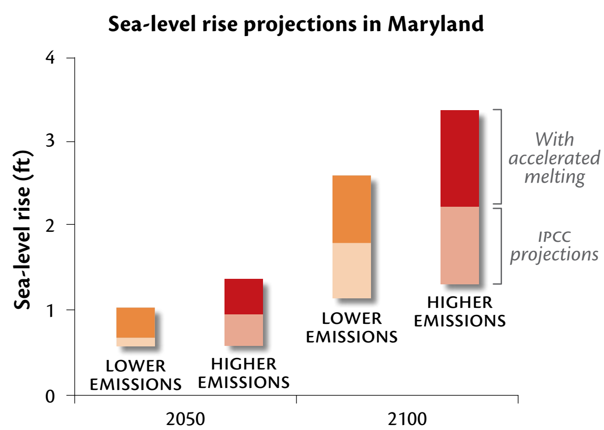


Figure 4. When including coastal Maryland subsidence rates, relative sea-level rise as little as 0.6 ft (probably unlikely because this is scarcely above the 20th century rate) to much as 1–1.3 ft could be experienced along Maryland's coast by the middle of the century. By the end of the century, accelerated melting could produce a relative sea-level rise of 2.7 ft under the lower emissions scenario to 3.4 ft under the higher emissions scenario.[5,6,7,8]

environment. Approximately 31% of Maryland's coastline is currently experiencing some degree of erosion, with some areas losing as much as 8 ft of upland per year. State-wide, approximately 580 acres of land is lost per year due to shore erosion processes. Sea-level rise is a causal force which influences the on-going coastal processes that drive erosion, in turn making coastal areas ever more vulnerable to both chronic erosion and episodic storm events.

Coastal flooding. As demonstrated by Tropical Storm Isabel in 2003, Maryland's coast is extremely vulnerable to coastal flood events. Sea-level rise increases the height of storm waves, enabling them to extend further inland. In low-lying coastal areas, a one-foot rise in sea level translates into a one-foot rise in flood level, intensifying the impact of coastal flood waters and storm surge. The risk of damage to properties and infrastructure all along Chesapeake Bay and the Atlantic coast will be heightened as sea level continues to rise.

Inundation. For many coastal areas, slope is the primary variable controlling the magnitude and range of sea-level rise impact over time (Figure 6). In areas such as Maryland's Eastern Shore where elevation change may only be as much as one foot per mile, gradual submergence of a large geographic area, including large expanses of tidal wetlands,

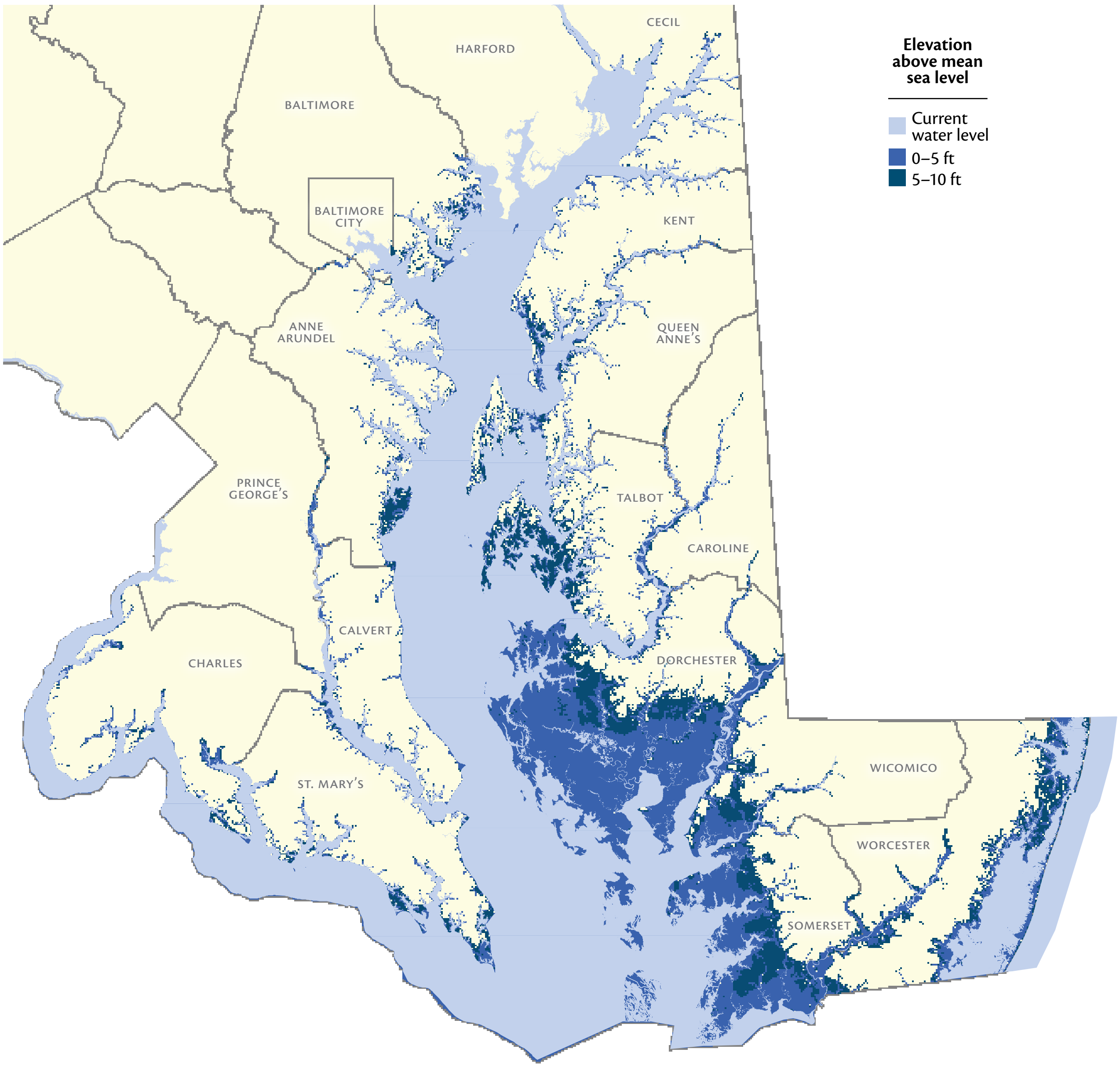


Figure 5. Sea-level rise vulnerability in the coastal areas of Maryland, calculated using LIDAR elevation data. Note: LIDAR elevation data were not available for Baltimore City, Harford County, and Prince George's County. Therefore, vulnerability data do not exist for those areas and cannot be shown on this map.

is quite likely over time. Land inundation due to sea-level rise is already occurring along low-lying coastal areas in Dorchester and Somerset Counties.

Impacts to barrier and bay islands. Barrier islands are highly dynamic coastal landforms, under constant pressure from the driving forces of waves, wind, ocean currents, and storm surge. These forces, coupled with rising sea levels, act to continually reshape barrier islands, as well as to advance landward migration of the island itself (Figure 7). Fenwick and Assateague Islands form the barrier between Maryland's mainland and the Atlantic Ocean. Extensive development in Ocean City, located on Fenwick Island, restricts the natural process of barrier island migration and in turn puts billions of dollars of public and private infrastructure at risk. Islands, such as James Island in Chesapeake Bay (Figure 8), are also extremely vulnerable to sea-level rise. Thirteen charted Chesapeake Bay islands have completely disappeared beneath the water's surface.[3]

Higher water tables and salt water intrusion. As sea level rises, the groundwater table, in general, will also rise and salt-water will begin to intrude into fresh water aquifers. Evidence of these gradual processes has already started to appear along Maryland's Eastern Shore. Analysis of aerial photography taken over the last 50 years confirms that large expanses of upland areas in Dorchester County are being converted to nontidal wetlands and, as the mean high tide has begun to encroach further inland, these freshwater wetlands are becoming infiltrated with saline water. Over time, these impacts will grow to be ever more

Flooding vs. inundation

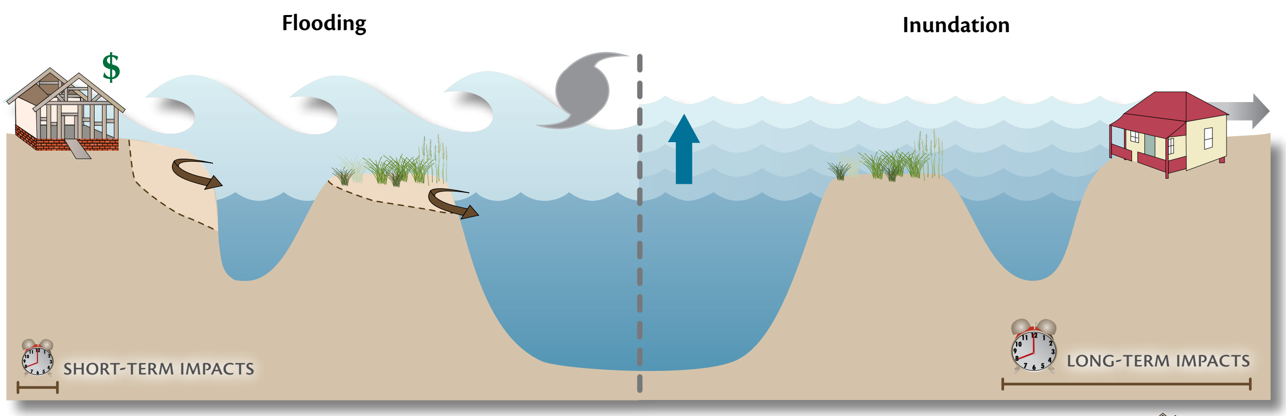


Figure 6. Flooding from stronger and more frequent storms results in erosion and expensive property damage $. Inundation from sea-level rise , which occurs over a long period of time, includes land loss and disappearing islands . Inundation threatens buildings in coastal areas. These buildings may need to be relocated to higher elevations .

Sea level rise and Maryland's Coastal Bays

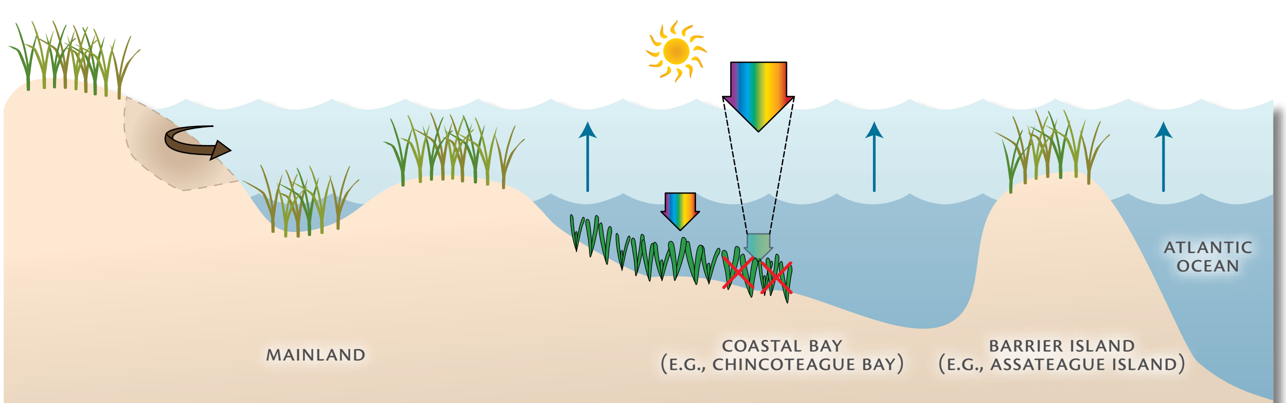
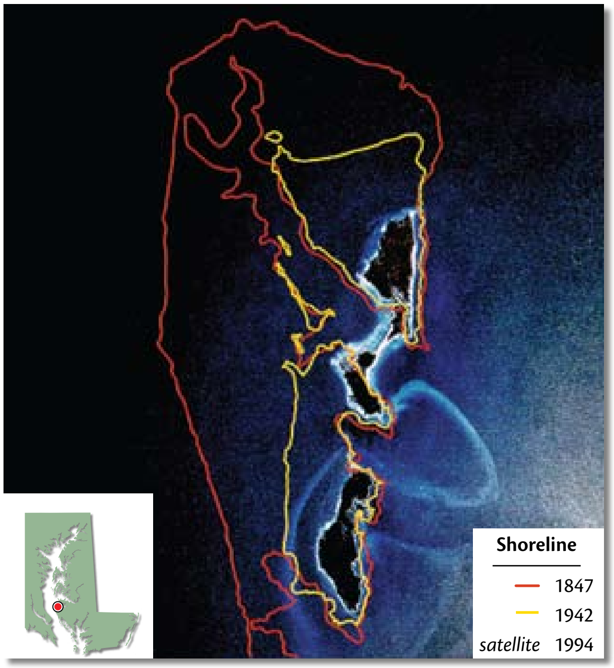


Figure 7. Sea level rise will flood coastal lagoons, which in turn drowns islands and increases coastal erosion . Increased water depth caused by sea level rise reduces the amount of light available to seagrass . The reduced light availability will cause seagrass to decline .

James Island shoreline, 1847–1994



Maryland Department of Natural Resources.

Figure 8. James Island shoreline in 1847, 1942, and 1994 (satellite image). Thirteen Chesapeake Bay islands have disappeared due to sea-level rise over the past century.[3]

problematic as fresh water drinking water supplies are diminished, septic tanks and associated drain fields begin to fail, and non salt-tolerant plants and crops start to die off in surrounding agricultural fields and forests.

Two to three feet of additional sea-level rise will result in a dramatic intensification of coastal flood events, increase shore erosion, cause the intrusion of salt-water into freshwater aquifers, and submerge thousands of acres of tidal wetlands, low-lying lands and Chesapeake Bay's last inhabited island community in Maryland—Smith Island (Figure 9). Sea-level rise poses a significant threat to resources and infrastructure in Maryland's coastal zone. As growth and development continues, especially within low-lying Eastern Shore communities, these impacts are likely to escalate. In the short-term, coastal areas already under natural and human-induced stress are most vulnerable. Of these, barrier and bay islands and the lower Eastern Shore of Chesapeake Bay are in critical need of protection. However, much larger portions of Maryland's coast will become threatened over time.[3]

Chesapeake Bay vulnerability to sea-level rise and storm surge

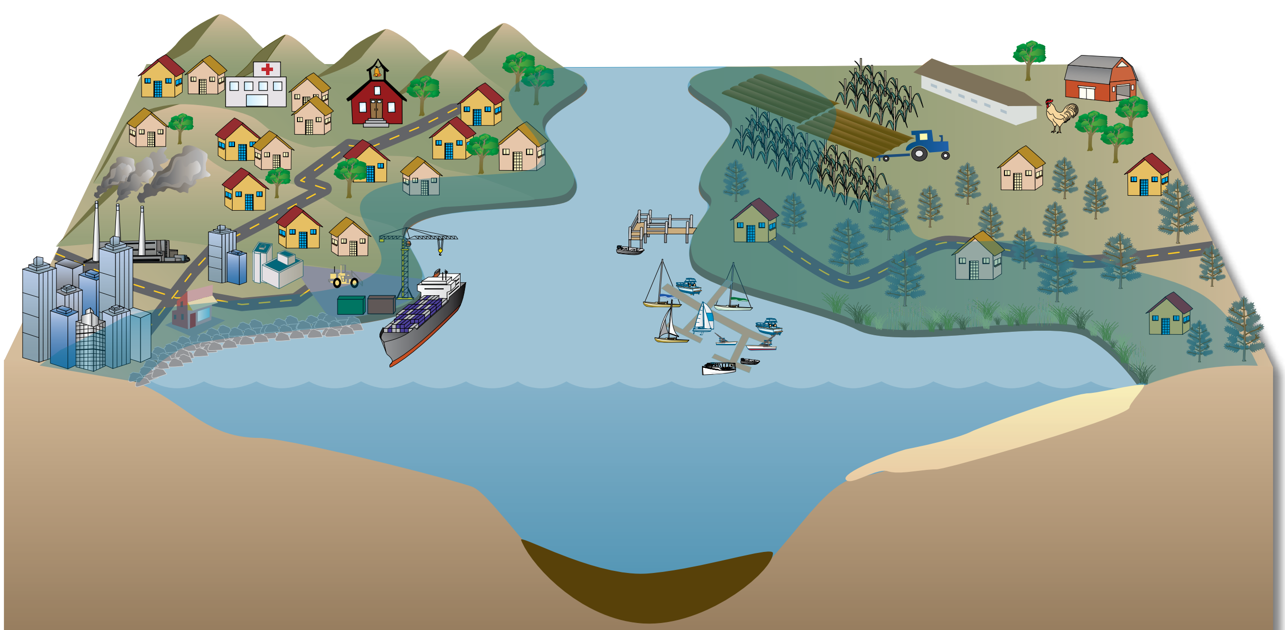


Figure 9. Chesapeake Bay is vulnerable to sea-level rise and storm surge. The western shore has a dense built environment , including industry and ports . The grade of slope affects shoreline movement, so areas with steep slopes, such as Calvert Cliffs, will have a slower rate of shoreline movement than flatter areas. The Eastern Shore's flat landscape contains low-lying roads , animal feeding and agricultural operations , marinas , marshes , and forests .

VISION/STATEMENT OF INTENT

Protect Maryland's future economic well-being, environmental heritage, and public safety

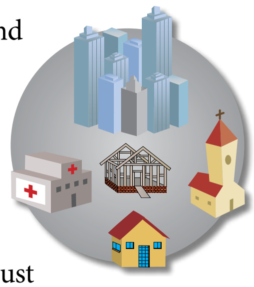
Climate change, sea-level rise, and associated coastal storms are putting Maryland's people, property, natural resources, and public investments at risk. To protect Maryland's future economic well-being, environmental heritage, and public safety, and to guide the fundamental intent of the Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change, the ARWG recommends that the Governor and the Maryland General Assembly take legislative and policy actions to:

- Promote programs and policies aimed at the avoidance and/or reduction of impact to the existing-built environment, as well as to future growth and development in vulnerable coastal areas.
- Shift to sustainable economies and investments and avoid assumption of the financial risk of development and redevelopment in highly hazardous coastal areas.
- Enhance preparedness and planning efforts to protect human health, safety, and welfare.
- Protect and restore Maryland's natural shoreline and its resources, including its tidal wetlands and marshes, vegetated buffers, and Bay islands, that inherently shield Maryland's shoreline and interior.

Smith Island—Maryland's last inhabited Chesapeake Bay island community—is vulnerable to sea-level rise. Photo by Tom Darden.

REDUCTION OF IMPACT TO EXISTING AND FUTURE GROWTH AND DEVELOPMENT

Take action now to protect human habitat and infrastructure from future risks



Leadership by state and local governments of Maryland is imperative to reduce Maryland's vulnerability to climate change, sea-level rise, and coastal storms. Maryland's state agencies and its local governments must take action now to protect human habitat and infrastructure from future risks. The state can accomplish this by taking steps to effectively *reduce* the impact to existing-built environments by requiring that public and private structures be elevated and designed to reduce damage, and to *avoid* future impact by directing new growth and development away from vulnerable coastal areas.

> Leadership by state and local governments of Maryland is imperative

Priority policy recommendations

Integrated planning: Require the integration of coastal erosion, coastal storm, and sea-level rise adaptation and response planning strategies into existing state and local policies and programs.

Planning for sea-level rise and its associated impacts is extremely complex. There is no single methodology, management strategy, or regulatory program that can be used by state or local governments to respond. Instead, efforts to reduce vulnerability can be greatly advanced by integrating sea-level rise planning into existing state and local planning, policy, and management efforts (Figure 10). This policy recommendation includes two sets of targets: (1) Integration of adaptation strategies into *local* comprehensive plans and implementing codes and ordinances; and (2) Integration of adaptation strategies into *state* plans and underlying management and regulatory programs.

Local government components

Maryland Planning Article 66B amendments. Maryland Planning Article 66B, §3.06(b) of the Annotated Code of Maryland should be amended to expand sensitive areas, and/or add a Sea-Level Rise Planning Element under county comprehensive plans and/or local hazard mitigation plans.

Integrated sea-level rise adaptation and response

Figure 10. Due to the variation, range, and magnitude of sea-level rise impacts expected to occur, there is not a single means of response, nor is there one entity that can effectively implement all adaptation planning activities. Sea-level rise adaptation and response planning is most effective if integrated into existing sector- or issue-based planning, management, and regulatory programs.

Chesapeake and Atlantic Coastal Bays Critical Area Act. Local Critical Area Program should be amended to modify current Critical Area buffer provisions to enhance sea-level rise adaptation and response. Options include: (1) expanding the distance of vegetated buffers in areas experiencing significant erosion (2+ ft per year); and/or (2) developing criteria to enable the designation of wetland migration corridors and natural shore erosion areas within Critical Area buffers.

Guidance development and selection of plan mechanisms. Planning guidance should be developed jointly by state and local governments to ensure consistency and clarity and facilitate the integration of the Sea-Level Rise Planning Element with existing comprehensive planning and zoning requirements.

Local capital planning projects. Planning efforts for new or modified capital projects, such as transportation planning, stormwater management, and infrastructure siting, should assess sea-level rise and storm surge vulnerability in the planning process.

Emergency management and mitigation plans. Effective approaches should be developed to communicate appropriate responses that protect human health during large-scale floods, storms, and storm surges. Of particular concern are communication systems and plans that address health issues associated with low-income and underserved populations and other vulnerable groups. Plans should be developed for moving critical acute and longer-term care facilities that are vulnerable to sea-level rise or coastal storm surge.

State agency components

Designation of areas of critical state concern. State Finance and Procurement Article, Title 5, Subtitle 6 establishes the authority for the Maryland Department of Planning (MDP) to define areas of critical state concern. State and local governments should work together to define the geographic limits of areas potentially impacted by sea-level rise, coastal erosion, and storm surge. Once defined, these areas should be formally designated as areas of critical state concern.

Planning and policy integration. Maryland has emerged as a national leader in sea-level rise adaptation and response planning and should continue to lead by example by integrating sea-level rise issues into state agency policy and planning and implementing sound sea-level rise adaptation measures on state lands through the allocation of state fiscal resources. Targeted activities should include the following:

- Utilize Geographic Information Systems (GIS) technology to analyze areas vulnerable to sea-level rise in combination with jurisdictional and regulatory mandates of existing management programs, including but not limited to Green Infrastructure, Smart Growth, and Resource Conservation Areas.
- Align State Smart Growth strategies, including Priority Funding Area requirements, to reflect population growth and development patterns in relation to areas vulnerable to sea-level rise and coastal hazards.
- Integrate planning for climate change and sea-level rise into the Maryland State Development Plan, currently under development.
- Direct existing land conservation programs, such as Green Infrastructure, Rural Legacy, Program Open Space, the Conservation Reserve Enhancement Program, and the Coastal and Estuarine Land Conservation Program, to consider the use of conservation easements and other land conservation initiatives as a means to protect key coastal areas vulnerable to sea-level rise and to provide sufficient lands for wetland migration.
- Evaluate state natural resource management practices and advocate the means for enhanced protection through such efforts as the promotion of 'living shorelines', tidal marsh restoration, increased vegetative buffers, bay island restoration, and land conservation.

State capital planning projects. Establish a directive and means to review all state-funded projects to determine the cost-effectiveness of minor alterations in the setback and/or design standards based on life expectancy of proposed structures in relation to projected levels of sea-level rise. Potential changes include increasing building setbacks to accommodate a change in the shoreline position due to erosion or inundation, designing structures to accommodate more frequent storm events, such as a 25-year vs. 100-year flood, and elevating structures in tidal floodplains two or more feet above the 100-year base flood elevation.

Implementation

Local components: Implementation of several local government components will require legislative action. The lead agencies, the Department of Natural Resources (DNR) and MDP, with support from the Maryland Emergency Management Agency (MEMA) and the Maryland Department of the Environment (MDE), will begin working together immediately to assess local government capacity and identify specific state and local plans, programs, and policies where climate change and sea-level rise response planning should be integrated. Within one year, the lead agencies will prepare proposed administration legislation for the 2010 session. The lead and supporting agencies will then work together to develop planning guidance to help local governments achieve integration of a Sea-Level Rise Element into

Jane Thomas.

Waterfront properties, such as those in Ocean City and Fenwick Island, are vulnerable to sea-level rise and storm surge.

comprehensive plans. The guidance document will be part of the MDP Models & Guidelines series.

State components: Several state agencies are already undertaking efforts or implementing programs that are consistent with the goals of this policy option. MDP will be integrating relevant components related to land use and planning into the State Development Plan to be implemented by MDP, the Smart Growth Subcabinet, and all state agencies. Components of the policy recommendation that are not currently being addressed can be implemented by Executive Action.

Adaptation of vulnerable coastal infrastructure: Develop and implement state and local adaptation policies (i.e., protect, retreat, abandon) for vulnerable public and private sector infrastructure.

Maryland has thousands of miles of developed waterfront property along Chesapeake Bay, the Atlantic Coastal Bays, and the ocean coast. Much of the state's coastal areas contain public and private sector infrastructure that will be adversely impacted by sea-level rise and the intensification of coastal storm events. Locations like the City of Annapolis, Shady Side Peninsula in Anne Arundel County, and the Town of Crisfield in Somerset County have considerable amounts of infrastructure vulnerable to sea-level rise (Figure 11). The state must take action to reduce the vulnerability of Maryland's public and private sector infrastructure to impacts associated with sea-level rise and increased severity of coastal storm events. There is a clear need to identify impacted public and private sector infrastructure, determine a feasible set of adaptation options and strategies, and formulate strategies to integrate action plans at the federal, state, and local levels.

As sea level continues to rise and storm surge intensifies, both state and local governments, as well as many other public and private property owners, are facing the very real and hard decision about how to adapt and at what expense. Decisions about how to adapt to the impacts of sea-level rise will be different for varying land uses, and must take into account the value of the land, public opinion, public safety and risk, ecosystem survival, environmental factors, and development opportunities.

Adaptation options including protection, relocation, or abandonment can all be utilized to respond to sea-level rise. Protection of vulnerable coastal infrastructure can be accomplished by use of structural bulkheads, seawalls, or revetments, which are the least desirable means. It may not be

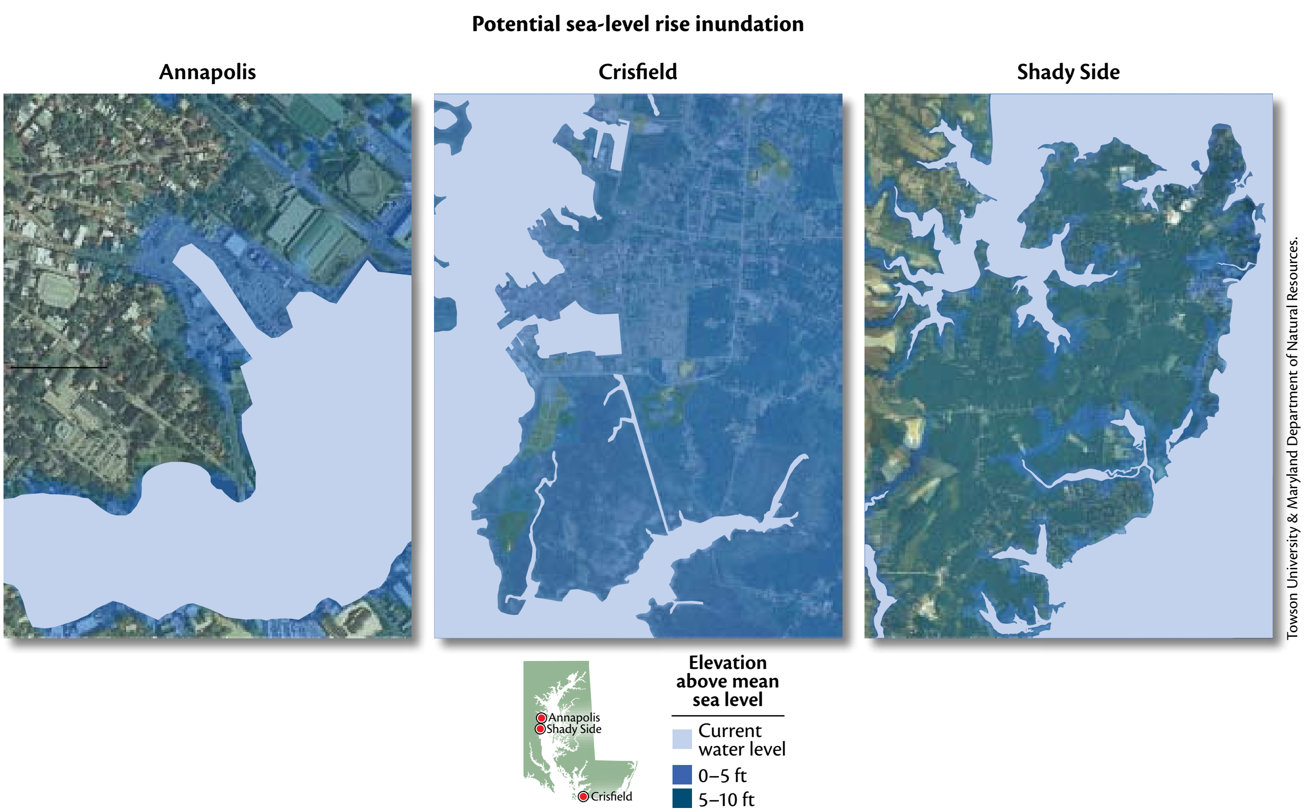


Figure 11. Areas of Annapolis, Crisfield, and Shady Side that would be inundated with various sea-level rise scenarios.

feasible or environmentally beneficial, however, to protect all vulnerable coastal infrastructure—some will undoubtedly have to be relocated or abandoned. Developing a framework for making protection, abandonment, and retreat/relocation decisions must be done in combination with other comprehensive planning and emergency management decision-making processes at both state and local levels.

Implementation

The lead state agencies, DNR and the Maryland Department of Transportation (MDOT), have already initiated efforts consistent with the goals of this policy option. Over the next one to two years, MDOT and the affected agencies will begin an assessment of Maryland's critical transportation facilities and systems' vulnerability to projected sea-level rise and extreme weather damage. That assessment will provide the information necessary to evaluate the options for dealing with potential impacts to infrastructure and connectivity. With the results of the assessment, MDOT will formulate adaptation policies for existing and planned transportation facilities and ultimately develop a long-term strategic plan for system adaptation that can account for the uncertainty of future climactic conditions.

Over the next year, DNR's Chesapeake and Coastal Program will begin identifying vulnerable sea-level rise inundation areas along Maryland's shoreline using newly acquired topographic data and will start assessing public and private sector infrastructure within these vulnerable areas. DNR will work with other state agencies, including MDP and the Maryland Historical Trust, to identify the types of infrastructure that will be included in the inventory of potentially impacted infrastructure. An update on the efforts of MDOT and DNR, along with a more detailed implementation plan, will be presented to the MCCC at its Spring 2009 meeting.

Building code revisions and infrastructure design standards: Strengthen building codes and construction techniques for new infrastructure and buildings in vulnerable coastal areas.

Many existing building codes were originally intended to ensure the safety of new residential and commercial construction; therefore, implementation of this recommendation will involve evaluating existing codes and design standards with respect to their proven effectiveness in past storm events, identifying causes of failure, and recommending and implementing changes to improve performance in the future. In addition to past performance, codes and standards should be reviewed and strengthened by taking into account future increased hazards caused by sea-level rise and the associated possible increase in storm intensity caused by climate change.

All types of building development, including residential, commercial, institutional, etc., and public infrastructure, such as roads, bridges, water and sewer, etc., should be analyzed. Standards for piers, wharves, and other marine-related structures should be included in this review as well. In addition to the overall evaluation and strengthening of codes, the entire development process must change to allow for an integrative process that recognizes and takes into account potential impacts of sea-level rise and climate change at all stages, including early design and decision-making. Design professionals must look for ways to reduce future impacts, and local governments must increase plan review, inspection, and enforcement efforts.

The State of Maryland has adopted, with modifications for Maryland law, the International Building Code (2006) and the International Residential Code (2006) as the Maryland Building Performance Standards (MBPS or Standards). As of July 2007, the Standards apply to all building structures within Maryland for which building permit applications are received by a local jurisdiction. Each local jurisdiction may, by local amendment, modify the provisions of the Standards to address issues relevant to that jurisdiction. Many jurisdictions have, in fact, made amendments in addition to the MBPS. Therefore, any review must include an evaluation of the MBPS as well as local building code ordinances. Reviews should include, but not be limited to, the following targets:

- *Elevation of buildings*. Require two or more feet of freeboard for structures located in tidally influenced floodplains. Freeboard is an elevation above a designated high-water level (base flood elevation; Figure 12). For example, the bottom of the lowest horizontal structural member should be elevated a minimum of two feet (or more) above the base flood elevation. This is especially pertinent with regard to sea-level rise, since base flood elevations will be higher in the future.
- *Foundation design*. Certain types of foundations are more effective in flood situations than others. Deep pile or column

foundations are desired if significant erosion is possible in oceanfront locations as well as bay locations where the following conditions exist: erodibility of the soil; exposure to damaging waves (greater than 1.5 ft); potential for velocity flow; potential for flood-borne debris; and required resistance to wind forces. These locations include V-zones, as well as A-zones, that are identified under the National Flood Insurance Program (NFIP).

- *Long-duration flood impacts*. Long-duration flooding, which may be a result of sea-level rise in the future, can cause extensive damage to interior contents and building materials. Moisture entrapment within walls and floors can impact structural integrity and cause biological and chemical contamination. Elevation will reduce this problem, as will the use of flood-resistant building materials above the minimum elevation.
- *Debris impact*. Substantial damage can be caused by floating or wind-driven debris in a flood or storm event. Current codes and construction standards should be evaluated with regard to debris resistance.
- *Building envelope*. A 'building envelope' is the entire exterior surface of a building, including walls, windows, doors, and roofs. All parts of the building envelope must provide protection from wind, wind pressure, and wind-borne debris. Building codes are very specific regarding these issues, but they should continually be reviewed and improved as needed.
- *Capital project design*. Design of future public projects, including roads, bridges, tunnels, landfills, water, and wastewater treatment plants, etc., should consider the effects of climate change and sea-level rise. In addition, standards should be developed for the modification of existing facilities in response to sea-level rise.
- *Abandoned facilities*. Provisions should be made to minimize the negative impacts of both public and privately maintained structures, facilities, and utilities that may be abandoned due to sea-level rise. Such impacts may include social, economic, navigational, and environmental hazards.

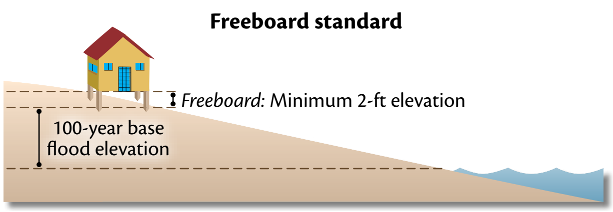


Figure 12. Freeboard is an elevation above a designated high water level (base flood elevation). For example, the bottom of the lowest horizontal structural member should be elevated a minimum of two feet (or more) above the 100-year National Flood Insurance Program base flood elevation. This is especially pertinent with regard to sea-level rise, since base flood elevations will be higher in the future.

Implementation

Implementation of this recommendation will initially involve an evaluation of existing codes and regulations with specific regard to the threats associated with climate change and sea-level rise. If deficiencies are found, changes to codes, regulations, and laws should be pursued. Legislative action will be necessary to amend the Maryland Flood Hazard Management Act of 1976 (Environment Article, Title 5) to require that all counties adopt standards requiring two or more feet of freeboard in tidally influenced floodplains. Over the next year, MDE will conduct a policy analysis of the Maryland Flood Hazard Management Act and will take the lead role in developing any necessary legislation or regulatory amendments to remedy policy deficiencies.

This policy recommendation dovetails with certain requirements of House Bill 1353 of the 2008 session of the Maryland General Assembly. Under the Omnibus Coastal Property Insurance Reform Act, the Maryland Department of Housing and Community Development (DHCD) is charged with reviewing current state-wide building codes and developing enhanced building codes for coastal regions of the state that promote disaster-resistant construction. DHCD is required to report their findings and recommendations to the Senate Finance Committee and House Economic Matters Committee on or before October 1, 2010. DHCD will fulfill its obligations under this Act and at the same time implement the recommendation as discussed above.

FINANCIAL AND ECONOMIC WELL-BEING

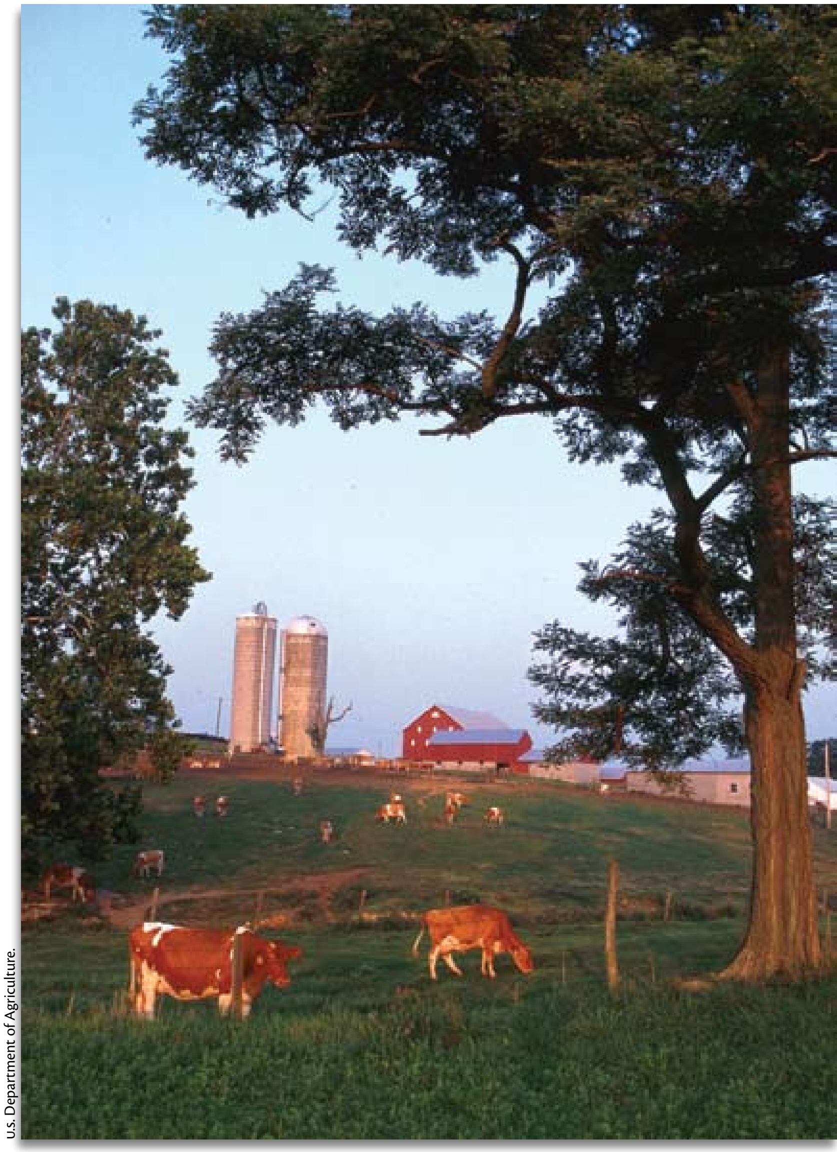
Minimize risks and shift to sustainable economies and investments

Maryland's people, property, natural resources, and public investments are all vulnerable to climate change and sea-level rise and, at some point, the inevitability of climate change will require critical actions to protect them rather than purposeful foresight and preparedness planning. Two to three feet of sea-level rise would inundate thousands of properties in low-lying areas and expose millions of dollars' worth of public infrastructure to the threat of submergence and/or storm surge. Billions of dollars more of public and private investments are at risk. Over time, federal, state, and local governments will not be able to afford to assist all in need—the costs will be just too high. Maryland should begin a sweeping shift to develop sustainable economies and investments, and at the same time, must work hard to avoid assumption of the financial risk of development and redevelopment in highly hazardous coastal areas.

Priority policy recommendations

Resource-based industry economic initiative: Develop and implement long-range plans to minimize the economic impacts of sea-level rise to natural resource-based industries.

Resource-based industries, such as forestry, agriculture, commercial and recreational fishing, and sportsmen's activities, represent the economic backbone of rural Maryland. These industries are heavily dependent on the health and vitality of the Atlantic Coastal Bays and Chesapeake Bay ecosystems. While potential climate change impacts to these industries are widespread, including changes in salinity, temperature, rainfall, disease, and invasive species, sea-level rise and coastal storms will specifically impact areas where the current primary land use supports these industries. Adaptation and response strategies that investigate all possible impacts should be addressed, recognizing that many will fall outside the focus of this phase of adaptation planning.



U.S. Department of Agriculture.

Impacts to resource-based industries such as farming and agriculture need to be minimized.

Baseline information regarding the impacts of climate change, including sea-level rise and associated coastal hazards, on the economics of varying sectors of resource-based trades and industries is lacking. Research within each respective field should aim to identify these potential impacts, and lead to developing an appropriate strategy to buffer such effects, as well as identifying potential opportunities for expansion and development. State agencies, in cooperation with the private sector, should develop and implement long-range plans, such as fishery management plans, forestry management plans, marine sensitive

Two to three feet of sea-level rise would inundate thousands of properties in low-lying areas

areas initiatives, and agriculture land use plans, that institute protection mechanisms to minimize the economic impacts of sea-level rise on natural resource-based industries. These plans should be flexible enough to adjust to ongoing and future change.

Implementation

Several lead agencies, including DNR, the Maryland Department of Agriculture (MDA), and the University System of Maryland, will work together to implement this recommendation. Implementation will occur over several phases. Phase 1 will focus on research and data collection, followed by Phase 2, which will be a strategic planning exercise. The first step in this process will be the development of several research teams, each comprised of individuals with expertise in sector-based issue areas. These teams will be coordinated by the lead agencies and will work over a two-year timeframe to evaluate key vulnerabilities and potential economic impacts of climate change on resource-based industries (fisheries, forestry, aquatic, and agriculture) and to develop appropriate adaptation and response strategies. A more detailed implementation plan will be presented at the MCCC Spring 2009 meeting.

Climate change insurance advisory committee: Establish an independent Blue Ribbon Advisory Committee to advise the state of the risks that climate change poses to the availability and affordability of insurance.

Due to sea-level rise and a likely increase in the intensity of coastal storm events, climate change will significantly impact the financial status of insurers and reinsurers, their ability to pay future claims, and consequently, the availability and affordability of insurance to Maryland's households and businesses. Maryland must take a proactive approach to risk reduction and take steps to maintain the insurability of financial investments.

Maryland must take two important steps to assess its options for state regulation of insurance in the face of climate change. First, there is a need for information on the risks posed by climate change. An independent Blue Ribbon Advisory Committee should be established to advise the State Insurance Commission and the Governor of the risks that climate change poses to the availability and affordability of insurance for Maryland citizens and businesses. The Blue Ribbon Advisory Committee should assess the following targets:

- The adequacy of data availability to insurers to assess risks posed by climate change, including sea-level rise, and recommend steps to improve data where it is deficient.
- The degree to which adaptive options, such as zoning that recognizes risks of building in high-risk areas and improved building codes to protect against more severe weather and flooding, may mitigate insured losses due to climate change, and whether insurance rate structures could be constructed that provide incentives for early adaptive actions.
- Options to promote partnerships with policyholders for loss mitigation.

It is also essential to have a focused assessment and a strategy for managing the ramifications of climate change risks and uncertainties. The State Insurance Commission should undertake a study on the costs and benefits of requiring greater disclosure of the risks posed by climate change to investors on the part of all insurance companies operating in the State of Maryland.

Bhaskaran Subramanian.

Agriculture is a vital component of Maryland's economy.

Implementation

The Maryland Insurance Commissioner will convene a Climate Change Insurance Advisory Committee on or before September 15, 2008. Membership will be composed of citizens, business owners, members of civic and conservation organizations, representatives from the insurance industry, and local and state government representatives. Additionally, membership may consist of members from Maryland's Coastal and Watershed Resources Advisory Committee. The

Insurance Advisory Committee will provide an initial report to the Commissioner on or before January 1, 2009. An interim report will be due on or before July 1, 2009 and the final report will be completed on or before January 1, 2010.

Disclosure: Develop a *Maryland Sea-Level Rise Disclosure and Advisory Statement* to inform prospective coastal property purchasers of the potential impacts that climate change and sea-level rise may pose to a particular piece of property.

Maryland should develop a *Sea-Level Rise Disclosure and Advisory Statement* that would be applicable to all real-estate transactions taking place within Maryland counties bordering the Atlantic Ocean and the Chesapeake and Coastal Bays. The *Maryland Sea-Level Rise Disclosure and Advisory Statement* should contain general information about risks associated with sea-level rise, coastal storms, and/or shore erosion, as well as disclose property owner knowledge of any flooding, avulsion, erosion, or other damage that has occurred to a particular piece of property.

The *Maryland Sea-Level Rise Disclosure and Advisory Statement* would build upon the precedent of requiring residential property sellers to provide information regarding lead and lead-based paint. Federal and state law require both require persons selling or leasing most residential housing built before 1978 to provide purchasers and renters with a federally approved lead hazard information pamphlet and to disclose known lead-based paint and/or lead-based paint hazards in the sales contract. Information contained in the *Maryland Sea-Level Rise Disclosure and Advisory Statement* should be made available in as many stages of the property transaction and ownership as possible, including but not limited to the notification of potential buyers in the listing of the property, a disclosure notice at settlement, and recording on the plat maps, zoning maps, or with the title and deed.

The analogy to sea-level rise, erosion, storm surge, and other climate change-related risks is straightforward. First, the state may require property owners or managers to provide general information on climate-related risks, similar to the general notice regarding lead. This notice requirement could be triggered particularly for vulnerable properties. For lead, that includes residential buildings built before 1978. For sea-level rise, it could include houses in coastal counties or those located in areas specifically identified as vulnerable to sea-level rise, erosion, storm surges, and other related risks. Second, to the extent that a property owner or manager has knowledge regarding the risk to that particular property, the law would also require the property owner or manager to disclose that information.

Implementation

Within 180 days of the release of the *Climate Action Plan*, both DHCD and DNR, as lead agencies, will assemble a small group of key state agency staff to discuss accuracy, insurance, and legal issues that need to be resolved during the development of a disclosure and advisory statement relating to the transfer of real property. In addition, the group will address the pros and cons of different forms of communicating those statements and the timing and targets of those statements. Within one year, a public discussion of the proposed recommendations will take place in a forum to be determined by DHCD and DNR. The lead agencies will work together to draft new/revised legislation, as necessary, for the 2010 legislative session.

Green economic development initiative: Recruit, foster, and promote market opportunities related to climate change adaptation and response.

Maryland should take immediate steps to capture the emerging economic opportunities in climate change adaptation and response fields. While some greenhouse gas reduction strategies require new costs, many of these strategies and the expertise and technologies involved also offer tremendous opportunities for economic growth. Maryland is well-situated to capitalize on the state's expertise in environmental issues to become a leader in the 'green-collar' job creation and economic development while meeting the challenges of climate change. Maryland's efforts should encompass the development of new green businesses as well as the greening of more traditional businesses to improve their economic, social, and ecological performance.

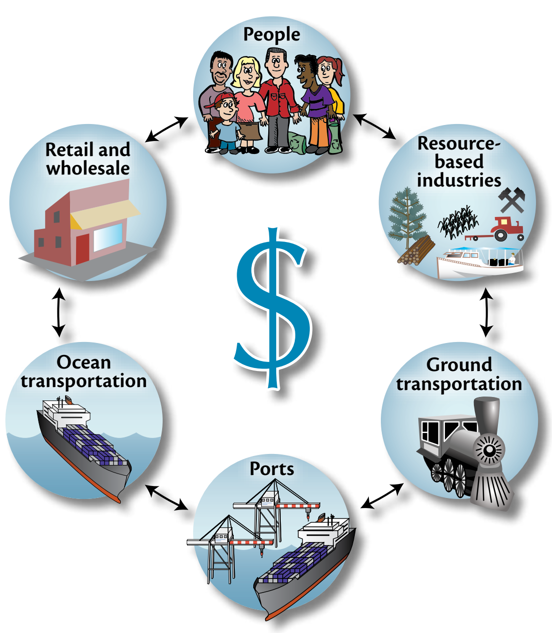
A Task Force should be established to identify priority initiatives and refine implementation strategies to establish strong capacity to recruit, foster, and promote market opportunities related to climate change adaptation and mitigation. The Maryland Department of Business and Economic Development (DBED) and other agencies with programs in business development and trade promotion should play a major role in this effort. Green economic opportunity targets include the following:

- Build public and business awareness of why a green, sustainable economy is good for Maryland.
- Promote the 'greening' of existing Maryland businesses.
- Use Maryland government investment to 'prime the pump' for green economic growth.
- Develop adaptation decision support services and tools for businesses.
- Market Maryland as a leader in adaptation and mitigation strategies.
- Build a 'green-collar' entrepreneurial workforce through education, training, and outreach.
- Create an environment to foster green business and markets.
- Support the development of sustainable resource-based industries.

Implementation

The lead agencies, DBED and DNR, will work together to implement this policy recommendation in coordination with implementation of the MCCC's Mitigation Working Group (MWG) policy option CC-9, which is aimed at promoting economic development opportunities associated with reducing greenhouse gas emissions in Maryland. DBED and DNR will convene and coordinate the efforts of the Task Force, as identified above. A more detailed implementation plan will be prepared by the lead agencies for presentation to the MCCC at its Spring 2009 meeting.

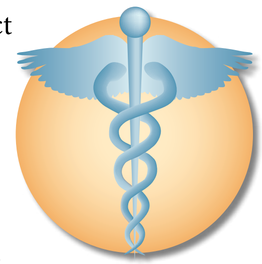
Economy of resource-based industries



Sea-level rise does not just affect coastal areas. It can affect all aspects of resource-based industries' economy, from production through transportation to consumption.

PROTECTION OF HUMAN HEALTH, SAFETY, AND WELFARE

Guarantee the safety and well-being of Maryland's citizens in times of foreseen and unforeseen risk



Sea-level rise will impact both the coastline and some interior portions of Maryland and will change the way health-related infrastructure and programs are maintained and managed in the future. The general population may take for granted that clean and adequate water supplies are available, waste water is cared for and properly disposed of, and that our population is generally safe from the impact of coastal flood events and vector-borne illnesses. However, with a projected growing population in Maryland, mostly in coastal areas, protecting human health and safety will become an increasing large responsibility for state and local governments. With that responsibility, new tools and adequate resources will be needed in order to protect Maryland's communities—both large and small.

Priority policy recommendations

Inter-agency coordination: Strengthen coordination and management across agencies responsible for human health and safety.

The Maryland Department of Health and Mental Hygiene (DHMH), Office of Preparedness and Response should undertake a gap analysis, in cooperation with MEMA and other target agencies to determine if there is adequate management, procedures, and coordination of county- and city-level options to ensure consistency in and capacity for adaptation and response to health-related impacts of climate change across boundaries. This gap analysis should evaluate state and local government capacity to respond to large-scale floods and storms, ensuring the safety and protection of drinking water sources and septic systems/waste treatment, and infectious disease outbreaks. Additional components should include: (1) organization of the response; (2) benchmarking; (3) capacity inventory; (4) information technology and communications; (5) needs analysis; and (6) state law and policy amendments. For example, a conclusion of the analysis might be that counties and municipalities be encouraged to adopt well and septic provisions, including water and sewer plans and re-mapping of zoning for areas that are at-risk for inundation due to gradual sea level rise or coastal flooding and storm surge.

Recommendations resulting from the proposal will recognize and account for differences in response capacity between counties and recommend mitigation and augmentation options to minimize disruption in services due to lack of capacity. The recommendations will be of benefit for all aspects of agency operations and coordination, as well as for specific responses to climate change. Implementation of this recommendation will increase the adaptive capacity of state institutions by increasing coordination and collaboration and raising awareness of how to appropriately address the health risks of climate change.

Protecting human health and safety will become an increasingly large responsibility

Implementation

The DHMH, Office of Preparedness and Response and MEMA will immediately begin the process to undertake the recommended gap analysis. The gap analysis should be coordinated with the 2008 Federal Gap Analysis, as applicable. The gap analysis should be completed by September 2009. A progress update and preliminary findings will be presented to the MCCC at its Spring 2009 meeting.

Zoë Johnson.

Protecting human safety during coastal flood events is an essential part of climate change planning.

Health impact assessments: Conduct health impact assessments to evaluate the public health consequences of climate change and projects and/or policies related to sea-level rise.

Health consequences for residents of Maryland may arise from the implementation of climate change adaptation and response options across all sectors. Health Impact Assessments (HIAs) should be used to assess the public health consequences of climate change and policies and measures related to sea-level rise prior to their adoption. HIAs are a proven approach to ensuring that potential public health concerns are identified and addressed before they become a problem. A HIA should be conducted, at a minimum, whenever an Environmental Impact Assessment is required or if a proposed policy is expected to have a health-related and/or safety impact. HIAs also can be used to identify the co-benefits of smart growth and development policies.

HIAs will increase the adaptive capacity of state institutions by incorporating consideration of possible public health considerations at the beginning of the policy process, rather than waiting for adverse consequences to be recognized and mitigated at the end of the policy or implementation process. Recognizing possible adverse health consequences early in the process will help prevent injuries and illnesses before they occur and result in less costly solutions. In addition, the cross-department and agency collaborations developed as a result of HIAs will increase the capacity of the state to prepare for and respond to climate change and sea-level rise risks.

Implementation

The lead agencies, DHMH and MEMA, will work to implement this policy recommendation in coordination with MWG policy option CC-11, which recommends the evaluation of climate change policy options to determine projected public health risks, costs, and/or benefits. DHMH and MEMA will work together to coordinate and participate in the efforts of the Maryland Climate Change Environmental Health and Protection Advisory Council.

Vector-borne surveillance and control: Develop a coordinated plan to assure adequacy of vector-borne surveillance and control programs.

One of the consequences of climate change may be alteration of the geographic distribution and intensity of transmission of vector-borne and zoonotic diseases. As the climate warms, the range of several insect- and arthropod-borne diseases is likely to expand northward. DHMH, along with DNR and MDA, is responsible for conducting vector-borne disease surveillance and control programs. A working group should be established between the departments to develop a coordinated plan to assure adequacy of the surveillance program given increased demand associated with climate change. In addition, there would be collaboration with agencies responsible for water storage, storm water management, etc., to ensure that these programs achieve their goals without increasing breeding sites for disease-carrying vectors.

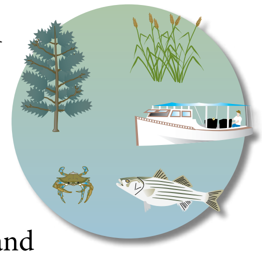
Vector and disease surveillance programs already exist within the state that could meet some, but not all, of the demands associated with increased monitoring of vector-borne diseases as a result of climate change. Significant increases in personnel and resources may be required if surveillance programs are to be expanded. Vector surveillance requires specialists trained in the collection of specimens, laboratory analysis, and GIS or other spatial analysis. While not immediately required, the long lead-time required to recruit and/or train the personnel necessary to fill these specialized positions necessitates advance planning and dedication of resources. Improving surveillance and control activities will need to include educational programs so that individuals do not over-spray when vector-borne diseases are identified, as using excessive amounts of insecticides has adverse health and environmental consequences.

Implementation

DHMH, along with the MDA and DNR, is responsible for conducting vector-borne disease surveillance and control programs. These lead agencies will convene a working group within 180 days of the release of the *Climate Action Plan* to develop a coordinated plan assuring adequacy of the surveillance program given increased demand due to climate change. This plan will be developed by the working group and should be completed within a one-year timeframe.

NATURAL RESOURCE PROTECTION

Retain and expand forests, wetlands, and beaches to protect us from coastal flooding



Maryland's natural resource lands provide critical wildlife habitats, have regional significance for migratory birds, sequester large amounts of carbon, provide sediment and nutrient water quality benefits, and generate economic benefits through farming, forestry, fishing, and passive recreation. Natural resources, particularly coastal wetlands and barrier and bay islands, also play a vital role in protecting Maryland's shoreline and interior by absorbing the damaging impact of coastal floods, heavy winds, and strong waves (Figure 13). Identifying undeveloped lands and ecologically and economically important lands will be critical for targeted conservation and coordinated restoration in response to sea-level rise and its associated effects. Preserving undeveloped, vulnerable lands also offers a significant opportunity to avoid placing people and property at risk to sea-level rise and associated hazards including storm surge, coastal flooding, and erosion in the future.

Priority policy recommendations

Natural resource protection areas: Identify high priority protection areas and strategically and cost-effectively direct protection and restoration actions.

Conservation and restoration of natural resource lands are currently facilitated through a number of state agencies and programs. To date, significant state resources have been invested to establish various assessments for identifying and prioritizing targeted lands. These existing assessments, however, are sometimes utilized independently of one another and do not consider sea-level rise and its associated effects. Rising sea levels will undoubtedly impact coastal ecosystems and natural resource lands; therefore, the criteria for which these lands are prioritized and targeted for strategic management will need to shift in order to account for associated impacts.

Natural resources play a vital role in protecting Maryland's shoreline and interior

The state should establish a scientific and technical framework to develop and test new and existing criteria for identifying priority protection and restoration areas in the context of sea-level rise. To the extent possible, the framework should use

Protective natural resources

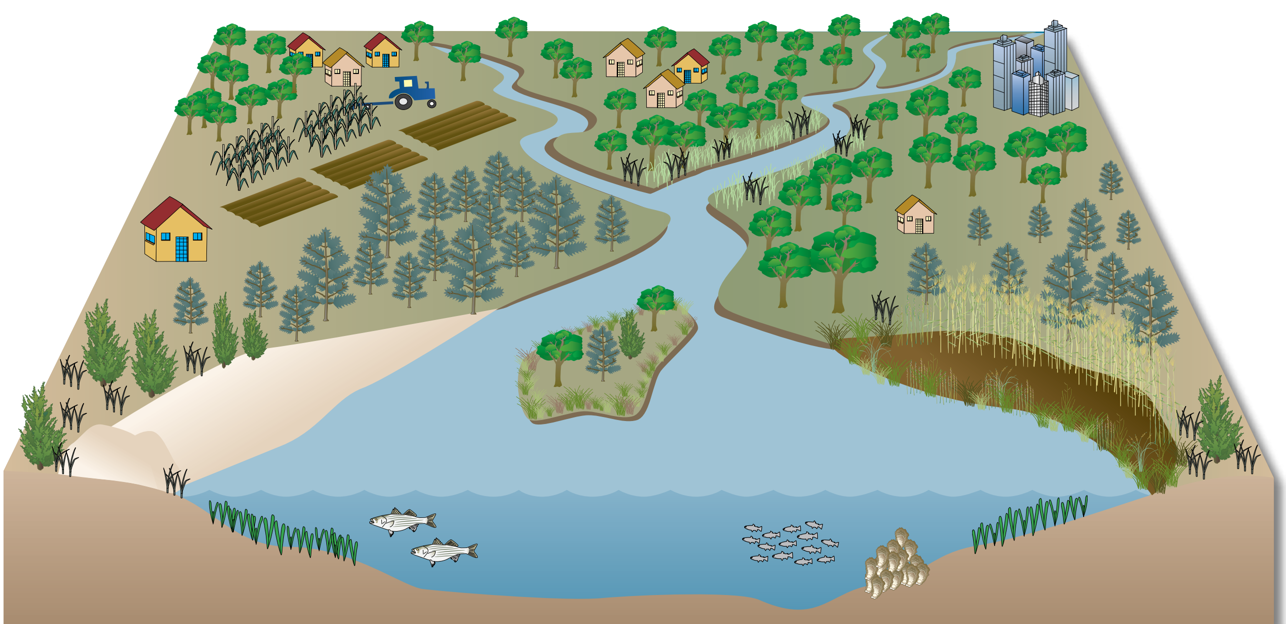


Figure 13. Natural barriers such as beaches, dune vegetation, wetlands, coastal forests, and vegetated stream buffers protect residential areas and urban areas from flooding, erosion, and inundation. Natural barriers also protect crops and agricultural areas.

existing assessments, such as Green Infrastructure and Blue Infrastructure, in order to identify high-priority ecological and economic natural resource lands and aquatic habitats in the coastal zone. Mapping and modeling data gaps and needs should also be identified and addressed. It is recommended that the framework be developed as a peer-reviewed model to graphically illustrate the potential location of wetland migration corridors, areas where accretion may keep pace with sea-level rise, and areas that are not suitable for migration and need active management to be sustained (Figure 14). Potential field sites should be identified in order to test site-scale suitability criteria for various restoration practices in response to sea-level rise.

The information generated from the model will enable programs to strategically and cost-effectively direct and implement specific conservation, restoration, and growth management actions. Undeveloped coastal land areas of high priority for targeted action include those identified as potential wetland migration corridors, those essential in maintaining ecosystem integrity and connectivity, those crucial in supporting farming, forestry, and fisheries industries, and those positioned to confer risk reduction to coastal communities in response to projected sea-level rise inundation and coastal flooding scenarios.

Implementation

Several state agencies, including DNR and MDE, are already undertaking efforts or implementing programs that are consistent with the goals of this policy option. Early analysis of natural resources protection and restoration priorities will be initiated immediately by these lead agencies using existing inundation maps and natural resource assessments. By September 2009, the lead agencies, along with input from other state agencies, will develop a comprehensive plan to integrate various models, identify data gaps, and evaluate sea-level rise and marsh migration models. Targeting priorities as recommended by the MWG for carbon sequestration will be incorporated, where possible.

Forest and wetland protection: Develop and implement a package of appropriate regulations, financial incentives, and educational, outreach, and enforcement approaches to retain and expand forests and wetlands in areas suitable for long-term survival.

Forest and wetland conservation will, without doubt, become increasingly complex in the face of climate change and sea-level rise. If sea level increases by three feet, by the year 2050, 21% of coastal forests and 66% of tidal marshes in Dorchester County will be lost (Table 1). These habitats are pivotal to Maryland's ability to adapt to climate change, as forests and wetlands provide a buffer to storm surge and have the ability to sequester carbon, reduce shoreline erosion, and mitigate peak runoff during storm events. Side benefits include improved water and air quality, enhanced wildlife and natural resource habitats, increased 'green' renewable construction

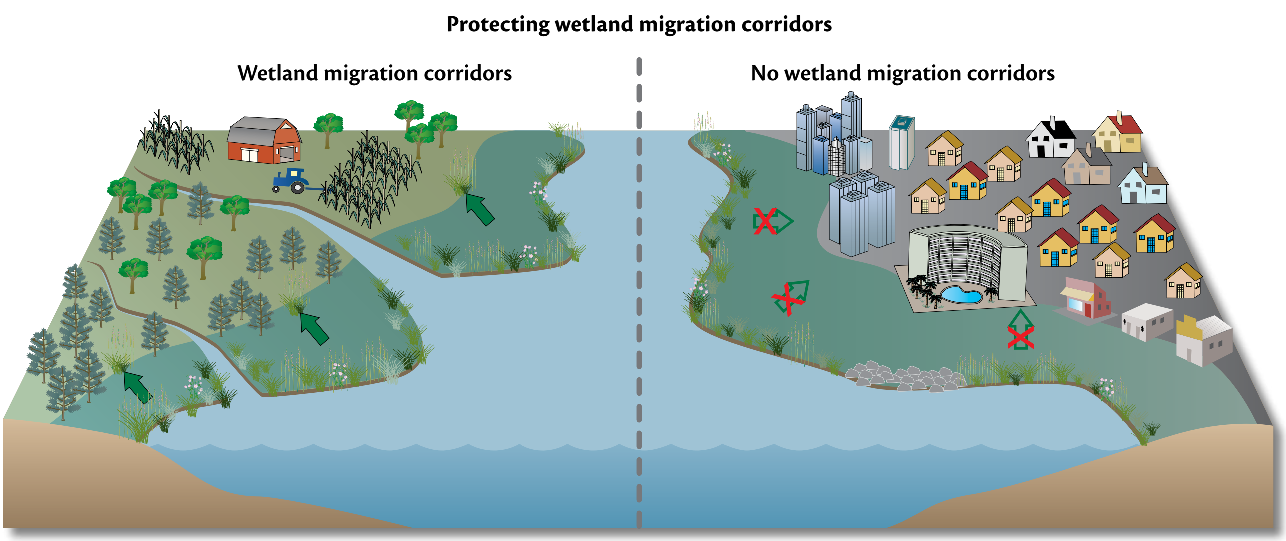


Figure 14. As sea level rises, wetlands may migrate into open spaces such as forests and fields. However, wetlands cannot migrate into areas with man-made barriers such as hardened shorelines and heavy development such as urban, commercial, and residential areas.

and fuel forestry products, and expanded resource-based industry jobs.

In light of sea-level rise, the state should establish new criteria, where appropriate, for identifying priority natural resource protection and restoration areas in order to integrate and streamline conservation, restoration, and growth management programs across state agencies and local governments. The costs of forest and wetland conservation and expansion are associated primarily with capital costs of land purchases and/or easements in areas identified as critical to buffering against the impacts of sea-level rise. Current state funding sources and incentives are limited and are not likely to be a leading instrument in executing this option. Funding programs and policies must be increased to be comparable with land values for development in order to be effective.

The state should develop and implement a package of appropriate regulations, financial incentives, and educational, outreach, and enforcement approaches to retain and expand forests and wetlands in areas suitable for long-term survival. Select targets may include the following:

- expanding priorities for existing land conservation to promote horizontal marsh migration or vertical accretion, where feasible;
- expanding financial incentives that encourage private forest and waterfront and riparian landowners to favor the retention of forests and other native habitats over development and conversion;
- managing forests and wetlands to enhance ecological services and storm impact reduction benefits;

Bhaskaran Subramanian.

'Living shorelines' involve using non-structural shoreline stabilization measures. Living shorelines provide erosion control benefits while also enhancing the natural shoreline habitat. They often allow for natural coastal processes to remain through the strategic placement of plants, stone, sand fill, and other structural and organic materials.

- identifying and developing programs to enhance and protect wildlife corridors and maintain connectivity of green forest core areas across the landscape; and
- achieving other land use goals.

Implementation

Implementation of this policy recommendation is tied to the process of identifying Natural Resource Protection Areas as outlined in the previous recommendation. In the interim period, the lead agencies, DNR and MDE, will work together to review existing programs and funding across all state, federal,

Table 1. Forests and wetlands of Dorchester County that will be lost in 25 and 50 years with sea-level rise rates of one and three feet per century.[9]

AREA INUNDATED BY SEA-LEVEL RISE OF ONE FOOT PER CENTURY (CURRENT RATE)					
		After 25 years		After 50 years	
	Current acreage	*Inundated*	*% loss*	*Inundated*	*% loss*
Forest	118,717	1,679	1.4%	4,943	4.2%
Wetlands	91,002	7,035	7.7%	18,164	20.0%
AREA INUNDATED BY SEA-LEVEL RISE OF THREE FEET PER CENTURY					
		After 25 years		After 50 years	
	Current acreage	*Inundated*	*% loss*	*Inundated*	*% loss*
Forest	118,717	8,737	7.4%	24,933	21.0%
Wetlands	91,002	29,314	32.2%	59,708	65.6%

and county agencies that can be focused on addressing both adaptation and mitigation options related to sea-level rise and carbon sequestration. Phase 1 of the implementation plan will be to use the initial results of the Natural Resource Protection Area assessment to target existing programs to high priority areas. Phase 2 will entail the identification of new policies, programs, regulations, and financial incentives that are needed to advance forest and wetland protection efforts. Phase 2 will be completed within a two-year timeframe and be followed by the development of new/revised state and local policy and regulation, as necessary.

Shoreline and buffer area management: Promote and support sustainable shoreline and buffer area management practices.

Shoreline management is facilitated through a network of programs housed in the Maryland Departments of the Environment (MDE) and Natural Resources (DNR) and also through local government Critical Area and erosion and sediment control activities. Involvement among these partners varies with respect to agency mandate, jurisdictional boundaries, and level of activity, whether through regulation, technical assistance, or project implementation. In light of the fact that problems associated with erosion will heighten as a result of sea-level rise, there is a need to more comprehensively address shore erosion management from a state-wide perspective.

Town of Ocean City Tourism Office.

Natural resources such as seafood are an essential part of Maryland's culture and economy.

Passage of the Living Shorelines Protection Act of 2008—which requires the use of non-structural, 'living shoreline' shoreline stabilization measures that preserve the natural environment, except in areas mapped by the state as being appropriate for structural stabilization measures—and the strengthened provisions of the Chesapeake and Atlantic Coastal Bays Critical Area Protection Program in 2008 were huge steps in the direction of sustainable shoreline and buffer area management. Implementing the statutory changes of these two bills passed during the 2008 General Assembly will be the initial step in executing a comprehensive approach to shoreline management planning. Additional targets include the following:

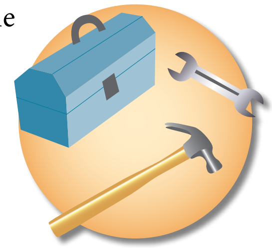
- Reorient DNR's Shoreline Conservation and Management Program to promote the installation of innovative shore protection techniques that maximize habitat restoration and enhancement and accommodate for projected sea-level rise.
- Develop a general permit that streamlines the rebuilding process of storm-damaged tidal marshes, including the placement of additional clean sandy fill, plants, and temporary, biodegradable structures to protect rebuilt areas.
- Direct a joint effort of state agencies to standardize design and construction methods and protocols employed for new, retrofitted, or replacement shore erosion control structures that consider climate adaptive strategies for coastal environments subject to sea-level rise, erosion, and storm hazards.
- Integrate mapping and modeling products into state and local planning and implementation efforts.
- Update the Maryland Comprehensive Shoreline Inventory to include type and quantity, location, and conditions of shore erosion control structures on a routine basis, possibly every 5–10 years.
- Expand current outreach and educational programs directed at the public and marine contracting professionals to help ensure a smooth transition toward broader implementation of non-structural and hybrid techniques.

Implementation

Several state agencies, including DNR and MDE, are already undertaking efforts or implementing programs that are consistent with the goals of this policy option. Specifically, DNR and MDE are currently working together to implement regulatory components of the Living Shoreline Protection Act of 2008, as well as the strengthened provisions of the Chesapeake and Atlantic Coastal Bays Critical Area Protection Program. For those elements of this policy option not related to those two pieces of legislation, DNR and MDE will start working together immediately to initiate implementation. A final implementation plan will be developed by DNR and MDE and be presented to the MCCC at its Spring 2009 meeting.

ADAPTATION AND RESPONSE TOOLBOX

Give state and local governments the right tools to anticipate and plan for sea-level rise and climate change



Over the last 10 years, the State of Maryland has made significant progress acquiring new technology and data, including state-wide high resolution topographic data (as depicted in Figure 15), and has utilized these data to undertake state-of-the-art sea-level rise mapping and research. The state has also been proactively working with select state agencies and coastal counties to provide the necessary funding and technical assistance to build capacity to integrate data and mapping efforts into decision-making processes and to identify specific opportunities, such as statutory changes, code changes, or comprehensive plan amendments, that will advance climate change and sea-level rise adaptation planning. These efforts have made Maryland a national leader in sea-level rise modeling, research, and response planning.

> A continued commitment on the part of both state and local governments is still essential

To adequately plan and respond to sea-level rise, it is imperative that both state and local governments have access to the right tools at the right time. Maryland is well on its way to providing the tools, technical resources, and educational programs; however, a continued commitment on the part of both state and local governments is still essential.

> **Integrated observation systems:** Strengthen federal, state, local, and regional observation systems to improve the detection of biological, physical, and chemical responses to climate change and sea-level rise.

The State of Maryland relies heavily on information obtained from existing federal, state, local, and regional integrated observation systems located throughout the Mid-Atlantic region to support ongoing sea-level rise adaptation and response planning efforts. Information and data gathered from observational networks is also used to evaluate and measure the effectiveness of related coastal resource management and restoration programs. There is a need, however, to strengthen and better integrate a number of the system components already in place within natural and urban settings to detect biological, physical, and chemical changes and responses due to direct and indirect effects of climate change. The state should focus its efforts on the following targets to strengthen and enhance integrated observation systems:

- Enhance federal, state, local, and regional integration and coordination of observation systems that detect trends in coastal water levels, elevation and/or subsidence, shoreline change, wetland loss, and tidal influence on estuaries and water supplies.
- Assess the suitability of vertically controlled tide gauges and investigate the feasibility of installing additional tide gauges in particular locations.
- Investigate the need for the installation of additional surveillance equipment in coastal areas where current public and private infrastructure is potentially vulnerable to small increases in sea level.

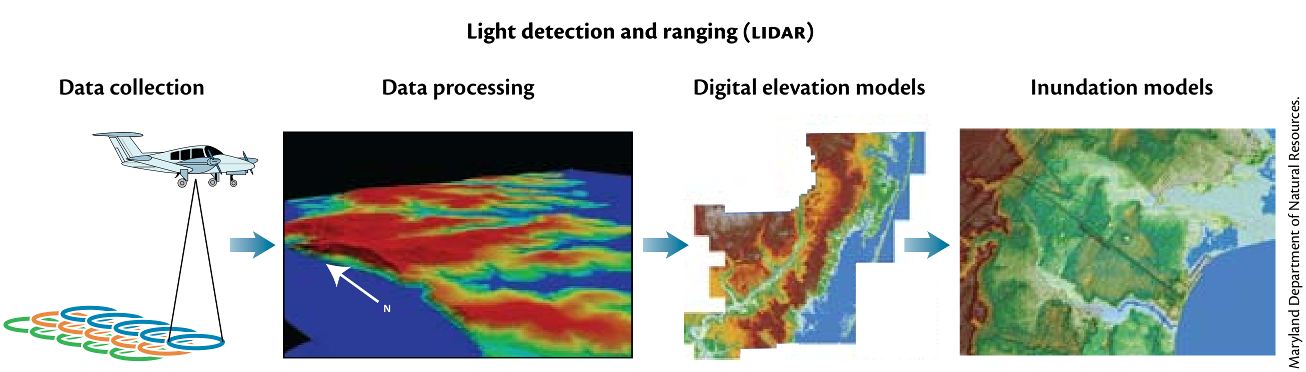


Figure 15. LIDAR is a method of collecting and processing high-resolution elevation data to inform models and predictions of flooding and inundation.

- Assess the adequacy of Surface Elevation Tables (Figure 16) to measure whether marsh accretion is keeping pace with erosion/inundation and examine opportunities to add more Tables in select locations.
- Observe and record changes for a set of leading indicators of specific climate change impacts. This should include indicators that are representative of specific geographic ranges, behaviors, or population characteristics of certain species, including plants, birds, mammals, and insects, that are known to be sensitive to sea-level rise and other climatic changes.
- Enhance the utilization of the Maryland Geological Survey Groundwater Quality Network to conduct well water quality assessments in areas where saline intrusion adjacent to tidal waters is known to occur.
- Evaluate the need to expand the Maryland Geological Survey Subsidence Studies Program to assess the risk of elevation declines due to groundwater withdrawals, which would exacerbate any impacts of sea-level rise.

Implementation

A number of federal, state, and local government partners are already working to undertake efforts or are implementing programs that are consistent with the goals of this policy recommendation. DNR will work with these agencies to inform them of the *Climate Action Plan* recommendations and, where possible, work to partner on implementation of specific components. Implementation of several components can be undertaken immediately. For those that cannot, DNR will work with specific partners, including the Maryland State Geographic Information Committee, to develop an implementation plan for presentation to the MCCC at its Spring 2009 meeting.

Maryland Department of Natural Resources/Maryland National Estuarine Research Reserve/Patricia Delgado.

Figure 16. Surface Elevation Table established at the Jug Bay freshwater tidal marsh to measure sediment elevation.

GIS mapping, modeling, and monitoring: Update and maintain state-wide sea-level rise mapping, modeling, and monitoring products.

The effectiveness risk and vulnerability reduction strategies will depend on state and local access to high-quality information about climate change, sea-level rise, and their related risks. Maryland's state agencies have been aggressively acquiring and analyzing various data and technological resources to both gain a better understanding of sea-level rise vulnerability and increase state and local government capacity to adapt and respond. One of these products was the Worcester County Sea-Level Rise Inundation Model, developed cooperatively between DNR, the U.S. Geological Survey, and Worcester County in 2004. Outputs from the model are shown in Figures 17 (Ocean Pines) and 18 (Public Landing). However, more work in the following areas is needed to complete state-wide sea-level rise modeling and develop mapping and monitoring products to support both state and local sea-level rise planning efforts:

- Utilize Maryland iMap, an internet-based interactive map currently under development for use by state agencies, local governments, and the public, to house and display existing and future sea-level rise data and spatially based information.
- Complete state-wide sea-level rise inundation and storm surge modeling at a scale appropriate for both state and local planning.
- Adopt a production and maintenance schedule for mapping and modeling activities including the data necessary for both activities. This schedule should include anticipated costs, financing options, data sources, and increasing the accuracy of predicted results.
- Review institutional and organizational data management practices and make

Ocean Pines flooding with storm surge from a Category 2 hurricane

Figure 17. Areas of Ocean Pines that would be flooded by 1.5 m (4.9 ft) storm surge from a Category 2 hurricane today (left) and in 2050 after sea-level rise of 15 cm (0.5 ft), which is the current rate of sea-level rise (right).[10] However, the rate of sea-level rise is projected to increase above the current rate in the future, so this map likely underestimates the extent of flooding in 2050.

Sea-level rise inundation in Public Landing

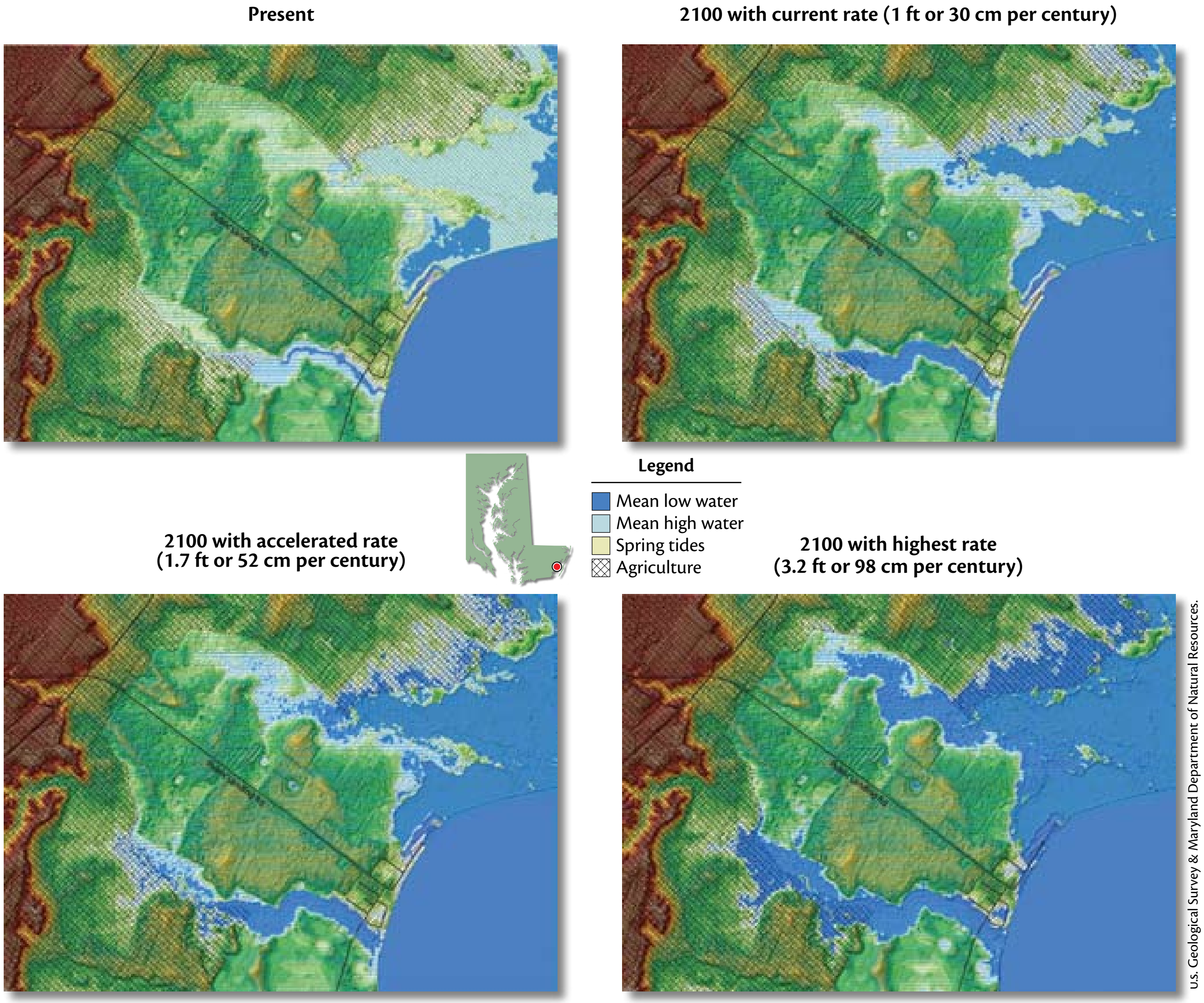


Figure 18. Areas of Public Landing that would be inundated by 2100 under various sea-level rise scenarios.[10] Data and maps such as these are important for visualizing and understanding potential impacts. Note that the highest rate (3.2 ft per century) is the maximum rate considered here, but is less than the maximum possible rate reported in the scientific literature.

recommendations to enhance efficiency and cost-effectiveness of data gathering, sharing, maintenance, and processing efforts and to minimize duplication of effort and data and modeling redundancies.

- Create a digital, spatial inventory of infrastructure potentially impacted by sea-level rise, including the identification of public and private systems and facilities and threatened historical structures. This database should be maintained relative to sea-level rise projections and scenarios.
- Utilize GIS systems to model and monitor specific 'leading indicators' of climate change impacts.
- Encourage federal agencies to factor climate change and sea-level rise risk into NFIP floodplain mapping efforts.

Implementation

A number of federal, state, and local government partners are already working together to undertake efforts and/or implementing programs that are consistent with the goals of this policy option. Specifically, DNR is currently working to facilitate the use of Maryland iMap to house and display spatially-based information, including existing and future sea-level rise data. Using existing communication lines and working relationships with local governments, MDP and DNR will ensure access and delivery of all relevant climate change planning data needed for land use planning efforts. For those elements of this policy option that cannot be implemented immediately, DNR will work together with other partners to develop an implementation plan for presentation to the MCCC at its Spring 2009 meeting. This implementation plan will include a schedule and the estimated cost for completing state-wide sea-level rise inundation and storm surge modeling at a scale appropriate for both state and local planning.

Public awareness, outreach, training, and capacity building: Utilize new and existing educational, outreach, training, and capacity building programs to disseminate information and resources related to climate change and sea-level rise.

Sea-level rise and increases in the intensity of flooding and storm surge are expected to have complex and far-reaching consequences for Maryland's residents, businesses and trades, and local governments. Better preparation, through the modification of existing law and policy and the implementation of new strategies and policies, will reduce the impacts experienced. There is a significant need, however, to increase public awareness of the risks and appropriate responses among those responsible for preparation and response, as well as those likely to be affected, including the media and non-governmental organizations.

Two key sets of activities to improve targeted public awareness, outreach, training, and capacity building have been identified: 1) development of coordinated and cohesive communication messaging, and 2) effective distribution of the messaging to a wide variety of people and professions across all levels of government, sectors, and organizations. Of particular concern is the development of communication plans to reach low-income and under-served populations. Implementation of the following targets will increase the ability of residents, businesses, and local governments to understand the potential climate change risks, gather the information necessary to make informed decisions, and to work with partners to identify solutions.

- Work with Public Information Officers of relevant federal, state, and local agencies to develop a communication framework and to ensure clear, consistent, and cohesive messaging.
- Identify and engage all licensing, training, and capacity-building programs that currently exist in areas at serious risk from sea-level rise and extreme storm events.
- Target educational, outreach, training, and capacity building to specifically address the needs of low-income and under-served populations.
- Develop specific educational programs to achieve the following:
  - Inform the public of appropriate behavior before, during, and following extreme storm events.
  - Increase awareness of the risks of vector- and water-borne diseases in a warmer climate.
  - Inform private landowners of the availability of applicable wetland and forest protection programs.
  - Train marine contractors on the design and installation of 'living shoreline' shore erosion control practices.
  - Educate local elected officials about climate change and sea-level rise dynamics and

what local governments can do to promote adaptation and response planning.

- Create greater public awareness of the integral relationship between Chesapeake Bay restoration actions and climate change and sea-level rise adaptation and response activities.

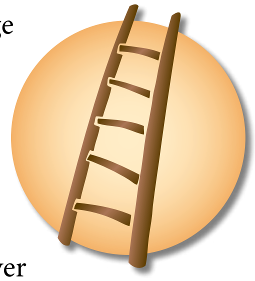
Implementation

DNR's Coastal Training Program and its Chesapeake and Coastal Program will coordinate agency efforts to implement this policy recommendation. These Programs will coordinate implementation with the MWG's Education and Outreach Work Group (See MWG Policy Option CC-5). For those elements of this policy option that cannot be implemented immediately, DNR will work together with the Education and Outreach Work Group and other agency partners to develop an implementation plan for presentation to the MCCC at its Spring 2009 meeting.

In 2006, the Maryland Chesapeake and Coastal Program worked with Maryland Sea Grant to develop four Coastal Hazard Public Outreach Panels to promote public awareness on the impacts of sea-level rise, coastal erosion, storms, and coastal flooding to coastal communities around the state. The panels are displayed in tourist access areas throughout the Maryland portions of Chesapeake Bay.

FUTURE STEPS AND DIRECTION

State and local governments must commit resources and time to assure progress



Planning for climate change and sea-level rise is extremely complex—there are many potential impacts and no single remedy. While climate change and sea-level rise are both gradual processes occurring slowly over time, the impacts of both are already being detected. Maryland's state and local governments must take specific action now to plan for inevitable impacts. The recommendations laid out in this report are intended to guide adaptation activities over the next five years and along the way, Maryland's state and local governments must measure and track progress, keeping in mind that many of the implementation strategies must be adaptable to change. Progress will take time, fiscal resources, flexibility, and continual commitment.

Local government planning guidance: Develop state-wide sea-level rise planning guidance to advise adaptation and response planning at the local level.

The ARWG identified a specific need to improve the capacity of local governments to plan for and adapt to sea-level rise, and where that capacity does not currently exist, to develop guidance to assist with identifying specific measures, such as local land use regulations and ordinances, to adapt to sea-level rise and increasing coastal hazards.

Written guidance should be developed to address the following four phases of sea-level rise response planning: 1) vulnerability and impact assessment; 2) long-range and comprehensive planning; 3) code, regulation, and development standards; and 4) public education and outreach. The guidance should specifically lay out the process, methodology, including draft language, and a proposed timeline for incorporating sea-level rise and coastal hazard response planning into local planning processes and frameworks. It should also provide recommendations for sequencing and integrating the four planning phases and identify financial and technical assistance needs.

Implementation

DNR is already working to support the needs identified in this policy recommendation. DNR's Chesapeake and Coastal Program is currently providing funding to Dorchester, Somerset, and Worcester Counties to develop written sea-level rise planning guidance. Following completion of these projects in September 2008, DNR, MDP, and MDE, and other state agencies as appropriate, will work together to develop the state-wide local government sea-level rise adaptation and response planning guidance. Implementation will be coordinated with the development of the written guidance for the Sea-Level Rise Elements of comprehensive plans. It is projected that completion of this project will take two years.

Progress will take time, fiscal resources, flexibility, and continual commitment

Adaptation-Stat: Develop and implement a system of performance measures to track Maryland's success at reducing its vulnerability to climate change and sea-level rise.

Maryland's state agencies with programs, policies, or activities affected by issues related to sea-level rise should immediately begin to review and respond to the recommendations contained in the *Climate Action Plan*. Specifically, respective agencies should report on how these issues and recommendations affect their missions and programs, provide action plans for integrating relevant issues into their

BayStat is a powerful new state-wide tool created by Governor Martin O'Malley in February 2007 to assess, coordinate, and target Maryland's Bay restoration programs and inform our citizens on progress. BayStat allows Maryland state agencies to work more effectively by coordinating efforts and programs, basing decisions on the best available science, targeting resources to get the biggest 'bang for the buck', and to be more open and accountable to Maryland citizens.

planning programs and activities, and participate in the development of performance measures.

Performance measures should be reported annually to track process and progress in adaptation to sea-level rise and associated hazards. In their initial evaluation report, agencies should consider opportunities for integration with existing programs, new programmatic efforts, and barriers to response. Topics for evaluation programs, policies, standards, and activities include: engineering, design, and construction; siting and planning; funding; coastal zone management activities, including permitting of shoreline activities and monitoring; staff training programs; and educational and outreach programs.

Implementation

The MCCC Executive Order calls for annual reporting on the *Climate Action Plan* to the Governor and General Assembly on or before November 1 of each year, including an update on implementation timetables and benchmarks. Adaptation and response performance measures will be a component of this reporting requirement. Additionally, performance measures will be implemented through BayStat and/or StateStat, powerful new statewide tools, created by Governor Martin O'Malley to make Maryland state government more accountable and efficient and to assess, coordinate, and target Maryland's Bay restoration programs. DNR and MDE will work together to implement this policy recommendation.

Future adaptation strategy development: Pursue the development of adaptation strategies to reduce climate change vulnerability among affected sectors, including agriculture, forestry, water resources, aquatic and terrestrial ecosystems, and human health.

The MCCC should continue to evaluate adaptation strategies in addition to sea-level rise and coastal vulnerability over the next year and beyond. The sector-based impact and issue assessments provided by the STWG (see Chapter 2) will serve as a useful basis for evaluation of adaptation strategies appropriate for Maryland in the areas of human health, water resources, forest management, and the restoration of the Chesapeake and Atlantic Coastal Bays.

Implementation

Phase II of the *Comprehensive Strategy to Reduce Maryland's Vulnerability to Climate Change* should be initiated within one year. Sector-based working groups, comprised of a broad array of stakeholders and issue experts, will be necessary to fulfill this task.

Chairs of the ARWG and STWG will begin working immediately to develop a more detailed implementation plan for development of Phase II and will present the plan to the Commission for its consideration at its Spring 2009 meeting.

ENDNOTES

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Jane Hawkey.

CHAPTER SIX

Building a Federal-State Partnership

Building a Federal-State Partnership

MARYLAND

Commission on Climate Change

August 2008

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Lessons Learned in Maryland

Building a Federal-State Partnership to Address Climate Change
Top 10 Things We Need From a Federal Program

1. A comprehensive national program that demonstrates leadership and allows the United States to be a strong, committed, pro-active voice in the international debate over global warming.
2. A strong effective national cap-and-trade program that creates a level playing field and directs allowance or auction proceeds to achieve greenhouse gas (GHG) reductions as expeditiously as possible.
3. A system, like the one now being piloted by the Regional Greenhouse Gas Initiative (RGGI), that insures that allowance or auction proceeds from a national cap-and-trade program are converted into maximum reductions in GHGs as quickly and efficiently as possible. Because the fastest path to GHG emission reductions is through energy efficiency and conservation, State and Local governments, working in partnership with citizens and the business community, are uniquely positioned to develop and implement programs to maximize energy efficiency, energy conservation and GHG reduction for each dollar spent.
4. Recognition of the strong connection between transportation choices and reducing GHGs in a process like the Clean Air Act's Transportation Conformity requirements to insure that GHG reduction efforts and transportation planning work hand-in-hand.
5. A process for coordinating with coastal states on adaptation policies.
6. A national program to implement the GHG reduction requirements of the California Low Emission Vehicle Program (CA LEV).
7. More and stronger national standards for energy efficiency (lighting, appliances, etc.).
8. Recognition that there is more a to comprehensive, national GHG reduction program than just cap-and-trade and that there is a critical role for State and Local governments in reducing GHG emissions from other critical areas like smart growth, transportation, energy efficiency, agriculture and programs to reduce Vehicle Miles Traveled (VMT) and adaptation.
9. Recognition and support for the comprehensive, cutting edge work, now being undertaken in many states to incubate and develop economy-wide climate action plans to address GHG reductions on all fronts.
10. A well funded, national research and development program to kick-start technological development, like clean-coal technologies, zero emission vehicles and new technologies for energy efficiency, that is needed to achieve very deep reductions in GHG emissions.

CLIMATE CHANGE MITIGATION

Spurred by the growing momentum of state leadership in climate protection, the U.S. Congress is now seriously engaged in shaping a federal climate policy centered around an economy-wide GHG cap-and-trade program. Seven cap-and-trade bills are currently working their way through the 110th Congress; one of them, the Lieberman-Warner Climate Security Act of 2008 (S.3036), was debated by the full Senate in June 2008. Although the bill was pulled from floor debate without moving to a final vote, it made history by being the first cap-and-trade bill to make it out of committee to the Senate floor. Seasoned observers see this as a "dress rehearsal" for a full debate and vote on comprehensive federal cap-and-trade legislation in 2009 under a new Administration and Congress.

The intervening months give Maryland and other leadership states and regional consortiums such as RGGI the opportunity to help shape the debate and architecture of the approaching federal regulatory regime. The Congressional cap-and-trade proposals would regulate GHG emissions primarily in the electric power generating, large manufacturing, and transportation fuels sectors. This is a good and necessary start. However, climate protection requires a comprehensive portfolio of GHG reduction strategies in all economic sectors and levels of government. In sectors not amenable to cap and trade (e.g. unregulated markets with many participants, such as small manufacturers and residential and commercial heating and power), the most cost-effective reductions are achieved through more decentralized policies, including regional standards and state-specific actions. Congress should actively engage the states and regional consortiums in shaping a federal climate policy built upon a federal-state partnership.

The Commission recommends that U.S. climate mitigation policy be structured according to the following principles:

- Ongoing federal-state consultation, collaboration, and information-sharing.
- National science-based mandatory GHG reduction goals.
- National cap-and-trade legislation covering GHG emissions from power plants, large industrial sources, and producers of transportation fuels and natural gas, with a meaningful role for states in allocations of allowances, use of auction revenues, and offset rules.
- National technical and performance standards and research and development (R&D) funding for technological advancement and improved energy efficiency in sectors not amenable to cap-and-trade, such as appliances, lighting, low carbon fuels and vehicle emissions.
- Amendment of the Clean Air Act and Surface Transportation Authorization Act to create a regulatory and funding framework for reducing GHG emissions in the transportation sector through State Implementation Plans (SIPs) and the Transportation Conformity Process. This must incorporate the synchronization of transportation, land use, housing, environment, social, and energy policies.
- No preemption of state governments that take more stringent actions than the federal government to reduce GHG emissions within their jurisdictions, with incentives for "first mover" states.

> "There is a long and proud history of federal leadership on environmental issues in this country ... together we can develop national programs to tackle greenhouse gas emissions ... we can transform our carbon based economy into a green sustainable economy."
>
> Governor Martin O'Malley
> September 2007

National Programs

Recommendation: The Commission urges Maryland to advocate for the Administration and Congress to adopt comprehensive climate protection legislation in the 111th Congress that establishes mandatory science-based GHG emission reduction goals for the United States necessary to avoid dangerous anthropogenic climate change, in accordance with the findings of the Intergovernmental Panel on Climate Change (IPCC). The goals should include short-term, medium-term (2020) and long-term (2050) reduction targets and should be updated periodically to reflect the best-available science.

Recommendation: The Administration and Congress should adopt comprehensive climate protection legislation in the 111th Congress that establishes a cap-and-trade program regulating GHG emissions from fossil fuel burning power plants, large stationary sources such as steel and cement manufacturers (downstream points of regulation), and oil and natural gas producers, importers and processors (upstream points of regulation).

Notably absent from most of the current Congressional bills is a role for states in decisions about critical components of a cap-and-trade program. Congressional legislation should provide states a meaningful role in deciding:

- How GHG emission allowances will be allocated (i.e. auctioned versus freely given to emitting sources);
- How auction revenues will be distributed and how states may use the revenues; and
- What percent of a source's reduction obligation can be met by offset credits, what types of offsets will qualify, and how will their validity be determined (i.e. are they "real, surplus, verifiable and permanent").

Recommendation: For certain economic sectors not amenable to cap-and-trade controls, the federal government should adopt national technical and performance standards for energy efficiency, and to fund research and development (R&D) for technological advancement. Standards for lighting, appliances, low carbon fuels, and vehicle emissions (using California's CA LEV standards), would be included in this category. State or regional standards that are more stringent than federal standards should not be preempted if the regulating jurisdiction(s) capture a certain percentage of the national market.

Recommendation: The Administration and Congress should amend the Clean Air Act (CAA) in the 111th Congress to create a regulatory and funding framework for states to reduce GHG emissions in the transportation sector, modeled after the Transportation Conformity Process and State Implementation Plans (SIPs) used for other criteria air pollutants under the CAA. Federal transportation funding to states should be re-aligned to favor mass transit projects over the construction and expansion of highway capacity, with financial incentives and disincentives for compliance or non-compliance.

Recommendation: The Administration and Congress should amend the Surface Transportation Authorization Act in the 111th Congress to establish appropriate and clear performance standards to minimize impacts from passenger and freight transportation systems and system improvements on GHG emissions while enhancing community and environmental quality. At the same time the amendments should reduce, and not increase, federal requirements on states or other transportation fund recipients to improve, not burden, program delivery.

Reforms relative to climate change should include provisions for each state to:

- Continue systematic and climate change sensitive planning to guide all investment to where it is most needed and useful;
- Certify that it has established performance-based, outcome-driven programming of funding in pursuit of climate change issues;
- Provide accountability for achieving results;
- Establish reforms in environmental reviews and permitting to speed project delivery. Federal planning requirements should also be simplified.
- Provide additional funding in the form of a "block grant" style approach to maximize flexibility for states to respond to climate change issues.

Recommendation: The Administration and Congress should provide research, technical assistance and guidance on linking transportation and land use planning to maximize the leverage on climate change and other transportation and environmental benefits from coordinated planning. The federal government should consider providing appropriate performance measures to help efforts to reduce GHG emissions and sequester carbon.

Non-Preemption of State Programs

Recommendation: The Administration and Congress should enact a savings clause in all federal climate legislation ***expressly*** not preempting state governments from taking more stringent actions than the federal government to reduce GHG emissions within their jurisdictions.

More than half of the U.S. states already have climate action plans and energy efficiency programs in effect or underway. This is the fastest and most cost-effective path to energy efficiency and GHG reductions. Despite this, federal policy is still in flux over states' authority to go beyond federal programs. The importance of express non-preemption language in federal statutes is underscored by EPA's recent denial of California's waiver petition to implement vehicle emissions standards (CA LEV) that result in greater fuel efficiency than the federal CAFE standards.

Express non-preemption would give Maryland and other states the autonomy to implement mitigation programs in areas within their traditional purview, such as land use and transportation (Smart Growth), building codes, roads, water, sewer and other infrastructure, agriculture, school curricula, and energy conservation.

Other non-traditional programs better suited to state implementation include Renewable Portfolio Standards (RPS) tailored to capitalize on the state's natural resources and economy, utilities' demand-side management programs, integrated resource planning by state public service commissions, and removing siting and regulatory obstacles to clean distributed generation.

Recommendation: The Administration and Congress should provide incentives for "first movers" – i.e. early action states that adopt goals and mandatory climate action plans by a specified date, with accountability requirements such as annual reporting and demonstration of adequate progress toward goals. (Incentives in current Congressional bills go to regulated entities rather than to states and thus do not directly promote state programs.)

Incentives to states could include:

- Authority to determine the appropriation and allowable uses of cap-and-trade auction funds in the state's jurisdiction (rather than the federal government);
- Authority to establish the state's own emission offset rules; and
- Priority for federal funds for research or other implementation programs.

The Supreme Court recognized the stake that states have in regulating GHG emissions in its seminal decision in *Massachusetts v. EPA* that GHGs are air pollutants subject to regulation under the CAA. The Court rebuffed the EPA's challenge to the State of Massachusetts' standing to bring the lawsuit. It found that as a state vulnerable to sea level rise, Massachusetts had important state interests to protect. Maryland of course is also vulnerable, but each of the fifty states faces its own set of global warming challenges and is in the best position to assess the risks and implement solutions.

The Administration and Congress should recognize the primacy of states as "first responders" in protecting the health, safety and welfare of their citizens, economies, natural resources, and built environments, and to leave them the autonomy to continue their leadership and be the "laboratories for innovation" in climate protection.

The recommendations below, specifically as they relate to the coordination of programs, policies, research, and information and the need for additional funding, are as relevant to Mitigation as they are Adaptation and should be considered for each.

CLIMATE CHANGE ADAPTATION

In the 110th Congress, Members have introduced numerous bills that would directly or indirectly address climate change. However, only a few of these bills address the issue of adaptation to climate change. Currently, there are no stand-alone adaptation bills; adaptation provisions are contained in broader legislation on climate action or research.

While mitigation of GHGs is necessary to help minimize future impacts, Maryland must prepare now to adapt and respond to existing and future impacts with the support of the next Administration and Congress. Because of earlier GHG emissions, some level of warming will occur regardless of mitigation activity. Maryland believes that the nation should strategically focus on preparing communities and natural systems to adapt to the effects of a changing climate.

With regard to adaptation, proposed federal legislation calls for research on the causes and effects of climate change and on methods to measure and predict climate change; and the authorization of grants or other incentives to affected communities (e.g., coastal communities) to prepare for the potential effects of climate change. Examples of pending legislation include the Lieberman-Warner Climate Security Act of 2008 (S.3036), the National Climate Program Act (S 2355), and the Global Change Research Improvement Act of 2007 (S. 2307).

Maryland has been collaborating with the Coastal States Organization* to document the nature and status of the coastal states' efforts related to climate change and has identified principles upon which any national adaptation legislation should be based. To facilitate effective coastal adaptation, the nation needs:

- A clear federal strategy for intergovernmental coordination on coastal adaptation to climate change;
- A coordinated research and information system implemented through observation systems and other tools;
- Federal funding to protect coastal communities and the national interest from the impacts of climate change; and
- To recognize the critical role of coastal states in adapting to climate change.

*The Coastal States Organization (CSO) was established in 1970 to represent the Governors of the nation's thirty-five coastal states, commonwealths and territories on legislative and policy issues relating to the sound management of coastal, Great Lakes and ocean resources.

Coordination of Federal Programs and Policies

Recommendation: The Administration and Congress should develop a national coastal adaptation strategy to ensure intergovernmental coordination on coastal adaptation to climate change; to clearly define the roles of various agencies; and to identify the mechanisms by which federal programs will coordinate with state partners on coastal adaptation issues.

During the development of the Maryland ***Climate Action Plan***, it became evident that a climate change adaptation strategy must address and proactively plan for a multitude of impacts on natural resources and resources-based industries, coastal communities, the economy, public and private infrastructure, as well human health and safety. Not only are the impacts broad, but the mechanisms to address the impacts are wide-ranging and involve research, data acquisition and management, mapping, modeling, monitoring, integrated planning, public awareness, outreach, training, capacity building, economic development and many others.

Adequate federal intergovernmental coordination is needed to ensure the most effective implementation and efficient use of funds, and to provide opportunities for complementary efforts among local, state, regional or national programs. A coordinated strategy would improve awareness and understanding of the resources available to states and local governments. A key component of this federal strategy for coastal adaptation should be a new and stronger focus on interagency cooperation between the National Oceanic and Atmospheric Administration (NOAA), state coastal management programs, the Federal Emergency Management Administration (FEMA), and state floodplain managers. In addition, because the impacts of climate change will vary regionally, an opportunity exists to develop a regional framework for federal-state coordination on climate change adaptation.

PROTECTING STATES' RIGHTS

In February of 2008, the National Associaltion of Clean Air Agencies (NACAA) convened an innovative two-day conference for local, state and federal government air pollution officials to discuss the role states and localities can and should play in federal climate change legislation and programs to combat global warming. The three key findings that emerged from this preliminary meeting are listed below. NACAA is continuing to discuss this issue.

- Most participants agree that a ***program of national emissions limits is necessary*** to ensure continuing progress in lowering GHGs and to demonstrate to the rest of the world that the U.S. is serious about reducing emissions. Moreover, most are familiar with ***cap-and-trade as a mechanism*** and support its application to GHG reduction.

- However, most participants also expressed the belief that a national cap-and-trade program, by itself, would not result in the GHG reductions that are needed or likely to be called for in national legislation. ***There was broad agreement that additional state and local policies and implementation activities would be needed to meet national goals.*** Those policies include building codes, land use and transportation planning, end-use energy efficiency programs and agriculture and forestry policies, among others.

- For this reason, most participants concluded that ***active participation by states is essential***. A related common theme in many sessions was that ***any apportionment value or auction proceeds should be made available to states for the purpose of implementing those essential, complementary programs***. Participants concluded that a national cap-and-trade program that does not support these techniques will be too expensive and likely ineffective in securing deep reductions.

More than once during the conference the comment was made that climate change regulation is a "brave new world" for state and local air officials, and that there is much we do not know and cannot anticipate right now. We face not just an "air" issue, but a multi-disciplinary, multi-agency, multi-venue set of challenges and opportunities. State and local air officials will be at the forefront in meeting climate challenges, and federal laws and agencies will need to forge creative and effective partnerships with them as part of any national program to meet GHG reduction goals.

Coordination with Coastal States

Recommendation: Congress and the Administration should recognize the critical role of coastal states in adapting to climate change, by:

- Reauthorizing the Coastal Zone Management Act with strengthened authorization for climate change-related activities; including funding to voluntarily develop and implement a coastal adaptation plan that recognizes the individual needs of each state while building into a proactive national strategy;
- Ensuring consultation with coastal states, in any new climate change legislation, programs, or research;
- Developing a strategy to identify the information needs of coastal states to effectively respond to natural hazards and ecosystem changes resulting from climate change;
- Coordinating federal agency activities, research, and data collection efforts related to coastal impacts of climate change with coastal states; and
- Clarifying the roles and responsibilities of coastal states and federal agencies in climate change adaptation activities. State authority and sovereignty should be strongly maintained in a national strategy to adapt to climate change.

Additional Financial Support

Recommendation: The Administration and Congress should provide funds over and above existing appropriations to meet the increasingly complex and unmet needs of the coastal states and their coastal communities to address the existing and emerging climate change adaptation challenges.

Maryland has used federal, state and local program funds to support climate change-related activities for research and data acquisition, as well as to expand technical, planning, and education activities needed to address key climate change adaptation issues and to build capacity.

Over the years, the State has benefited from a variety of federal funding sources, including NOAA, the Environmental Protection Agency, U.S. Army Corps of Engineers, FEMA, and the U.S. Geological Survey. Existing and additional federal funds will be needed to address the adaptation recommendations contained in the Climate Action Plan. Maryland is not alone in this need for federal funds. Many of the coastal states have significant mapping, monitoring, and research needs and need to strengthen state and local capacities for adaptation planning. This will require an unprecedented national investment and effort that will not succeed without the full engagement and support of the next Administration and Congress.

Monitoring, Assessment And Forecasting

Recommendation: The Administration and Congress should ensure that the nation has a coordinated climate change monitoring, assessment and forecast system implemented through appropriate observation systems and other tools. This will require advancing federal investments and programs for integrated observing systems and climate services. This should be done in partnership with the states, which will bear the primary responsibilities for mitigating the effects of climate change.

In general, there is insufficient monitoring of Maryland's climate, environmental conditions and resources to characterize their present state and variability. Because these will change more rapidly in the future, a better system of observations is required—one that is reliably continuous, strategically targeted, and thoroughly integrated. Reliable observations, interpreted with scientific understanding and innovative models, can dramatically reduce uncertainty about the path of climate change in Maryland and its consequences, allowing us to make better informed and wise decisions about the State's future. It is clear that traditional approaches to adaptation will not suffice in a future that no longer resembles the past. Climate models can be downscaled to incorporate locally important phenomena, such as urban heat island and forest cover effects, and resolve important differences across our slice of the mid-Atlantic landscape.

In recognition of the State's vulnerability to sea level rise and its ensuing coastal hazards, Maryland's state agencies have been aggressively acquiring and analyzing various data and technological resources both to gain a better understanding of sea level rise vulnerability and to increase the state and local government capacity to adapt and respond. To date, the State has amassed a significant amount of data and undertaken state-of-the-art research, making Maryland a national leader in sea level rise modeling, research and response planning. However, more work is needed and the State is seeking ways to support, enhance and integrate observation systems already in place in Maryland. The output of this effort will be a series of recommendations regarding how current observation networks could be reinforced and/or new components added to better address changing conditions regarding sea level rise.

In addition, the State also plans to review its institutional and organizational data management practices and make recommendations to enhance efficiency and cost effectiveness of data gathering, sharing, maintenance and processing efforts and to minimize duplication of effort and data and modeling redundancies. Effective federal, state, regional and local interagency integration and coordination of observation systems for sea level and other inundation threats will be critical to accomplishing these objectives.

CLIMATE CHANGE SCIENCE AND TECHNOLOGY

Recommendation: Maryland should develop a strategy to become a national and international center of excellence in climate change science and technology, based on targeted investments in its universities, strong partnerships with federal agencies and laboratories, and effective engagement of the private sector.

Maryland and the world will depend on increased and sustained investments and advances in science and technology to in order to understand how our climate is changing, predict future conditions in ways that allow adaptation to these new conditions, and provide the innovations required to mitigate greenhouse gas emissions while ensuring our economic and social well being.

Fortunately, Maryland is in a exceptionally strong position to be a national and international leader in regional-to-global climate change analysis and in technologies to mitigate emissions and allow prudent adaptation. There is already considerable, world-recognized expertise within our public and private universities on which to build. And, Maryland has the unmatched advantage of the location of the Goddard Space Flight Center, which leads the National Aeronautics and Space Administration's earth science program, at Greenbelt; the headquarters of the National Oceanic and Atmospheric Administration's line offices at Silver Spring and NOAA's Climate Prediction Center soon to be relocated to College Park; the National Institutes of Health in Bethesda; and the National Institute of Standards and Technology in Gaithersburg; among other federal agencies. In addition, Maryland has a robust private sector to support technology innovation and application, one that is also very experienced in providing services to the federal government.

Marshalling and enhancing this university-federal-private sector capacity to continually improve climate change forecasting and impact assessment and finding effective means to mitigate and adapt to climate change would greatly benefit not only our state, but our planet, Earth.

RGGI LETTER TO CONGRESS, OCTOBER 31, 2007
GUIDING & DESIGN PRINCIPLES FOR A FEDERAL GREENHOUSE GAS CAP-AND-TRADE PROGRAM

Guiding Principles:

- Take action now to establish strong, science-based emissions reduction requirements. A federal program should embody mid-term as well as long-term greenhouse gas emissions reduction requirements, with appropriate monitoring and a built-in mid-course review to ensure that necessary emissions are achieved.
- Periodically review climate science and adjust emissions reduction limits as needed.
- Pursue a portfolio of cost-effective policies and programs to reduce greenhouse gas emissions. A cap-and-trade program is an important tool for reducing emissions in some sectors (e.g., electric generating facilities and other large stationary sources), but may not be appropriate for all sectors.
- Respect state authority to implement state programs that are in addition to federal requirements. States that have undertaken early action have made considerable political and economic investments to achieve success in reducing greenhouse gas emissions. These efforts should be encouraged and rewarded. Federal programs should not punish early action by states, and should not reward states for failing to take early action.
- Investment in energy efficiency, clean energy technologies, and renewable energy should be a cornerstone of our national greenhouse gas emissions reduction and energy policies, as greater societal benefit is achieved when environmental and energy policies are aligned. These investments would reduce greenhouse gas emissions, promote energy independence and, in the case of energy efficiency, reduce costs to consumers. Sale of allowances could provide revenues to support, in part, such policies and investments.

Design Principles:

- In the electric power sector, allowances should be sold, in recognition that the majority of national electricity load is served in regions that have instituted competitive wholesale electricity markets. Resulting sales revenue should be used for cost-effective measures that both reduce our carbon footprint and enhance our economic competitiveness, such as end-use energy efficiency.
- Allow states to distribute sales revenue. States have a unique capacity to implement a portfolio of polices and measures that improve electric end-use energy efficiency and reduce electricity demand.
- New conventional coal-fired power plants constructed from this day forward should not be grandfathered under a federal cap-and-trade system, and should be required to purchase their allowances on the open market.
- Incorporate the use of emissions offsets a s flexibility mechanism that is designed to be supplemental to emissions reductions achieved within the capped sector or sectors.
- Design program provisons to ensure that emissions offsets are of high quality. Offset provisions should incorporate robust additionality criteria to ensure that eligible offsets represent incremental emissions reductions beyond those that would have otherwise occurred. Quantification and verification protocols should be rigorous and detailed, and apply conservative assumptions where appropriate. The process for accrediting the independent verifiers of offset projects should incorporate rigorous standards.
- Ensure that flexibility mechanisms that are incorporated into program design maintain the integrity of the cap and do not cause price distortions. Avoid the use of safety valves or price caps that functionally undermine the cap by allowing regulated facilities to submit an alternative compliance payment at a set price in lieu of the submission of allowances. Flexibility mechanisms employed should not distort long-term carbon price signals that are required to ensure that capital investiments under consideration today are properly evaluated based on their long-term emissions potential. Price distortions could actually increase the long-term costs to society of achieving significant greenhouse gas emissions reductions.
- Establish sound greenhouse gas reporting protocols to ensure that "a ton equals a ton," and to the extent practicable, utilize already existing reporting platforms such as The Climate Registry to avoid unnecessary duplication.

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CHAPTER SEVEN

Legislative Update and Next Steps

Cover Photo: Katy Perry

Legislative Update and Next Steps

Commission on Climate Change

August 2008

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LEGISLATIVE UPDATE

Early Action Recommendations

Nearly all of the Commission's ***Interim Report*** recommendations for 2008 legislation were acted on by the General Assembly in its 2008 Session. Although not all were adopted, on balance, the enacted measures will enable Maryland to build on existing programs and make progress on achieving early reductions in GHG emissions and reducing the vulnerability of its citizens, natural resources and built environment to sea level rise and other climate change impacts. Legislative "Early Action" highlights include:

- Adopting an Energy Efficiency Performance Standard
- Establishing a Publicly Administered Energy Investment Fund
- Requiring State Building Codes to Improve Energy Efficiency
- Strengthening Maryland's Renewable Portfolio Standard
- Updating Jurisdictional Boundaries of Bays Critical Areas
- Protecting Shorelines

Mitigation

Maryland Legislation

EARLY ACTION RECOMMENDATION: Adopt an Energy Efficiency Performance Standard (EEPS).

Enacted as "EmPOWER Maryland Energy Efficiency Act of 2008" (HB374).

The ***Interim Report*** recommended legislation requiring utilities to reduce per capita electricity consumption and peak demand by implementing energy efficiency programs targeted to consumers. It suggested pegging the reductions to Governor O'Malley's ***EmPOWER Maryland*** goal of reducing the State's per capita electricity consumption and peak demand by 15% by 2015. The Governor's initiative, announced in July 2007, is one of the nation's most ambitious energy efficiency targets. It was codified in the ***EmPOWER Maryland*** legislation in the 2008 Session, introduced at the Administration's request. According to the Maryland Energy Administration (MEA), the law will save Maryland households on average $16 a month or $190 each year when fully implemented. To meet the law's targets, utilities are expected to establish a range of cost-effective programs to reduce consumer bills, such as:

- Rebates for the purchase of ENERGY STAR® appliances
- Incentives for home energy audits and improvements
- Voluntary seasonal payments for the use of interruptible load devices on air conditioners
- Incentives to construct more energy efficient homes.

According to other reports prepared for MEA, when ***EmPOWER Maryland*** is successfully implemented, it will:

- Generate $5.7 billion in total electricity savings for Maryland households
- Avoid using 10 billion kWh of electricity in 2015, which is enough to power one-third of Maryland's homes that year
- Prevent the need to build at least three new large power plants, which reduces the state's carbon footprint and avoids billions of dollars in new costs
- Add 8,000 new "green collar" jobs to the Maryland economy by 2015. This is the equivalent of 100 new manufacturing plants relocating to Maryland, without the costs for infrastructure.

EARLY ACTION RECOMMENDATION: Create a Publicly Administered Energy Investment Fund.

Enacted as "Regional Greenhouse Gas Initiative – Maryland Strategic Energy Investment Program" (SB268/HB368).

To meet the ***EmPOWER Maryland*** goals, the Commission recommended that Maryland create a publicly administered energy investment fund for energy efficiency programs, using revenues generated from the Regional Greenhouse Gas Initiative (RGGI). By request of the Administration, legislation was introduced and passed codifying this recommendation. It creates the Maryland Strategic Energy Investment Fund that creates a revenue stream for designated programs from the sale of carbon allowances to power plants as part of RGGI, which Maryland joined pursuant to the 2006 Healthy Air Act. A portion of the fund revenues will be returned to ratepayers to offset their utility bills.

The fund will allow MEA to provide services to traditionally underserved markets, such as providing window air conditioner and refrigerator exchange programs to low-income residents and providing below-market financing to encourage energy efficiency investments by homeowners and small businesses.

This fund also allows Maryland to take control of its energy future by investing in energy efficiency and conservation programs, promoting renewable energy, stimulating Maryland's emerging clean energy industry and sponsoring other programs to reduce climate change impacts in Maryland.

EARLY ACTION RECOMMENDATION: Amend State Building Codes to Improve Energy Efficiency.

Enacted as "High Performance Buildings Act of 2008" (SB208).

This Administration bill, as passed, requires all new and significantly renovated State buildings over 7,500 square feet, and all new public schools that receive state construction funds, to meet the LEED Silver green building standard. While not going as far as the Commission's early action recommendation to amend building codes state-wide to incorporate green building design and energy efficiency performance standards, the legislation aligns with the recommendation in the Commission's Policy Option RCI-4, "Government Lead by Example", that new and renovated State buildings be LEED certified. (RCI-4 is described and analyzed in detail in Chapter 4 and Appendix D-3 of this ***Climate Action Plan***.)

EARLY ACTION RECOMMENDATION: Strengthen Maryland's Renewable Portfolio Standard (RPS).

Enacted as "Renewable Portfolio Standard Percentage Requirements – Acceleration" (SB209/ HB375)

This legislation increases Maryland's renewable portfolio standard (RPS) percentage requirements and the fee charged to electric suppliers for shortfalls beginning in 2011. Introduced as Administration bills, the legislation closely tracks the ***Interim Report*** recommendation. Its features include the following:

- Increases the RPS requirement to 20% by 2022, including a 2% level for solar.
- Limits the geographic scope to generation resources located within the PJM region to promote generation on Maryland's grid, or adjacent the PJM region if the electricity supplied is going to the PJM.
- Increases the Alternative Compliance Payment (penalty for failure to comply) to ensure that the RPS will be effective.

A related bill, ***"Renewable Energy Portfolio Standard – Tier 1 Renewable Source – Poultry Litter" (SB348/HB1166)*** (passed), encourages the use of poultry litter as a source of energy by making it a Tier 1 renewable source within the RPS.

EARLY ACTION RECOMMENDATION: Adopt Legislation Requiring Maryland to Develop and Implement Programs to Reduce GHG Emissions 25% by 2020 and 50% by 2050.

Introduced but not adopted: "Global Warming Solutions – Reductions in Greenhouse Gases" (SB309 and HB712)

The Global Warming Solutions (GWS) bill was introduced by Senator Paul Pinsky and Delegate Kumar Barve (both Commission members) as lead co-sponsors and was supported by the Administration. The General Assembly concluded its 2008 session without taking final action on the bill.

If adopted, the GWS bill would have legislated a core recommendation of the ***Interim Report*** establishing a mandatory goal of reducing the State's GHG emissions 25 per cent below 2006 levels by 2020, using a suite of regulatory programs.

As amended, the GWS bill also called for Maryland to establish a goal to reduce GHG emissions in Maryland by 90% below 2006 levels by 2050, with four-year updates including a summary of the state of the science. The Commission's recommended non-regulatory reduction targets of 10% below 2006 levels by 2012 and 15% below 2006 levels by 2015 were included as early action benchmarks.

Also included in the GWS bill were Commission recommendations for offset allowances, including carbon sequestration projects, and credit for voluntary early reductions. The bill's requirements for a statewide GHG inventory and emissions monitoring and reporting by sources also tracked the ***Interim Report*** recommendations.

Federal Legislation

EARLY ACTION RECOMMENDATION: Increase Lighting Efficiency Standards.

Enacted as part of Federal "Energy Independence and Security Act" (EISA) (P.L. 110-140, H.R. 6).

This legislation, which Congress passed in December 2007, includes improved standards for appliances and lighting. Light bulbs sold in and after 2012 will be required to be 25 per cent more efficient. The sale of most incandescent light bulbs will be banned. Exempt from this ban are various specialty bulbs, including appliance bulbs, colored lights, and 3-way bulbs.

Adaptation

EARLY ACTION RECOMMENDATION: Update Jurisdictional Boundaries of Chesapeake and Atlantic Coastal Bays Critical Areas

Enacted as "Chesapeake and Atlantic Coastal Bays Critical Area Protection Program" (HB1253/SB844).

The ***Interim Report*** highlighted the need for legislative action to:

- protect and restore Maryland's natural shoreline and its resources (e.g., tidal wetlands and marshes, vegetated buffers, Bay islands) that inherently shield Maryland's shoreline from the impacts of sea level rise and coastal storm events; and
- promote programs and policies that reduce the impacts of sea level rise to future growth and development in areas vulnerable to sea level rise and its ensuing coastal hazards.

While the State's existing Chesapeake and Atlantic Coastal Bays Critical Area Protection Program has fostered more sensitive development activities along Maryland's shorelines since 1984, the ***Interim Report*** acknowledged the need to modify several components of the Program, including updating the Critical Area boundary. The current boundary is based on 1972 State wetlands maps that no longer reflect the location of the shoreline due to shoreline changes, erosion, sea level rise and inherent inaccuracy of the original maps.

By request of the Administration, legislation was introduced and passed that called for the State to create new Critical Area maps for each local jurisdiction. The new maps will be based on the Statewide Base Map (iMAP) using aerial imagery obtained in 2007 and 2008. In addition, the State is now required to establish a process and standards for future map and boundary updates to accommodate future changes in shoreline conditions and sea level rise.

As part of this enacted legislation, the General Assembly also instituted a variety of changes that should ultimately help Maryland protect its shoreline and natural resources and reduce the impacts of sea level rise and coastal flooding in areas of future growth and development.

In general, the changes:

- provide greater authority to the Critical Area Commission;
- update the basic components of the program;
- enhance buffer and water quality protection;
- coordinate new development more closely with growth management policies and other environmental protection/planning processes; and
- strengthen enforcement and variance provisions.

EARLY ACTION RECOMMENDATION: Develop a Unified Approach to Shoreline Management.

Enacted as "Living Shoreline Protection Act" (HB973).

The Commission's ***Interim Report*** included a recommendation that the State develop a unified approach to shoreline management by pursuing several executive, legislative, and programmatic actions. One key objective of these actions is to ensure that the most suitable method of shore protection is used to protect property from erosion while also protecting, restoring or enhancing natural shoreline habitat.

The Living Shoreline Protection Act of 2008 requires improvements to protect a person's property against erosion shall consist of nonstructural shoreline stabilizations measures (i.e., living shorelines) except where the person can demonstrate that such measures are not feasible. The Act also requires MDE, in consultation with the Department of Natural Resources (DNR), to adopt regulations to implement specific provisions.

"Living shorelines" are shoreline management practices that provide erosion control benefits by protecting, restoring or enhancing natural shoreline habitat. Through the strategic placement of plants, stone, sand fill and other structural and organic materials, these approaches help maintain important coastal processes occurring on natural shorelines, especially the physical, hydrologic, and biological connections between upland, wetland, and aquatic zones.

Other Legislation

Maryland

The General Assembly passed several other bills that will yield GHG reductions and will improve Maryland's ability to adapt and respond to climate change impacts. Although not recommended as Early Action items, they are highlighted here and their alignment with policy options recommended in this ***Climate Action Plan*** is noted. The policy options are described and analyzed in detail in Chapters 4 and 5 and Appendices D and E of this ***Plan***.

"Solar and Geothermal Tax Incentive and Grant Program" (SB207/HB377)

This Administration bill passed, increasing grant awards and tax incentives for both solar and geothermal systems. It addresses shortcomings in Maryland's existing solar/geothermal grant and tax incentive program administered by the Maryland Energy Administration (MEA).

Maryland's tax system has imposed a significant barrier to residents who want to invest in clean energy systems for their homes. The sales tax on solar systems alone would cancel much of the State grant used to encourage Marylanders to invest in solar power. In addition, the current grants provided by MEA for solar energy and geothermal heating have proved to be too low to induce significant household participation. By increasing grants and tax incentives, the new legislation will increase investments in clean energy, increase supply, and promote energy security through distributed (as opposed to centralized) generation.

The legislation provides the following:

- For solar (photovoltaic) energy systems, increases the grant to $2,500 per kilowatt installed with a cap of $10,000.
- For solar water heaters, increases the grant to $3000 or 30% of system cost.
- For geothermal heating systems, increases the grant up to $1,000 per ton with a cap of $3,000 for residential customers and $10,000 for non-residential systems.
- Exempts all solar and geothermal systems from state sales tax and local property tax valuation.

The legislation aligns with the Commission's Policy Option ES-5, "Clean Distributed Generation", which includes a recommendation for subsidies and tax credits to buyers of distributed renewable energy technologies.

"Maryland Transit Administration – Transit–Oriented Development" (HB373/SB204)

This legislation explicitly supports and promotes transit–oriented development throughout the state as being in the interest of the citizens of the state and as a critical element of a high functioning transportation system and efficient energy use.

This legislation aligns with Policy Option TLU-2, "Integrated Planning for Land Use and Location Efficiencies", which includes a recommendation to adopt State planning process reforms that encourage more compact and transit-oriented development.

Transit-oriented development" means a mix of private or public facilities – such as parking facilities, commercial and residential structures, that are part of a deliberate development plan or strategy involving property that is located within one-half mile of the passenger boarding and alighting location of a planned or existing transit station. This type of development is designed to maximize the use of transit, walking, and bicycling by residents and employees of the TOD area, and is formally designated as a TOD area by the Secretary of Transportation in consultation with other State agencies and the local government or multi-county-agency with land use and planning responsibility for the relevant area.

"Maryland Clean Energy Center" (HB1337)

This legislation will promote and assist the development of clean energy jobs and industry in the State and establishes the Maryland Clean Energy Technology Incubator Program. Working in coordination with MEA, the Center (MCEC) will lead a collaborative effort of all of Maryland's existing resources to: (1) advocate and promote clean energy industries and green jobs in Maryland; and (2) drive development of the State's energy efficiency and renewable energy resources. MCEC will also help identify funding sources and tie together industry, universities, research and State agencies around these goals.

This legislation aligns with:

Policy Option ES-2, "Technology Focused Initiatives for Electricity Supply" which recommends State funding and incentives for clean energy technology R&D.

Policy Option CC-9, "Promote Economic Development Opportunities Associated with Reducing GHG Emissions in Maryland", which supports continued funding for MCEC and calls for the State to work with public and private entities to identify, promote, and finance opportunities for economic development of green industries, green collar jobs and energy efficiency.

"The Jane E. Lawton Loan Program" (SB885/HB1301)

This legislation consolidates the existing Community Energy Loan Program and Energy Efficiency and Economic Development Loan Program into the Jane E. Lawton Loan Program to provide financial assistance in the form of low interest loans to nonprofit organizations, local jurisdictions, and eligible businesses for projects to conserve energy, reduce consumption of fossil fuels and improve energy efficiency.

This legislation aligns with Policy Option RCI-3, "Low-cost Loans for Energy Efficiency", which recommends the creation of revolving low-interest loan fund(s) to improve the energy efficiency of buildings. The policy is designed to include small businesses in its initial target group and later expand to larger businesses and the industrial sector.

"Omnibus Coastal Property Insurance Reform Act" (HB1353)

Insurance is a central, cross-cutting element to an overall climate change adaptation strategy. The insurance industry faces sea level rise, coastal erosion, and increased likelihood of severe storms, including hurricanes. It is clear that climate change is likely to have widespread impacts on the insurance industry, and is also likely to have significant impacts on the financial condition of insurers and reinsurers, the ability to pay future claims, and hence on the availability and affordability of insurance to Maryland's citizens and businesses.

The Omnibus Coastal Property Insurance Reform Act was a direct result of the Legislative Task Force created by HB 1442 during the 2007 legislative session. Several new sections were added to the Insurance Article. These sections:

- Prohibit an insurance carrier that writes homeowners' insurance policies in Maryland to have a "Hurricane or Storm" deductible in an amount greater than 5% of Coverage A (or 5% of the dollar limit on the dwelling) absent the Insurance Commissioner's prior approval.
- Require insurance companies to provide discounts to homeowners who take steps to harden their homes against storm related losses. Any mitigation efforts undertaken by the homeowner that will reduce the amount of damage or loss following a storm will result in a credit towards the homeowner's insurance premium.
- Address the growing use of catastrophe modeling by insurers by requiring some disclosure about the model.
- Require the Maryland Department of Housing and Community Development to review the current statewide building codes and to develop enhanced building codes for the coastal areas of the State that will promote disaster-resistant construction.

This legislation should help protect Maryland homeowners and encourage them to undertake mitigation to protect their homes from storm related damages. This legislation complements the other Commission recommendations that address building code revisions, integrated planning, and modeling potential impacts by taking a proactive approach to reducing risk, avoiding future costs, and helping the state to maintain insurability of investments.

Federal

"Reconciliation Omnibus Act" (H.R. 2764).

As part of its omnibus spending bill for FY2008, Congress appropriated funds to the Environmental Protection Agency (EPA) to adopt rules requiring the mandatory reporting of GHGs in all sectors of the U.S. economy. The stated purpose is to provide data that will inform and support development of national climate policy. The mandate covers all six GHGs and both upstream and downstream sources. Upstream sources include fuel and chemical producers and importers (e.g., oil refineries, natural gas processors, HFC producers). Downstream sources include GHG emitters such as power plants, iron and steel plants and cement manufacturers. EPA will establish reporting threshold levels. It is directed to publish draft rules by September 2008 and adopt final regulations by June 2009. It will build on the work of existing mandatory and voluntary GHG registries such as The Climate Registry, of which MDE is a founding member.

This federal mandate aligns with Policy Option CC-2, "Reporting and Registry", which recommends the establishment of a GHG emissions reporting system and registry for Maryland sources.

NEXT STEPS

The ***Climate Action Plan*** is a planning document. With its completion, the work of implementing the Commission's recommended mitigation and adaptation strategies now begins. The Executive Order that established the Commission does not have a sunset provision; it calls for an annual report to the Governor and General Assembly every November.

"H. Reporting. The Commission shall report to the Governor and General Assembly on or before November 1 of each year including November 1, 2007 on the ***Plan of Action***, including an update on development of the ***Plan of Action***, implementation timetables and benchmarks, and preliminary recommendations, including draft legislation, if any, for consideration by the General Assembly."
Executive Order 01.01.2007.07, Commission on Climate Change.

Thus, the Commission will continue to operate, re-orienting its work toward implementing the ***Plan***.

Create Institutional Capacity

The first and fundamental task is to build the institutional capacity within State government to address climate change comprehensively and systematically (Policy Option CC-7). Sustained progress toward the Commission's 2020 and 2050 GHG reduction goals and adaptation objectives depends on this continuity of structure and commitment.

The Commission agrees that institutional capacity changes will be needed to implement this ***Plan***. The following are options Maryland's government needs to consider and implement to ensure the goals established by the Commission are met:

1. Adopt the Commission's recommended 2020 and 2050 GHG reduction goals and 2012/ 2015 interim targets as Maryland's goals (Policy CC-3).
2. Create an Office of Climate Change within the Governor's office to oversee and coordinate ***Plan*** implementation across all executive departments and agencies of State government.
3. Prepare and issue a statewide Inventory and Forecast of GHG emissions in 2009 and periodically update it (Policy CC-1).
4. Establish a system for mandatory GHG emission reporting to MDE, starting with large stationary sources in Maryland and expanding to other sources, to dovetail with regulations to be issued by the U.S. Environmental Protection Agency in 2008-09 for mandatory reporting. Start implementation by amending COMAR 26.11.01.05. –1 or 26.11.02.19D. to expressly require reporting of GHG emissions by sources required to report other criteria air pollutants. (Policy CC-2).
5. Establish a statewide Registry to enable emitting sources to record GHG reductions as a foundation for building inventories and forecasts and for establishing "banking" credits for trading programs and offsets (Policy CC-3).
6. Adopt and broadly disseminate a policy ensuring that State credit will be given to emitting sources that take early actions to reduce their GHG emissions. Begin the process for quantifying these credits through RFPs for banking and offsets protocol, 3rd party certification of offsets, accreditation of certifiers, grandfathering cutoff dates, and related issues.
7. Adopt a policy that credits already registered in The Climate Registry or other credentialed registry with high integrity will be given credit under Maryland GHG control programs, to the extent not preempted by existing or future federal law.
8. Government Lead by Example: implement the GHG reduction measures by State agencies as recommended in Policies CC-4 and RCI-4 and as directed in existing executive orders.
9. Require State agencies and other large capital project sponsors to perform a Climate Impact Assessment under an approved State protocol prior to undertaking new capital projects, including build / no-build analysis and examination of alternatives with lower GHG emissions impacts, and assessment of the project's impact on adaptation issues. (This recommendation builds on Policy TLU-11).
10. Create a statewide Education/Outreach

program that incorporates the elements of Policy CC-5 and ARWG Common Option - Public Awareness, Outreach, Training & Capacity Building, building on the groundwork laid by the Commission's newly formed Education and Outreach work group.

11. Establish a framework for future work by the Commission, including annual Fall ***Climate Action Plan*** updates, and the formation of work groups recommended in the ***Plan*** or otherwise advisable.
12. Direct Maryland's State agencies to work together to "lead by example" by demonstrating and implementing sound climate change and sea level rise adaptation and response measures on state lands and through the allocation of state fiscal resources.
13. Adaptation-Stat: Develop and implement a system of performance measures to track Maryland's success at reducing its vulnerability to climate change and sea level rise.

Develop Agencies' Implementation Plans

Although implementation of some of the Commission's policy options is already underway, a number of them will require more analysis and refinement by State agencies and other appropriate entities before implementation can occur. The Commission recommends that this additional work begin immediately. Each of the MWG's forty-two policy summaries in Chapter 4 and the ARWG's nineteen policy summaries in Chapter 5 identifies the lead agency for implementing that policy. Program development will in many cases require cooperative effort from supporting agencies. Working with these agencies, the lead agencies will in the months ahead develop a more detailed implementation plan for each policy recommendation, and will present them to the Commission for its consideration in its Spring 2009 meeting. Many of the strategies involve the creation of a work group, task force or other stakeholder process. The lead implementing agency shall be responsible for establishing any such groups as part of the implementation plan.

Each implementing agency will provide a status report, timeline and overview of the implementation plan at the Commission's November 2008 and Spring 2009 meetings.

Develop Future Adaptation Strategy

The Commission should continue to evaluate adaptation strategies to reduce climate change vulnerability among affected sectors. The sector-based impact and issue assessments provided by the Scientific and Technical Working Group (STWG) in Chapter 2 will serve as a useful basis for evaluation of adaptation strategies appropriate for Maryland in the areas of human health, water resources, forest management, and the restoration of the Chesapeake and Maryland Coastal Bays.

Phase II of the *Comprehensive Strategy to Reduce Maryland's Vulnerability to Climate Change* should be initiated within one year. Sector-based working groups, comprised of a broad array of stakeholders and issue area experts, will be necessary to fulfill this task.

The ARWG and STWG Chairs will begin working immediately to develop a more detailed implementation plan for development of Phase II and will present the plan to the Commission for its consideration in its Spring 2009 meeting.

"... But we cannot go it alone. We need our federal government.

There is a long and proud history of federal leadership on environmental issues in this country. Many environmental issues are inherently local and appropriately dealt with at the state level. But from Teddy Roosevelt and the very first national parks to President George H.W. Bush and the Clean Air Act, we have always relied on strong action from Washington to protect the water, air and land that we love. We desperately need that leadership now.

Together, we can develop national programs to tackle greenhouse gas emissions – from fossil fuel burning power plants, from cars and buildings, and from other sources. We can transform our carbon based economy into a green, sustainable economy – an economy that does not prolifically emit greenhouse gases into the atmosphere as a byproduct of progress. Economic progress at the cost of environmental sustainability is not progress at all. And we can proactively plan for the consequences of climate change in our coastal zone plans, in our flood programs and in our national policies."

Governor Martin O'Malley
September 26, 2007

Photo: Mary Jane Rutkowski