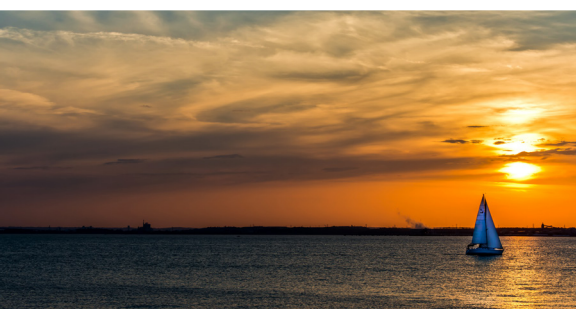
2017 ANNUAL REPORT

Maryland Commission on Climate Change

Prepared for:

Governor Larry Hogan
State of Maryland

and the Maryland
General Assembly



Commission Membership

Commission Chair

Secretary Ben Grumbles
Maryland Department of the Environment

Co-Chair

Anne Lindner
Business Community Representative

Stuart Clarke
Philanthropic Organization Representative

Commission Members

Nancy K. Kopp
Maryland State Treasurer

Secretary Joseph Bartenfelder
Maryland Department of Agriculture

Secretary Pete Rahn
Maryland Department of Transportation

Acting Secretary Robert McCord
Maryland Department of Planning

Donald Boesch
Professor at UMCES

Russell Dickerson
Climate Change Expert

Senator Paul G. Pinsky
Member of the Senate

Lori Arguelles
Environmental NPO Representative

Jim Strong
Organized Labor Representative

Michael Powell
Business Community Representative

Councilwoman Deni Taveras
Maryland Association of Counties

Charles Deegan
Chair of Critial Area Commission

Karen Salmon
Superintendent of Maryland Schools

Secretary Mark Belton
Maryland Department of Natural Resources

Secretary Ellington Churchill
Maryland Department of General Services

Mary Beth Tung
Director of Maryland Energy Administration

Chuck Fry
Agriculture Community Representative

Jane Kirschling
Public Health Expert

Delegate Dana Stein
Member of the House of Delegates

C. Richard D'Amato
Philanthropic Organization Representative

Mike Tidwell
Environmental NPO Representative

Larry Kasecamp
Organized Labor Representative

Commissioner Michael Bibb
Maryland Municipal League

Table of Contents

Executive Summary 1

Chapter 1 - Introduction 3
- **1.1** The Science of Climate Change . . . 3
- **1.2** History and Structure of the Commission . . . 6
- **1.3** Report Overview . . . 7

Chapter 2 - State of Maryland: Present & Future 8
- **2.1** Maryland's Environment . . . 9
  - 2.1.1 *Maryland Ecosystems* . . . *9*
  - 2.1.2 *The Built Environment* . . . *11*
- **2.2** Jobs and the Economy . . . 13
  - 2.2.1 *Agriculture, Fisheries and Forestry* . . . *13*
  - 2.2.2 *Tourism* . . . *15*
  - 2.2.3 *Energy* . . . *16*
- **2.3** Public Health and Equity . . . 16
  - 2.3.1 *Extreme Heat and Air Quality* . . . *17*
  - 2.3.2 *Water Quality, Extreme Precipitation, and Infectious Disease* . . . *19*
  - 2.3.3 *Food and Energy Security* . . . *19*
  - 2.3.4 *Equity* . . . *21*

Chapter 3 - Policy & Progress 22
- **3.1** The 2016 Greenhouse Gas Emissions Reduction Act (GGRA) - Reauthorization . . . 22
- **3.2** Progress towards the 2020 Goals . . . 22
  - 3.2.1 *EmPOWER Maryland* . . . *23*
  - 3.2.2 *The Maryland Renewable Energy Portfolio Standard* . . . *23*
  - 3.2.3 *The Regional Greenhouse Gas Initiative* . . . *24*
  - 3.2.4 *Other Energy Programs* . . . *24*
  - 3.2.5 *Transportation Initiatives* . . . *26*
  - 3.2.6 *Zero Waste* . . . *28*
  - 3.2.7 *Managing Forestry and Agricultural Lands* . . . *28*
  - 3.2.8 *Land Use Development* . . . *30*
- **3.3** Long-Term Goals: Beyond 2020 . . . 31
  - 3.3.1 *Emerging Technologies* . . . *31*
- **3.4** The Role of the Maryland Commission on Climate Change . . . 35
- **3.5** Federal Efforts . . . 35

Chapter 4 - Recommendations 37
- **4.1** Commission Recommendations . . . 37
- **4.2** 2017 Working Group Recommendations . . . 40
  - 4.2.1 *Adaptation and Response Working Group* . . . *40*
  - 4.2.2 *Education, Communication and Outreach Working Group* . . . *41*
  - 4.2.3 *Mitigation Working Group* . . . *42*
  - 4.2.4 *Scientific and Technical Working Group* . . . *42*

Works Cited 44

Appendices
- Working Group Recommendations . . . A-1
  - *Adaptation and Response Working Group* . . . *A-1*
  - *Education, Communication and Outreach Working Group* . . . *A-4*
  - *Mitigation Working Group* . . . *A-6*
  - *Scientific and Technical Working Group* . . . *A-9*
- Commission and Working Group Rosters . . . A-16
  - *Maryland Commission on Climate Change* . . . *A-16*
  - *Adaptation and Response Working Group* . . . *A-18*
  - *Education, Communication and Outreach Working Group* . . . *A-19*
  - *Mitigation Working Group* . . . *A-20*
  - *Scientific and Technical Working Group* . . . *A-22*
- An Act Concerning the Maryland Commission on Climate Change (House Bill 514) . . . A-23
- Acronyms . . . A-33
- Photo Credits & Licensing . . . A-34

Executive Summary

The climate of a region is defined by its long-term average temperature and precipitation trends, which shape many of the physical, chemical, and biological components of ecosystems as they develop. Significant and rapid changes in the climate, therefore, are expected to have pervasive and in some cases devastating impacts to ecosystems, and consequently to the resources and services upon which humans rely *{Ch1.1}*. The body of scientific evidence for global climate change is both clear and growing, and has demonstrated with a very high degree of certainty that the dominant cause is human activities, particularly the emission of heat-trapping greenhouse gases (GHGs) into the atmosphere *{Ch1.1}*. Maryland is facing consequences of climate change including, but not limited to *{Ch1.1; Ch2}*:

- Changes expected to negatively impact coastal, bay, and inland water quality parameters and potentially change the viable uses of surface water, such as irrigation, recreation, or human consumption;
- More frequent disruptions to urban and coastal infrastructure in Maryland caused by extreme weather events and sea-level rise that may indirectly impact the economy of the region by restricting the flow of goods and affecting days worked;
- Common stressors experienced among ecosystems, agriculture, fisheries and forestry, such as those caused by general changes in temperature and precipitation regimes; increased extreme weather events; and increased pressures from weeds, diseases and pests;
- Changes in the severity, frequency, or distribution of human health issues which are affected either directly or indirectly by climate, including impacts on food and water supply, air quality, and extreme weather events;
- A higher probability of negative outcomes for individuals and communities inherently more sensitive or with a reduced adaptive capacity for responding to the impacts of climate change.

The Maryland Commission on Climate Change, initially established in 2007, has played an integral role in Maryland's efforts to combat climate change, beginning with its 2008 Climate Action Plan that catalyzed the Greenhouse Gas Reduction Act (GGRA) of 2009 *{Ch1.2}*. The Commission is currently working in concert with the Maryland Department of Environment and other State entities to develop a plan to reduce its emissions by 40 percent from 2006 levels by 2030, as required by the updated GGRA of 2016 *{Ch3.1; Ch3.4}*. The Commission utilizes the best science available in order to move forward with progress on limiting climate change (or mitigation) and adapting to the changes that do occur, keeping open lines of communication in both directions with the residents of Maryland.

This report includes an update on the science of climate change; how the changing climate is already impacting Maryland's ecosystems, infrastructure, and socioeconomic framework; and how the changing climate is expected to impact the State in the future. It culminates in progress being made to address the projected changes and the State's emission reduction requirements at various points along the timeline, and the Commission's recommendations to the State and State agencies to continue the path forward. In order to protect the State's economy, the local environment, and the health of Maryland's citizens, it is crucial that the State maintain its aggressive course of mitigation and adaptation actions. At the same time, it is important to remember that climate change is a global problem, and Maryland's programs and policies must be part of a larger climate action plan to be broadly effective at preventing many of the costs of unmitigated climate change to the State.

Over the course of 2017, the Commission has developed recommendations for the State of Maryland for mitigation of and adaptation to the likely consequences and impacts of climate change, including strategies to reduce Maryland's GHG emissions as outlined in the GGRA. These recommendations are laid out in Chapter Four as they relate to the GGRA Programs, Transportation Sector Emissions, Healthy Soils, Environmental Justice, Federal Issues, and Public Outreach. The State will rely upon the leadership of its agencies, and participation from all sectors and stakeholders, in order to achieve the goals and recommendations outlined.

Public involvement is also crucial to the Commission process, especially as work is concluded in 2018 to make recommendations related to MDE's draft 40 by 30 Plan, due in December. Stakeholders and members of the public are encouraged to share their thoughts on areas of interest with the Commission expeditiously, to allow ample time for review and consideration, and are welcome to attend meetings of the Commission and its working groups. Meeting information about is posted at http://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Pages/index.aspx. Each meeting has time set aside for public comment. Written comments can be sent to climate.change@maryland.gov or mailed to Maryland Department of the Environment, 1800 Washington Blvd, Baltimore, MD 21230.

1 Introduction

1.1 The Science of Climate Change

In its previous reports, beginning in 2008 and continuing through its *2016 Annual Report*, the Maryland Commission on Climate Change (MCCC) has relied upon the latest and most widely accepted science to guide its evaluations and recommendations. The body of scientific evidence for global climate change is both clear and growing, and has demonstrated with a very high degree of certainty that the dominant cause is human activity,[1, 2, 3, 4] particularly the emission of heat-trapping greenhouse gases (GHGs) into the atmosphere.[2, 3, 4, 5, 6, 7, 8, 9] The Intergovernmental Panel on Climate Change (IPCC) found that these anthropogenic GHG emissions (including carbon dioxide, methane, and nitrous oxide) have increased considerably since the pre-industrial era and are currently at atmospheric concentrations "unprecedented in at least the last 800,000 years".[1] The IPCC concluded that the effects of these and other anthropogenic drivers are "extremely likely to have been the dominant cause of the observed warming since the mid-20th century".[1] Additional statements affirming the occurrence, danger, and anthropogenic nature of climate change have been issued by many reputable U.S scientific organizations and national science academies.[10, 5, 11, 7, 8, 12, 13, 9, 14] Furthermore, the consensus among experts in the scientific community continues to be reinforced, as reflected in studies that have found 90 to 100 percent of climate scientists publishing peer-reviewed research agree that the current global warming trend has anthropogenic causes.[15]

The climate of a region is defined by its long-term average temperature and precipitation trends,[16] which shape many of the physical, chemical, and biological components of ecosystems as they develop. Significant and rapid changes in the climate, therefore, are expected to have pervasive and in some cases devastating impacts to ecosystems, and consequently to the resources and services upon which humans rely. While both eco- and human systems have a certain capacity to adapt to change, these mechanisms operate most effectively over a much longer time scale and may have limited success at the unprecedented speed at which effects are currently progressing. Continuation of society down a "business as usual" path will increase the likelihood and severity of potentially irreversible impacts to the global ecosystems and interconnected human system.[1] Yet, as very active modifiers of the environment, humans also have the ability to affect the outcome; actions taken at this time are still capable of lessening the damage of future impacts.[1, 4] Moreover, an urgent response is crucial to minimizing both costs and risks, and increasing our chances to survive and thrive in a changing world.[6, 11] In its *2015 Annual Report*, the Commission summarized the IPCC's analysis that an increase of global average temperature exceeding 2 degrees Celsius over pre-industrial levels would risk dangerous consequences.[2] In order to limit the temperature increase to this level, the IPCC calculated that global GHG emissions must be reduced by 40 to 70 percent from 2010 levels by 2050, and further to near or below zero in 2100.[1] The Commission noted that because these reduction goals were global, and the U.S. has far greater per capita emissions than all but a few nations in the world, the U.S. emissions must be reduced at least to the upper end of the range in order to constitute an effective contribution.[2] That trajectory of emissions reductions informed the recommendation of the MCCC that Maryland should adopt a goal and develop a plan to reduce its emissions by 40 percent from 2006 levels by 2030, which in turn provided the basis of the Greenhouse Gas Emissions Reduction Act (GGRA) of 2016 which Governor Hogan signed into law.

During the past year, several studies have analyzed the likelihood of avoiding both a 1.5 degree and 2 degree Celsius threshold. One study has concluded that, under even the most aggressive emissions reduction pathway simulated by the IPCC (scenario RCP2.6), the probability of crossing the 1.5 degree threshold by 2100 varies from 61 to 88 percent depending on how the baseline is defined.[17] Other statistical approaches, using projections of population, economic growth and carbon use, indicate only a 5 percent chance of

Resiliency & Thresholds

Many of the most fundamental aspects of both ecosystems and human systems have evolved based on a climate which had, until recently, been changing very slowly since the last ice age. More rapid changes in temperature and precipitation patterns (and the resulting impacts) can be tolerated only within a certain range, based on the resiliency of a given system. Once this threshold is surpassed, the effects are irreversible and may be devastating to the environment, the economy, and human health.

limiting global warming to the 2 degree threshold.[18] The former Executive Secretary of the U.N. Framework Convention on Climate Change and five prominent climate scientists published a commentary this summer which asserted that peaking global emissions by 2020 and declining to near zero by mid-century are necessary to maintain these thresholds and avoid the most dangerous consequences of climate change (Figure 1).[19] As with any major adjustments, delaying action is likely to necessitate changes that are more dramatic and economically disruptive.

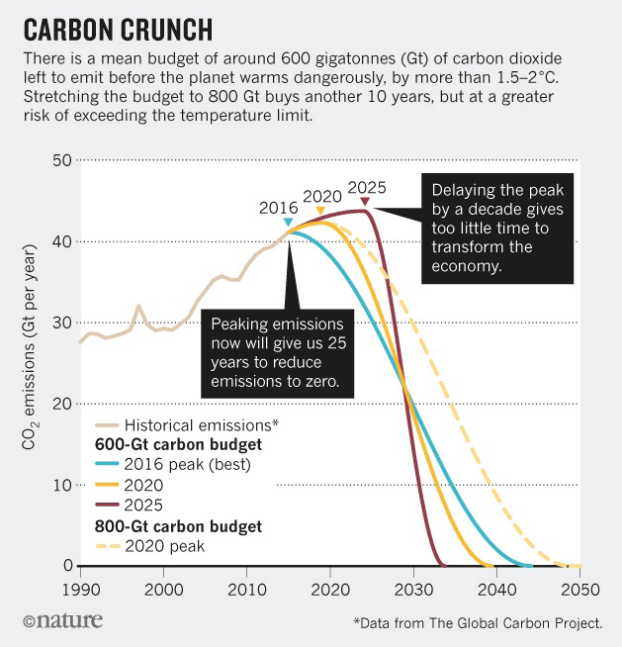


Figure 1. Recent analysis demonstrates that net global emissions of CO_2 must peak soon and decline to near zero before the middle of the century in order to avoid dangerous levels of warming.[19]

Notwithstanding our obligation to *contribute* to the global efforts, such global efforts are also expected to have a *net benefit* nationally. A 2015 report of the Climate Change Impacts and Risk Analysis project estimated that mitigating action would result in significant avoided costs for the U.S. – both human and economic. For example, global mitigation (compared to a business-as-usual scenario) was projected to avoid 12,000 deaths per year associated with extreme temperature events by the year 2100; save $4.2 to $7.4 billion on avoided road maintenance; avoid the loss of 230,000 to 360,000 acres of coldwater fish habitat; and reduce the predicted damages from sea-level rise through 2100 from $5 trillion to $810 billion.[20]

Regardless of the success of current and future global mitigation efforts, some changes are already underway and the response of the environment to the current levels of anthropogenic GHG emissions is still being realized;[1, 21, 4] therefore, adaptation is required. The MCCC's *2016 Annual Report* provided probabilistic projections of future sea level under scenarios of aggressively restrained and unrestrained GHG emissions. Important new research related to the causes of sea-level rise and polar ice sheet melting – a critical determinant of future sea level – was published during 2017. A reassessment of the causes of the increase in global mean sea level (GMSL) using satellite data uncovered an important increase in the rate of GMSL rise since 2004 compared to the 1993 to 2004 time span;[22] mostly due to the increased rate of loss of ice on Greenland. In the Northeastern U.S., the rate of sea-level rise already observed is greater than the global average, having increased about one foot since 1990 (average is 8 inches),[23] likely due to both increased Greenland ice loss as well as changes in regional currents and land subsidence.[20,24,34]

> *"Recent data add to the weight of evidence for rapid global-scale warming, the dominance of human causes, and the expected continuation of increasing temperatures, including more record-setting extremes"*
>
> *-- U.S. Global Change Research Program, 2017*

With regard to warming temperatures, despite the alleviation of the El Niño conditions that boosted global temperatures in 2015 and 2016, the first nine months of 2017 have ranked among the top four warmest on record, giving way to the second highest January-September period on record. Based on NOAA modeling scenarios, 2017 will likely rank in the top three warmest years on record.[25] Reconciliation of biases in instrumental measurements of ocean temperatures and from satellites has made it increasingly clear that there was no pause in global warming since the turn of the 21st century and that year-to-year variations have progressed around the warming trend projected by climate models.[26] When appropriately adjusted, even satellite temperature measurements – which have been purported to demonstrate no warming trend – in fact show continued warming over the past two decades.[27] More locally, the annual average temperature in the Northeastern U.S. increased at a rate of approximately 0.16 degrees Fahrenheit per decade between

1895 and 2011, with seasonal increases ranging from a rate of 0.11 degrees Fahrenheit per decade in the summer to 0.24 degrees Fahrenheit per decade in the winter.[28] Maryland has closely followed this regional trend, with a total increase in annual average temperature of 1.5 degrees Fahrenheit since the beginning of the 20th century, and a winter warming trend reflected in the average of less than one day per year of nights below zero degrees Fahrenheit since the mid 1990's as compared to an average of two nights per year between 1950 and 1994.[29] Annual precipitation, though more variable, increased by approximately 0.39 inches per decade in the Northeast during this same time,[28] with Maryland's annual mean precipitation having been above average for the past two decades. The climate in this region is generally expected to continue trending warmer and wetter over the next century, accompanied by an increase in extreme heat waves and precipitation events.[20, 29]

This year's extreme events – including scores of wildfires in the western United States, unprecedented rainfalls from Hurricane Harvey in Texas fed by unusually warm Gulf of Mexico waters, and the coincidence of three very strong hurricanes (Irma, Jose and Maria) active in the Gulf and Atlantic at the same time – cannot be individually attributed to climate change. However, events such as these have been made more likely or worsened by the warming climate. Furthermore, scientific techniques are advancing to allow scientists to more confidently attribute trends and events to human-caused climate change.[30, 31] These consequences to the physical systems will reverberate through biological and human systems, the three of which have co-evolved to exist under current conditions. While many communities in Maryland have already begun to address the changing climate, the State has a clear role to play in engaging and facilitating all communities in prudent and necessary preparations to reduce the vulnerability of Marylanders.

Photo 1. Texas National Guard soldiers arrive in Houston, TX to aid citizens in areas heavily flooded by Hurricane Harvey (August 2017).
{Photo by Lt. Zachary West, 100th MPAD}

A thorough understanding of the ramifications which accompany unmitigated climate change, as well as the complexity of costs and benefits (economic, environmental and human) associated with climate action, is essential to the core function of the Maryland Commission on Climate Change. The scientific community is constantly strengthening the models and projections for various emission reduction scenarios, providing the Commission with increasingly detailed information on which to base its policy and program recommendations. According to the most recent report from the IPCC, "effective adaptation and mitigation responses will depend on policies and measures across multiple scales: international, regional, national and sub-national".[1] The actions Maryland takes to mitigate climate change at the state level are integral to protecting the future and prosperity of not only the state of Maryland but also the United States of America and the global community of which it is a part.

It is the ongoing work of the Commission to ensure that we are utilizing the best science available in order to move forward with progress on limiting climate change (or mitigation) and adapting to the changes that do occur, keeping open lines of communication in both directions with the residents of Maryland.

1.2 History and Structure of the Commission

Maryland has historically been at the forefront of states taking action to address both the drivers and consequences of climate change, demonstrated by the State's policy record. The State has consistently advanced efforts to combat climate change with legislation and policy initiatives over the past decades. These include, but are not limited to:

- Development of A Sea-level Rise Response Strategy for Maryland in 2000
- Maryland's Renewable Portfolio Standard, starting in 2004
- Passage of the Healthy Air Act of 2006
- Passage of and update to the Clean Cars Act (2007 and 2017)
- Participation in the Regional Greenhouse Gas Initiative (2007 to present)
- Creation of the Coast Smart Council and Bay Acidification Task Force in 2014
- Passage and reauthorization of the Greenhouse Gas Emissions Reduction Act (2009 and 2016)
- Governor Hogan's creation of a mitigation grant program within the Department of Natural Resources (2017)

In 2007, the Maryland Commission on Climate Change was established by Executive Order (01.01.2007.07) and charged with developing an action plan and firm timetable for mitigation of and adaptation to the likely consequences and impacts of climate change in Maryland, including strategies to reduce Maryland's GHG emissions to 1990 levels by 2020 and 80 percent of 2006 levels by 2050. As a result of the work of more than 100 stakeholders and experts, the MCCC produced a climate action plan which was the catalyst for the GGRA of 2009. In 2014, a second Executive Order (01.01.2014.14) expanded the scope of the MCCC and its membership to include non-state government participants.

During its 2015 session, then Maryland General Assembly codified the MCCC into law, with a charge to "advise the Governor and General Assembly on ways to mitigate the causes of, prepare for, and adapt to the consequences of climate change" (Appendix F). The Commission is chaired by Maryland Department of the Environment (MDE) Secretary Ben Grumbles and consists of 26 members representing State agencies and legislature, local government, business, environmental non-profit organizations, organized labor, philanthropic interests, and the State university system. The work of the Commission is supported by a Steering Committee and four working groups.

The members of the working groups are appointed by the Commission Chair, and embody both public and private interests in climate change, including representatives of academic institutions, renewable and traditional energy providers, environmental organizations, government agencies, labor organizations and business interests. The Mitigation Working Group (MWG) focuses on regulatory, market-based and voluntary programs to reduce GHG emissions while supporting economic development and job creation. The Adaptation and Response Working Group (ARWG) is charged with developing a comprehensive strategy for reducing Maryland's climate change vulnerability, providing state and local governments with tools to plan for and adapt to the more extreme weather and rise in sea levels anticipated as a consequence of climate change. The Scientific and Technical Working Group (STWG) is responsible for updating and informing the MCCC on the science of climate change, and the Education, Communication, and Outreach (ECO) Working Group assists with the Commission's public outreach and public meetings on climate change as well as educating Marylanders on what the State is doing to address its causes and impacts.

1.3 Report Overview

The Maryland Commission on Climate Change Act of 2015 (Appendix F) requires that the Commission issue a yearly report to the Governor and the General Assembly on the status of the State's efforts to mitigate the causes of, prepare for, and adapt to the consequences of climate change, including future plans and recommendations for legislation, if any, to be considered by the General Assembly. The first report, issued in 2015, provided background and recommendations on key challenges and opportunities related to the status of Maryland's response to climate change.[32] The 2016 report included an update on the science of climate change, as well as climate policy and action in our local and global community. This report also examined the potential and realized climate impacts to the State across various sectors.[33]

This year's report is another step in what is expected to be a continual process as we not only work to achieve a 25 percent reduction in GHG emissions by 2020 and 40 percent by 2030 (as mandated by the 2016 GGRA), but also move toward the State's anticipated long-term goal of reducing GHG emissions by up to 90 percent from 2006 levels by 2050 (as noted in the Act's legislative findings, and emphasized by the mandate for the State to develop its 2020 and 2030 plans in recognition of the IPCC finding that such reductions are needed in developed countries). The report builds on information provided in previous Commission publications. It contains an update on the science of climate change; how it is already impacting Maryland's ecosystems, infrastructure, and socioeconomic framework; and how it is expected to impact the State in the future. It culminates in progress being made to address these projections and the State's goals at various points along the timeline, and the Commission's recommendations to State agencies and other state entities to continue the path forward. In order to protect the State's economy, the local environment, and the health of Maryland's citizens, it is crucial that the State maintain its aggressive course of mitigation and adaptation actions. At the same time, it is important to remember that climate change is a global problem, and Maryland's programs and policies must be part of a larger climate action plan to be broadly effective at preventing many of the costs of unmitigated climate change to the State. The Commission recognizes that many other states and municipalities are making great strides in similar efforts, and hopes that Maryland's proactive and economically balanced approach may serve as model to inspire additional action from neighboring states and beyond. With causes and consequences interwoven among nearly all sectors of state and inter-state economy and society, it is clear to the Commission that national leadership will be imperative to ensure adequate and equitable progress into the future.

2 State of Maryland: Present & Future

The global climate system is complex, and a large number of variables interact to determine the eventual impact of expected changes to various segments of the natural and built environment. While not every individual change is necessarily harmful, the negative consequences of unmitigated climate change will far outweigh those select benefits.[34] The Climate Action Plan prepared by the Commission in 2008 included a *Comprehensive Assessment of Climate Change Impacts in Maryland*. This chapter updates and expands on that assessment in terms of key indicators of climate change currently being analyzed, as well as future projections of particular relevance to the state of Maryland. These projections are typically informed by computer models of the global climate that estimate how temperature, precipitation, or sea level will change under scenarios of future GHG concentrations. Those concentrations, in turn, depend on scenarios of the rate of GHG emissions over time, which generally include a "reference" or "business-as-usual" scenario (in which emissions continue to grow through the 21st century, based on current policies and trends), and one or more "mitigation" scenarios (in which global emissions decline as related to a given set of policy decisions, or based on a desired 'end point'). Although projections of impacts under various reference and mitigation scenarios are referenced in this chapter, it is important to note that these are not always fully equivalent as they may rely on different sets of assumptions or parameters. For example, some earlier projections such as those used in the U.S. Environmental Protection Agency's (EPA's) *Benefits of Global Action* study[20] or the National Climate Assessment[14] are based on different climate models and emissions trajectories than used in the most recent IPCC assessment. Where these IPCC scenarios and models are used, the "mitigation" scenario is constructed to yield a reasonable likelihood of keeping the increase in global average temperature below 2 degrees Celsius.

Modeling Climate Change

Models are designed to take a complex system, such as the global climate, and characterize its main functional components and their interactions in a simpler and more easily manipulated representation of reality. Reliable predictive models are developed based on well-documented physical processes; and have been tested and calibrated by running the model using known past variables and comparing the results with actual observations. Climate models which perform well in this respect are considered to produce valid results for future scenarios as well. [116] At this point, the realized future depends mainly on which emissions scenario most closely represents the actual future. The remaining uncertainty is accounted for by presenting results as a range.

Furthermore, the following pieces of information in regards to the modeling and projections referenced in this chapter should be kept in mind. First, reliable predictions are necessarily limited to sectors in which there is a sufficient understanding of the effects that climate change could have, and for which quantifiable data and modeling methodologies exist to support analysis. In addition, areas of focus tend to be limited to those in which economic, iconic or cultural significance can be assigned to impacts or damages.[20] It is also likely that many other potential risks from climate change exist which have not necessarily been assessed or may not even be foreseeable. Finally, the impacts felt by Maryland will not be isolated to those directly experienced in the immediate vicinity. The state brings in electricity, food, and a number of necessities from other states and countries; meaning any impacts felt at the source of these essential goods will create problems for Marylanders. California's Central Valley, for example, produces 25 percent of the nation's food, and already relies heavily on irrigation.[35] The climate in this area is expected to become even hotter and drier which, among other changes, threatens the agricultural yield in the region and the nation's food supply.[36] The discussion in this chapter is not meant to be taken as an all-inclusive look at climate indicators and risks, but rather as an overview of those that are most high-profile, and generally well-accepted by the scientific community.

2.1 Maryland's Environment

Ecosystems consist of networks of interactions among the biosphere, atmosphere and geosphere (or – living and nonliving components, including chemical, biological and physical interactions); human systems, or the "built environment", can be considered a more recently evolved component which is equally intertwined with and dependent upon these same resources. As noted earlier, the climate in Maryland and the rest of the Northeastern U.S. is currently trending warmer and wetter, a trajectory which is expected to continue. Heat waves are likely to increase in frequency, intensity and duration corresponding directly to increases in emissions; and Maryland is expected to have a notable increase in days with extreme heat (over 90 degrees Fahrenheit) by 2050, as compared to the late 1900's.[23] The trend in average precipitation is expected to remain seasonal, increasing in the winter and spring, with less change expected in the fall and summer.[28] Combined with the higher summer temperatures, greater evaporation and earlier snowmelt will create a risk of drought during the growing season (significant for both ecosystems and human systems). Additional impacts in Maryland could include increased frequency and severity of other existing problems such as storms, flooding and forest fires, as well as erosion, saltwater intrusion and inundation of low-lying areas along the State's shoreline and coast.[37] In general, "climate change increases the risk, frequency, and intensity of certain extreme events like intense heat waves, heavy downpours, flooding from intense precipitation and coastal storm surges, and disease incidence related to temperature and precipitation changes".[14] The direct impacts to Maryland's ecosystems and built environment are assessed in the following sub-section.

Risk and Vulnerability

Risk is a term used frequently in discussing both present and future scenarios related to climate change impacts. It can be defined as the relationship between the likelihood of exposure to a given hazard, and the damage expected if exposure occurs. A change in either factor due to the influence of impacts associated with climate change alters the overall risk of a particular event or occurrence.

Vulnerability of individuals or groups can also increase either exposure or expected damage, amplifying their risk compared to that of the general population.

2.1.1 Maryland Ecosystems

When attempting to either qualify or quantify the value of ecosystems, a term commonly used is "ecological services", or "ecosystem services". These refer to the benefits afforded to people by the normal and healthy functioning of the ecosystem, such as robust fisheries, cleaner air and drinking water, and recreational opportunities.[38] Maryland has a wide diversity of ecosystems ranging across the Atlantic coast, the Chesapeake Bay, the piedmont region and the Appalachian Mountains; all of which are threatened in various ways by the changing climate. In general, rising temperatures are expected to change species distribution by latitude and elevation, a trend which has already been documented in scientific literature, particularly for temperate locations;[39, 40, 41] however additional factors such as changes in precipitation regimes may also play a role in the directional nature of these shifts.[41, 42] Such movement may cause habitat loss or local extinction, depending on the needs of the particular species and their capacity to either migrate or adjust to the changes.[23, 38] Variable adaptation which causes habitat shifting and changes in the timing of seasonal patterns and activities may result in asynchronies in the life cycles and distribution of species which have key interactions, such as plant/pollinator, or predator/prey.[23, 38] Additionally, insect pests, pathogens, and invasive plants may expand their ranges; and some have been shown to have increased success under predicted climate changes,[43] further stressing the systems.

Photo 2. A monarch butterfly feeds on the nectar of a common milkweed plant at Chino Farms in Queen Anne's County, MD (2016). *{Photo by Will Parson/Chesapeake Bay Program}*

Maryland's Atlantic coast provides ecosystem services such as fisheries, recreational opportunities, and storm-surge protection. It is particularly vulnerable to rising ocean temperatures and sea-level rise (contributed to by the former), as well as ocean acidification and the elevated levels of nutrients and sediment brought by increased precipitation. Higher ocean surface temperatures contribute to sea-level rise via thermal expansion, and have the potential to alter tropical storm activity and weaken circulation patterns.[34] Global sea surface temperature has demonstrated a warming trend since the 1950's,[44] and long-term in the Mid-Atlantic since the late 1800's (with a steady increase since the mid-1960's) ;[45, 46] including in the Chesapeake Bay.[47] Furthermore, it has been demonstrated that these warmer temperatures have impacted the species distribution of marine fish and invertebrates, with one study of U.S. coasts finding that for over 100 species sampled, the average center of biomass shifted north by approximately 10 miles and deeper by an average of 20 feet since the 1980's.[34]

The Chesapeake Bay ecosystem is an invaluable and iconic part of Maryland, providing a range of environmental, recreational, and economic services. Researchers from the University of Maryland Center for Environmental Science (UMCES), the National Estuarine Research Reserves (NERR) of Maryland and Virginia, and Chesapeake Environmental Communications have compiled and analyzed meteorological data from sites managed by NERR and the National Weather Service going back to 1910. They identified clear climactic trends for this region which are already influencing the Bay's habitats and the species that reside there.[48] Distinctive climactic changes noted over this period include a growing season which is expanding at an even greater rate than that of the East coast overall. This has been observed as an issue for some migratory species which reside in the Bay during the spring and summer months, but farther south during the winter. Warmer fall weather has meant that these species are not beginning their migration early enough, lacking the usual indicator of oncoming cold. Then, when the temperature drops suddenly, these species may suffer from cold-shock, resulting in incidents such as the cold-snap-associated death of thousands of Speckled Trout in February of 2014, or 2 million juvenile Spot in 2011.[48] In addition to temperature changes, an increase in total annual precipitation by approximately 12 percent holds particular significance in the Bay region, due to the correlation between precipitation and nitrogen/sediment pollution brought into the Bay with runoff.[48, 38] Algal blooms (caused by excess nutrients) can reduce oxygen levels at the bottom of the Bay as they decompose; and warmer summer temperatures have already exacerbated low-oxygen "dead-zones", since warmer water can hold less dissolved oxygen.[49] Aquatic vegetation, which provides food and habitat for fish, crabs, and waterfowl, tends to be stressed by any combination of these factors (increased temperatures, decreased oxygen, nutrient pollution, and reduced clarity). Bay grass health has shown recent improvement, however higher temperatures could threaten this progress.[48] Finally, sea-level rise is expected to have a direct impact on coastal estuaries such as the Chesapeake Bay, "moving estuarine shorelines by inundating lowlands, displacing wetlands, and altering the tidal range in rivers and bays".[52]

Photo 3. Oyster spat on shell grown at the University of Maryland Center for Environmental Science Horn Point Oyster Hatchery, being deposited for a restoration project on Tilghman Island (2012). *{Photo by Steve Droter/Chesapeake Bay Program}*

In addition to a change in temperature, many water bodies are becoming more acidic as the atmospheric concentration of carbon dioxide (CO_2) rises and a greater amount is absorbed by the ocean, lowering the pH.[3] This has already been identified as an issue for coral and shellfish globally, and the National Oceanic and Atmospheric Administration (NOAA) is doing a wide variety of research to determine additional impacts of ocean acidification on coastal ecosystems. Acidification in shallow estuarine environments such as the Bay is further mediated by nutrient availability, as the same algal bloom events which deplete oxygen also increase dissolved CO_2.[53] Besides generally being a concern for pH sensitive species, Bay acidification creates a particular issue for shellfish such as crabs and oysters which require specific chemical conditions

in order to create and maintain their shells.[53] The Maryland Ocean Acidification Task Force report released in 2015 identified a critical need for enhanced monitoring networks to gain a better understanding of the multitude of complex interactions that causes acidification in shallow, estuarine Bay waters, as well as the effects on the species that inhabit them.[53]

Farther inland, aquatic systems are also at risk from rising temperatures. From 1960 through 2014, the water temperature increased at 79 percent of all stream sites measured in the Chesapeake Bay region, and several stream gauges in Maryland demonstrated a statistically significant increase in temperature of 2 to 4 degrees Fahrenheit during this time.[34] According to the EPA, under a business-as-usual emissions scenario, those sites which are currently coldwater fisheries in western Maryland are projected to become unsuitable for this use by 2100, as is true for most of Appalachia; however, under a 2 degrees Celsius mitigation scenario, this use may be maintained.[20] The health of Maryland's forest ecosystem is important for residents due to the wide variety of ecosystem services it provides. These include decreasing the total runoff and maximum flow of rivers during storm events, which reduces incidents of riverine flooding; capturing or retaining soil and nutrients from runoff, which helps the State meet its Bay TMDL goals and keeps our drinking water reservoirs cleaner; acting as a sink for atmospheric carbon; and providing essential habitat for wildlife and recreational opportunities for people. In quantifiable terms, MDE estimates that forests and terrestrial ecosystems contribute $24 billion in ecological services annually.[51]

COASTAL RESILIENCY GRANT PROGRAM: BUILDING RESILIENCY THROUGH RESTORATION

While coastal hazards threaten our communities, habitats can help provide a buffer from the full impacts of flooding and erosion. Coastal forests, wetlands, dunes, and other natural features can help accumulate and stabilize sediment, slow and absorb water, and facilitate inland migration as sea levels rise. To identify areas where coastal habitats provide risk-reduction benefits, the Maryland Department of Natural Resources (DNR) completed a *Coastal Resiliency Assessment* in June of 2016. Throughout 2017, DNR worked to integrate targeting data into conservation and restoration activities, transitioning from planning to implementation. A new grant program was launched in July to build resiliency through restoration.

The *Coastal Resiliency Grant Program* supports natural and nature-based adaptation strategies by providing financial assistance to restore, enhance, and create coastal habitat; with a goal of protecting Maryland communities and public resources from the impacts of coastal hazards. During 2018, six living shoreline and coastal restoration projects will be designed in five different jurisdictions, to demonstrate risk reduction at different scales and in different coastal environments. By tracking the overall performance of these pilot projects, staff will undertake adaptive management techniques, ensure project success, and adapt techniques as they learn from advancing science and observations.

2.1.2 The Built Environment

Projections from the *Third National Climate Assessment* of the U.S. Global Change Research Program indicate that infrastructure (e.g., roads, bridges, and buildings) in the Northeastern U.S. is expected to be at particularly high risk from the impacts of sea-level rise, coastal flooding, and more intense precipitation events brought by climate change.[23] The East coast infrastructure represents some of the oldest in the U.S., and was designed to a certain standard based on the elements and stressors which it was expected to withstand. Climate change exposes these already aging structures to increased stress such as extreme temperatures and weather events which can shorten its useful lifetime, increase maintenance costs, or even render it un-useable.[54, 55, 14]

As previously noted, the Northeastern U.S. is actually experiencing a rate of sea-level rise greater than the global or national average. In its 2016 Annual Report, the MCCC projected likely sea-level rise in Maryland between 2.2 and 4.1 feet with unrestrained growth in global emissions, and between 1.4 and 2.8 feet even when emissions were reduced to achieve the IPCC mitigation scenario.[33] This puts the people and infrastructure of Maryland's extensive coastline at increased risk of damage from hazards such as flooding, salt-water intrusion, storm surge, and erosion.[34] Though many sites along the U.S. coastline have experienced a greater frequency of flooding since the 1950s, the Mid-Atlantic has experienced a disproportionately large increase.[34] The city of Annapolis is a particularly severe example, with the average number of flood events per year increasing from less than 10 over the 50s and 60s to more than 40 in the past decade.[34] For coastal areas, the impacts of storm surge on transportation infrastructure can compound the loss of human life during storm

events if major evacuation routes become impassable, and may lengthen the process of community recovery after events, due to a decreased ability to access work or school, or to receive much-needed supplies. Although factors which influence the formation, intensity and landfall of Atlantic hurricanes are numerous and complex, many models have indicated that increasing temperatures are most likely to result in a greater number of Category 4 and 5 hurricanes by the end of the century, with increased rates of average rainfall (about 20 percent greater near the center of the storm).[3] Outside of the immediate event impacts, such disturbances may affect the economic viability of main harbors, airports, and supply chains in coastal areas, as well as the areas further inland and even nationally which rely upon their goods and services.[56, 54] In 2016, the Port of Baltimore handled 31.8 million tons of international cargo (worth almost $50 million), ranking it 9th in all U.S. ports.[57] The Port generates $310 million in taxes, nearly $3 billion in annual wages and salaries, and supports 13,650 direct jobs.[57] For all of these reasons, much of the adaptation effort in Maryland thus far has been focused on identifying and addressing coastal hazards, namely sea-level rise and coastal storms. This was the focus of the MCCC Adaptation and Response Working Group's Phase I plan, *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change*, initiated in 2008.

Photo 4. Tide over the road at Elliott's Island, Dorchester County, MD. *{Photo by Guy W. Willey Sr., IAN/UMCES}*

While Maryland's coastal areas may be considered particularly vulnerable, many areas of the State have infrastructure susceptible to impacts from climate change. Non-coastal (riverine and urban) flooding is a result of multiple factors, including those related to the design of the built environment (e.g., river modifications, drainage, and land use) and climate factors such as precipitation.[58] Urban flooding can be caused by high-intensity, heavy rainfall events which have increased in frequency in the Northeast (71 percent from 1958 to 2012), and are expected to continue to increase with unmitigated climate change.[3] When combined with the low permeability of the majority of urban surfaces, large quantities of runoff may quickly overwhelm the capacity of stormwater drainage systems.[58, 20] Across the U.S. Geological Survey hydrologic region which includes most of Maryland (Hydrologic Unit Code 02, or HUC02), the cost of damages from inland flooding under a business-as-usual scenario is projected to be between $1 and $2 billion (in 2014 $) in 2100, significantly different from historic numbers.[20] Inland bridges are particularly vulnerable to increased riverine storm flow and flooding, and HUC02 is expected to experience some of the greatest impacts, with 76 percent (more than 20,000) of inland bridges projected as vulnerable by 2100 without mitigation; while a successful 2 degrees Celsius scenario reduces this number to 35 percent.[20] MDE manages the State's dam safety program, a part of the stormwater management program, which is also an important part of adaptation efforts related to riverine flooding. Legislation signed this year required dam owners to prepare and submit an approved Emergency Action Plan, to be updated annually, which includes information on monitoring weather and conditions during emergencies and actions to protect lives and property downstream.[59]

Photo 5. Flooding of the Jones Falls in Baltimore, MD after heavy rains (2008). *{Photo by Tim Windsor}*

Since urban infrastructure tends to be organized in an interdependent system, disruptions in one service caused by severe weather may affect others. If the transportation infrastructure of urban environments is compromised, for example, this limits not only the ability of the region to access supplies which are generally brought

in from outside the city, but also its capacity to export those supplies on which others (or the city's economy) may be dependent.[55] In addition to damage from flooding and severe weather events, increased average temperatures can have a direct impact on urban infrastructure as well. Unmitigated climate change is projected to increase the cost of road infrastructure maintenance by $4.2 to $7.4 billion nationally (in 2100) compared to the 2 degrees Celsius mitigation scenario.[20] In the Northeast, the majority of predicted costs were associated with higher temperatures, which necessitate the application of alternative pavement binders to avoid road cracking.[20] While in-depth analysis at the State level is still in the early stages, an increasing amount of work is focused on identifying and analyzing non-coastal risks and developing specific strategies to address them, considered Phase II of the ARWG's 2008 Plan.

2.2 Jobs and the Economy

More frequent disruptions to urban and coastal infrastructure in Maryland caused by extreme weather events may indirectly impact the economy of the region by restricting the flow of goods and impacting days worked. These events, combined with changes in the average climate of the region, are also likely to have a direct negative impact on yields in agriculture and fisheries. The decisions surrounding the management of various sectors is additionally complicated by the unique interplay of changes in management with mitigation and adaptation goals, and the ultimate climate impacts projected, particularly related to energy. If regions or communities become unfavorable for an activity or industry which was historically a large part of their economy, they may need to shift or diversify quickly to avoid substantial economic impact. These impacts may be disproportionately felt by rural communities, which tend to have less diverse economic portfolios.[60] Certainly, new opportunities can arise in the process; however as with many of the other anticipated changes, the speed with which they are occurring is the key factor. Adaptation at a matching pace could be challenging and not always entirely feasible, especially when considering the time and money invested, such as in equipment or training for a particular vocation. Efforts in mitigation are therefore required in addition to plans for adjusting to these changes, to reduce the extent and pace of adaptation that is needed, and make it more manageable. This section provides an overview of some of the major economic sectors in Maryland, and the anticipated climate impacts.

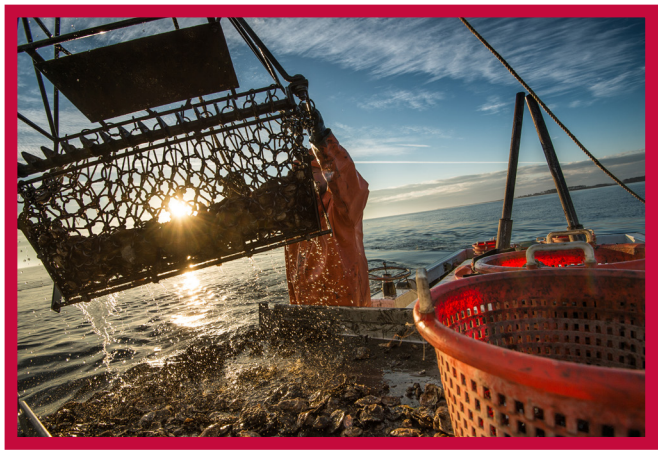


Photo 6. Dredging for oysters in Fishing Bay, Dorchester County.
{Photo by William Whaley}

2.2.1 Agriculture, Fisheries and Forestry

Agriculture and forestry are cultivated under human control, yet directly and clearly linked to the impacts of climate change on ecosystems. Common stressors will be experienced among ecosystems, agriculture, fisheries and forestry, such as those caused by general changes in temperature and precipitation regimes; increased extreme weather events; and increased pressures from weeds, diseases and pests. Maryland's Eastern Shore farmers will be at particular risk from additional issues such as sea-level rise, coastal storms, and saltwater intrusion. While not all individual impacts are necessarily negative (e.g., the growing season is expected to lengthen in Maryland, which may initially benefit some crops), issues such as increased temperature extremes and pest activity may negate these benefits;[61] and beyond 2050, impacts are expected to be increasingly unfavorable in most situations.[62] The overall impact, however, will depend in part on the level of adaptation that is achieved at the production level, as well as the response of the global market to these shifts.[62]

Although total farm acreage has been decreasing from historic levels,[63] agriculture remained the largest single land use in the state (almost one third of total land area), and employed approximately 350,000 Marylanders in 2016, making it the largest commercial industry in the State.[64] According to the U.S. Department of Agriculture

(USDA) *2016 State Agriculture Overview*, Maryland's total production included over $884 million in broiler chickens, $614 million in field crops, and $164 million in milk.[65] In 2015, the market value of all agricultural products was over $2.2 billion, which translated to a net farm income of more than $507 million ($41,297 per farm on average) in that year.[64] Poultry farms, the highest grossing agricultural industry in the state, are expected to see increased summer cooling costs, decreased growth rates, and increased mortality with increasing temperatures.[61] The interplay of expected seasonal trends in temperature and precipitation is also particularly relevant to the agricultural sector. As noted earlier in this chapter, average precipitation is expected to continue increasing in the winter and spring, with less change expected in the fall and summer.[28] Combined with the higher summer temperatures, this will likely increase the intensity of any droughts during the growing season.[29] Increased frequency of summer heat stress has the potential to negatively affect both field crops and milk production yields,[62] and may amplify water demand, increasing the risk of over pumping groundwater for irrigation. This latter tendency, combined with sea-level rise, places the Eastern shore (nearly half of the total farms in the state by acreage)[63] at particular risk from saltwater intrusion of aquifers. Saline water may also flood fields during storm events, leaving salt behind after evaporation which can disrupt the soil structure and leach vital trace minerals. Farmers may be able to adapt in part to the impacts of climate change by exploring new crop options or adjusting management practices, but as the *Third National Climate Assessment* notes, "these adaptations are not cost- or risk-free".[23] Adaptation may pose a further challenge for farmers whose crops are not single season (such as fruit trees and vines), as their life cycles often rely on particular seasonal cues, and because selective breeding would likely take many more years to become effective.[62] These perennial crops may become more sensitive to hard freezes, as unusually warm winters can de-harden vines, or cause spring growth to begin prematurely only to be later destroyed by a hard freeze.[62] As of 2016, Maryland has approximately 2,400 acres of apple and peach orchards, valued at over $12 million.[64] Additionally, the State has 858 acres of vineyards, 70 percent of which are owned by wineries that sold $29 million worth of product in 2014.[64]

Photo 7. Luke Paper Mill and Woodlands site in Allegany County, MD.
{Photo by World Resources Institute}

While the effect on forestry is not predicted to be as substantial as that on agriculture, and increased incidence of wildfires (the largest climate concern for forestry on the national level) is not expected to be as significant a concern in Maryland,[20, 23] there are still potential threats and changes to the industry that merit attention. In 2015, the forestry industry generated $244 million in income for its 5,178 employees, who mostly reside in Garrett and Allegany Counties.[66] This accounts for only a small subset of the estimated 18,000 people who depend either directly or indirectly on the $4 billion industry for their livelihood.[67] As noted in the ecosystem section, changes in average temperature and precipitation have the potential to shift, shrink, or expand the ranges for various species, including trees such as the loblolly pine, oak, and hickory which are most prevalent in Maryland.[68] The positive contribution to global forestry production from lengthened growing seasons and increased CO_2 concentrations is unclear; though similarly to agriculture, it is expected that negative climate impacts such as wildfires, insects and pathogens, heat and water stress, and extreme weather events may eclipse these benefits.[69, 68] In Maryland, DNR has already noted that pests such as the gypsy moth and the Southern pine bark beetle have begun to threaten forests in recent decades.[67] Not only may a changing climate impact the prevalence of these pests, but it may also stress the trees or otherwise affect defense mechanisms, making them more susceptible to damage.[69] In addition, forest management may be an important component of mitigation, since forests play a major role as carbon sinks in the near term, absorbing about 17 percent of anthropogenic CO_2 emissions the past several decades.[70] Depending on the chosen strategies, we may either expand or reduce this capacity.

The Chesapeake Bay fisheries are expected to be impacted by a combination of environmental stressors previously discussed for Bay and coastal ecosystems, including basic water quality issues such as changes in

temperature, salinity, and dissolved oxygen, as well as habitat loss due to sea-level rise and projected impacts on submerged grasses. Many commercially important fisheries species are projected to move northward as waters warm and suitable habitats shift; and as previously noted, this shift could also bring new pests or increase the damages done by diseases such as bacteria which thrive in warmer waters.[71] The Maryland seafood industry (not including imports) was responsible for over 7,000 jobs and $160 million of income in 2015.[72] The blue crab remained the most lucrative species by far, accounting for over $54 million in revenue that year, with the oyster coming in second at $15 million.[72] In addition to concerns regarding ocean acidification, oysters may be at an increased risk of suffocation by sediment loads, exposure to low-oxygen dead zones, and damages from the diseases Dermo and MSX; all of which have contributed to the historic decline of the oyster population[73] and may be exacerbated directly or indirectly by the changing climate as previously discussed. For blue crabs, a study of current life-cycle variations across their native range (Maryland/Virginia, North Carolina, and Florida) concluded that since the Chesapeake Bay is towards the northern edge, increased temperatures taken independently may provide certain benefits currently experienced by their more southern populations such as a longer reproductive season with additional broods, increased growth rate and maturation, and decreased deaths over winter.[74] However, the peak summer water temperatures of the three regions studied were very similar, despite the marked differences in temperature the remainder of the seasons, and so the current climates of the southern sites cannot necessarily be considered an accurate representation of those temperature differences expected in the Chesapeake as a result of climate change. Furthermore, many other impacts are projected to affect blue crabs negatively, including loss of submerged grass habitat and expanded dead zones.[74]

2.2.2 Tourism

Businesses involved in the State's tourism sector are also likely to feel the impact of climate change. In 2015, Maryland visitors spent $16.8 billion dollars, more than 60 percent of which was in the industries of transportation, food and beverage, and lodging.[75] Tourism in the State supported 140,625 direct full-time equivalent jobs in that year, bringing in wages of $5.7 billion;[A] while visitor spending generated almost $2.3 billion in state and local taxes.[B,76] The Maryland Office of Tourism Development touts Maryland as "America in miniature", noting the wide array of regional activities: boating, winter sports, and mountain scenery in the west; sports, restaurants, and shopping in the central cities; winery tours, fishing, and historic and natural history in the south; and seafood, beaches, and marshlands on the Eastern Shore.[77] Without action, all of the various activities and the natural beauty of the State could suffer the effects of climate change, depriving Maryland residents and visitors of this wealth of experiences.

Photo 8. Wine tasting and tour at Big Cork Vineyards in Washington County, MD *{Photo by Jess Herpel}*

Snow sports such as skiing "are at obvious risk from rising temperatures, with lower-elevation resorts facing progressively less reliable snowfalls and shorter seasons".[78] Wisp Mountain Park is a four-season resort but more significantly a winter sports destination whose employment jumps from 230 to 700 during the winter ski season, ranking it among the top employers in Garrett County.[79] In late December of 2015, the resort reported that only one of their 35 trails was open, having been unable to keep snow on the ground due to temperatures consistently above freezing.[80] This past year, winter sports closed for the season at the end of February after a consecutive 72 day

A Workers/wages include those in leisure and hospitality, retail, transportation, and other sectors affected by visitor spending.

B Taxes include income taxes from wages and industry employees, sales taxes for tourism goods and services, hotel occupancy taxes, property taxes, and other corporate taxes.

winter season (the shortest in 10 years) "due to the historic, unseasonably warm rainy weather".[C, 81] Though not specifically attributable to climate change, these issues do demonstrate how important dependably cold weather is to the resort's seasonal functionality, which increasing global temperatures could debilitate. Maryland's sizable sport fishing industry has an estimated economic impact of nearly 7,000 jobs and $300 million in income across the State; with 352,000 anglers (nearly half of the total) coming from out-of-state in 2015.[72] Similarly to commercial fisheries, key species will face increasing risks brought by higher temperature surface water, changes in precipitation, and other indirect effects. Maryland's beaches will be susceptible to more extreme weather events as well as sea-level rise, and are difficult to protect from storms and erosion without negatively impacting their aesthetics.[78] Ocean City generated around $60 million in tourism-related taxes each year during 2014, 2015 and 2016 (60 percent during the months of June, July, and August).[82] Maryland's *Greenhouse Gas Reduction Act Plan* from 2012 stated "it is estimated that beaches will move inland at a rate 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".[83] Even tourism in cities and urban centers is expected to be impacted by climate change, experiencing the effects of extreme heat and precipitation events as discussed surrounding the built environment.

2.2.3 Energy

The energy sector tends to be thought of in terms of its potential impact on emissions; however it is also at risk from negative impacts due to climate change. Particularly in the Northeast, hotter summer temperatures are expected to increase peak electricity demand in this season due to increased use of air conditioning units; with overall increased demand outweighing the decreased need for heating in winter.[20] This makes it more difficult and potentially more expensive for utilities to meet the immediate peak demand, and also increases the risk of system failure precisely when it is most needed.[23] In a scenario where global average temperature increases by 3.5 to 5 degrees Celsius, it is estimated that a 10 to 20 percent increase in total U.S. electric generating capacity will be required by 2050.[84] Beyond mitigation, programs for adaptation such as enhanced urban tree canopies can help increase resiliency by providing shade relief to buildings during the summer, which helps alleviate the demand for electric cooling. Additionally, extreme weather events which threaten coastal and urban infrastructure include threats to electricity infrastructure in these areas.[85] The majority of thermoelectric power plants are specifically located near bodies of water expected to become more susceptible to flooding, since they require constant cooling. Furthermore, as atmospheric temperatures increase, the temperature of surface water also increases and the water being used for this purpose becomes a less effective coolant, reducing the efficiency of thermoelectric generation.Warmer water would also be discharged back into the Bay, with potentially negative impacts on the ecosystem.

Photo 9. Broken utility pole with downed power lines after a storm.

2.3 Public Health and Equity

Climate change is expected to alter the severity, frequency, or distribution of health problems which are affected either directly or indirectly by temperature and precipitation.[20, 87] Impacts may be related to changes in the natural or built environment, including effects on our food and water supply, air quality, and extreme weather events.[20, 87] Not all individuals and communities will be equally at risk, however; health outcomes are ultimately influenced by a variety of social and institutional factors that may increase the likelihood of exposure to an impact of climate change, or the probability of a negative outcome from that exposure (Figure 2). Climate change may even impact one or more of these factors, altering the ability of a community or individual to respond to health

C The park did experience a brief revival for a few weeks at the end of March.

concerns such that they are unable to take appropriate measures to prevent or treat an illness or injury.[87] For example, a prolonged heat wave may simply mean one family changes their weekend plans from playing ball at the park to staying inside and watching a movie, assuming they have access to air conditioning and were aware of the dangers of being outside during that time. The same heat wave may have an entirely different health outcome for a middle-aged man who is taking a heart medication which places him at increased risk of heat stroke, and works outdoors (Figure 2b).

In 2009, under section 202(a) of the Clean Air Act, the EPA Administrator issued an endangerment finding which stated that "based on careful consideration of the full weight of scientific evidence and a thorough review of numerous public comments" the cumulative impacts of GHGs endanger the public's health and welfare.[88] This section provides an overview of the major health impacts anticipated due to a changing climate (i.e., the cumulative impacts of GHGs); as well as the inseparable issues of vulnerability, equity, and environmental justice.

2.3.1 Extreme Heat and Air Quality

Extreme heat events have been increasing in frequency over the past several decades at the national level,[34] and between 2050 and 2100 the incidence is expected to more than triple under a business-as-usual scenario.[20] These events are directly associated with a greater risk of illness or death due to "heat stroke, cardiovascular disease, respiratory disease, and other conditions",[20, 34] even if only small differences in average seasonal temperature occur.[87] Factors related to vulnerability which are expected to increase exposure include lack of access to air conditioning or having an outdoor job; while individuals at already increased risk of health problems from extreme heat, such as children and the elderly, are more likely to experience a negative health outcome.[87, 34] The *Maryland Climate and Health Report* released in 2016 found that, between 2000 and 2012, extreme summer heat events (95th percentile for the baseline day) increased the risk of hospitalization for heart attack by 11 percent state wide and by up to 43 percent in some areas; and increased the risk of hospitalization due to asthma by 22 percent.[89]

> *"The Administrator finds that six greenhouse gases taken in combination endanger both the public health and the public welfare of current and future generations."*
>
> *-- U.S. EPA Endangerment Finding, 2009*

Air quality is also projected to decline under a business-as-usual scenario, especially in the Eastern U.S.,[20] which increases the risk of cardiovascular and respiratory issues.[87] Increased atmospheric temperatures increase the rate of chemical reactions, such as the formation of ground-level ozone, when the pollutants that participate in these reactions (NO_x and VOCs) are present in sufficient quantities. All else equal, increased temperatures will make it more difficult for cities in particular to achieve or maintain compliance with ozone standards, and the risk of health impacts associated with non-attainment, including reduced lung function, asthma attacks, and premature death, will increase.[20, 87] Mitigation (2 degree Celsius scenario) is projected to avoid 13,000 premature deaths in 2050 and 57,000 in 2100 nation-wide,[D] with an estimated economic benefit of $160 billion and $930 billion respectively.[20] Furthermore, the allergy season for ragweed pollen has already begun to lengthen in a large percentage of locations studied, and is expected to continue this trend and exhibit higher pollen counts with earlier springs, increasing temperatures, later fall frosts, and increased CO_2 concentrations.[34] This will increase pollen exposure and may lead to increased incidence of asthma and other allergy-related impacts, especially in children.[34]

D This analysis assumed no change in emissions of traditional air pollutants from current levels, and is based on projected impacts from increased ozone and fine particulate matter.

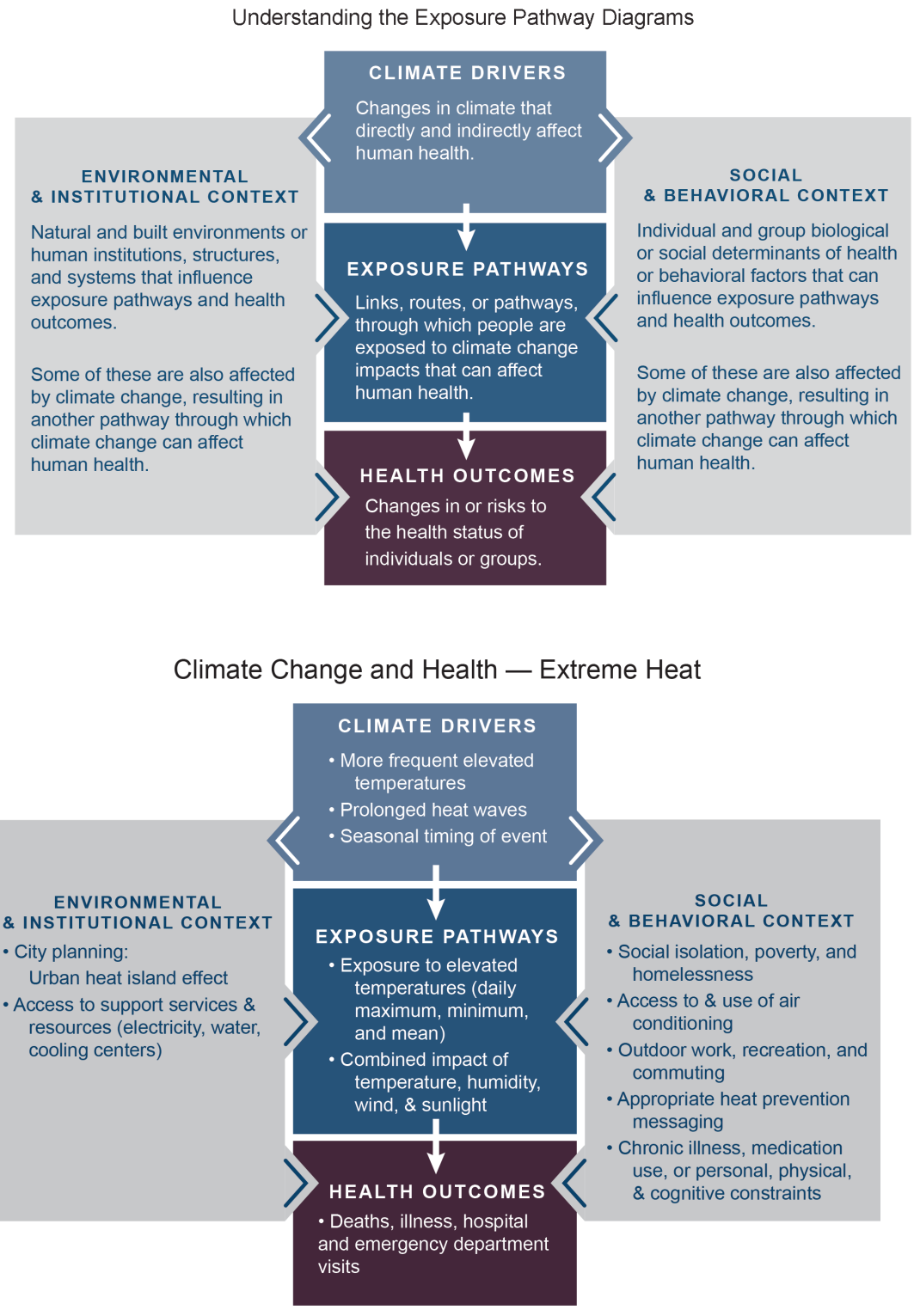


Figure 2. Exposure pathways diagrams from the U.S. Global Change Research Program report, *Impacts of Climate Change on Human Health in the United States.* Figure (a) demonstrates the general layout of exposure diagrams, which show how health outcomes are ultimately influenced by a variety of social and institutional factors that affect exposure to an impact of climate change. Figure (b) provides an example of this using "extreme heat" as the climate driver.[87]

2.3.2 Water Quality, Extreme Precipitation, and Infectious Disease

As previously stated, changes to precipitation in the Chesapeake Bay region are expected to increase the pollutant load to the Bay, a trend which is generally true for other water bodies in the State as well. Combined with increasing atmospheric temperatures, these changes are expected to negatively impact water quality parameters and potentially change the viable uses of surface water, such as recreation or human consumption.[20] Warmer winters and springs are associated with increased occurrence of *Vibrio* bacteria, including *V. cholerae,* which causes cholera, and *V.vulnificus*, which can cause similar symptoms or infect open wounds. Over the past century, the likelihood of encountering these bacteria in the Bay has already increased as conditions become more favorable to them.[48] Increased temperatures and nutrient loads are expected to expand suitable habitats for toxic freshwater and marine algae, to which people may be exposed through consuming contaminated seafood or drinking water, or via direct contact in recreational waters.[87] Another potential concern for exposure from seafood is heavy metals, especially methylmercury which is taken up at greater rates in warmer waters.[87]

> *"The impacts of climate change will not affect Americans equally. In addition to regional differences in impacts, socioeconomic factors (e.g., income, education) affect adaptive capacity and can make some communities more vulnerable to impacts"*
>
> *-- U.S. EPA, 2015*

Extreme precipitation poses a threat to drinking water supplies, and may be one of the largest climate threats to water quality, having preceded 68 percent of waterborne disease outbreaks between 1948 and 1994.[87] Such events may overburden stormwater and drainage systems, which can cause discharge of untreated sewage into waterways or back-ups into basements in cities with combined storm and sewer systems (e.g., Baltimore),[20] causing exposure to human pathogens such as those that cause diarrhea. Private wells can also be contaminated by extreme precipitation events, such as by livestock manure carrying the bacteria *E. coli*.[87] In other cases, flooding events may cause direct injury, or damage to infrastructure which leads to increased growth of mold or bacteria that can aggravate allergies and asthma.[34]

Climate influences the habitat, population, and active season of ticks which spread Lyme disease and mosquitoes that spread West Nile virus and other pathogens; however the specific influence of this is difficult to predict, owing to the large number of factors which influence the spread of these diseases.[87] For example, it has been determined that the recent increase in Lyme disease cases in the Northeast is driven by multiple factors,[34] though geographic location and seasonal climate variability are very likely to be significant factors in determining when and where exposure is most likely.[87] The adaptive capacity of a population is expected to have a large influence on the degree of increased infection,[87] which also means that certain populations who have this capacity are at a lower risk, while those who may not have access to air conditioning or vector control measures such as spraying are at a greater risk of infection.

2.3.3 Food and Energy Security

Climate change is expected to increase the exposure of food and consumers to pathogens, toxins, and chemical contaminants, and to increase the risk of disruptions to distribution systems (Figure 3).[87] Changes to precipitation patterns in the Mid-Atlantic region are likely to increase overland flow and therefore the chemicals and other contaminants discharged into bodies of water *{Ch2.1.1}*, including sources used for irrigation or fisheries.[87] Flooding caused by extreme precipitation further increases the likelihood that fields or fisheries are contaminated by pathogens, such as those released by overwhelmed sewer systems or carried from livestock manure, as noted in the section on water quality. Climate change may alter the ranges of bacterial and fungal pathogens which normally affect crops, and higher temperatures may improve growing conditions, increasing their concentrations where they exist during various stages of food production and storage.[87] Changes to the climate can increase risk of damage from pests and competitors *{Ch2.2.1}*; and in an effort to deal with these threats, many farmers are likely to increase pesticide use, thereby increasing the level of exposure to consumers.[87] Increased CO_2 levels may even decrease the nutritional content of crops, and has been shown to alter the ratio of macronutrients (decreasing protein concentrations) as well reduce the concentrations of micronutrients (e.g., iron, magnesium and zinc) per calorie.[87] Climate change also threatens the overall yields from agriculture *{Ch2.2.1}*, which may cause an issue regardless of where that occurs. As mentioned in the introduction to this

chapter, impacts to Marylanders cannot be thought of only in the most direct sense of impacts to the Northeast or Mid-Atlantic, because the Maryland economy and the other systems on which we rely are not isolated to these regions. According to an analysis done by the Johns Hopkins Center for a Livable Future, the amount of vegetables produced in Maryland accounts for little more than 10 percent of consumption; dairy production is estimated to fill almost 30 percent; and fruit approximately 20 percent.[90] Key agricultural import sources for the U.S. include Mexico and Canada (almost 40 percent by $U.S. in 2016 combined), followed by the European Union (another 18 percent), China, Brazil, Australia, Chile and Indonesia, among others.[91] These imports are, for the most part, processed goods such as coffee, wine, and cocoa (the top three by $U.S. in 2016), however staples such as beef, grains, fruits, vegetables and dairy products also make the top 25. Furthermore, in the event that prices are driven up by decreased supply, household food security may be the primary concern. The USDA estimated that around 12.3 percent of U.S. households (15.6 million) were food insecure in 2016, meaning at some time during the year, they did not have the resources to provide adequate food to all family members.[92] Although Maryland tends to fare better than the national average (about 10 percent average 2014 to 2016),[92] that is still a large number of households in the State that are already at risk in this scenario and particularly vulnerable to further related impacts. When food is available, distribution may also become an issue due to increased risk of transportation infrastructure being compromised by extreme weather events *{Ch2.1.2}*.[87]

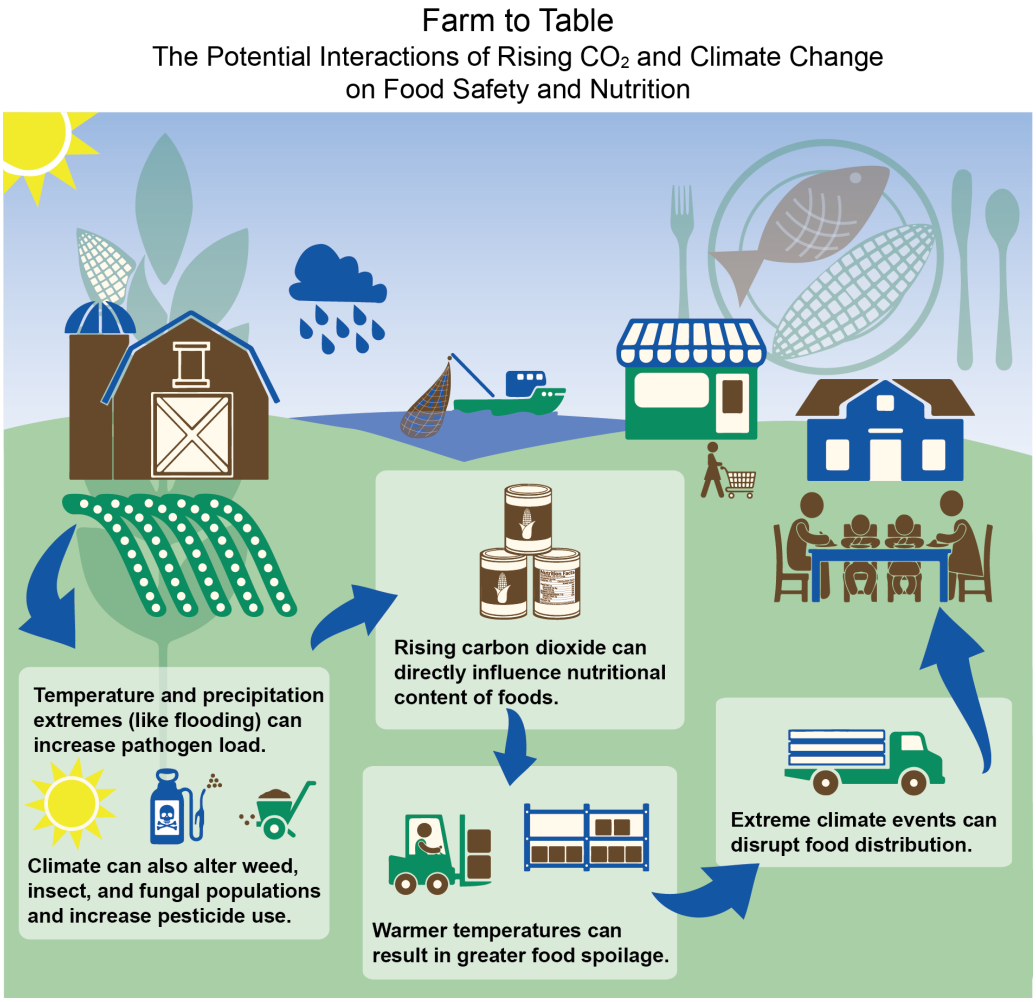


Figure 3. **Diagram demonstrating the impacts of increased CO_2 concentrations and changes in temperature and climate which affect the quality and distribution of food, as well as food safety and nutrition.[87]**

Extreme weather events are likely to disrupt infrastructure, and while transportation was discussed at length, this also includes electricity, water, and communication services that are important not only to daily life, but also emergency response services; reducing capacity to respond to and recover from an event.[87] An extended loss of electricity may impact human health by restricting access to clean water (pumping stations, water treatment plants, and household well pumps), temperature control (A/C units, fans, and electric heating), safe food storage and preparation (refrigerators, freezers, and electric stoves), and certain emergency medical services.[55, 87]

2.3.4 Equity

Communities that live in areas which are particularly vulnerable to the impacts discussed in this chapter are clearly more likely to be exposed to such events and scenarios; and individuals who may be inherently more sensitive or have a reduced adaptive capacity for responding to the scenarios have a higher probability of experiencing a negative outcome if exposure occurs. As noted previously, both factors are integral to describing the overall risk involved. While a few examples of vulnerable individuals and communities have been identified throughout this chapter, it is worth revisiting in a more cohesive manner. Sectors such as agriculture, fisheries and tourism were discussed in terms of jobs and the economy, for example, but it must not be overlooked that negative impacts to these industries have a very real and direct impact to individuals and families whose livelihoods depend on their yearly success. The U.S. Global Change Research Program refers to vulnerable groups as "populations of concern," and identifies that this includes "those with low income, some communities of color, immigrant groups (including those with limited English proficiency), Indigenous peoples, children and pregnant women, older adults, vulnerable occupational groups, persons with disabilities, and persons with preexisting or chronic medical conditions".87 Since all Marylanders are not starting out on equal footing, it is essential that these differences and disadvantages are taken into account during decision-making regarding resource allocation and prioritization of actions. The State engages this issue through multiple avenues, including the Commission of Environmental Justice and Sustainable Communities (CEJSC), the legislation of the GGRA, and through the recommendations provided by the Commission. It is one of the charges of the Commission to address any disproportionate impacts of climate change, and it is also integral to the Commission's work to consider unintended consequences of adaptation and mitigation efforts on these communities.

> *"Extreme precipitation events have been statistically linked to increased levels of pathogens in treated drinking water supplies and to an increased incidence of gastrointestinal illness in children."*
>
> *-- U.S. Global Change Research Program, 2016*

3 Policy & Progress

3.1 The 2016 Greenhouse Gas Emissions Reduction Act (GGRA) - Reauthorization

As noted in the introductory chapter, the GGRA of 2009 was created based on the recommendations of the MCCC's 2008 Climate Action Plan. The original law required Maryland to achieve a 25 percent reduction in statewide GHG emissions from 2006 levels by 2020. MDE's 2015 *GGRA Plan Update*, showed that Maryland was on target to not only meet but exceed this level of emissions reduction; and that it was being accomplished with an estimated economic benefit between $2.5 and $3.5 billion in increased economic output by 2020 as well as creation and maintenance of between 26,000 and 33,000 new jobs.[51] The *2015 GGRA Plan Update*, along with the MCCC's *2015 Annual Report*, informed a review of the State's progress that occurred at the end of that year. The review by the Governor and General Assembly was mandated by the original law, and culminated in a reauthorization of the GGRA in 2016. The updated law includes the same balanced requirements and safeguards as the original, such as additional reporting and a mid-course reaffirmation of goals by the General Assembly, as well as incorporating protection of jobs and the economy. The most significant enhancement was a new benchmark requiring a 40 percent reduction of emissions from 2006 levels by 2030. This additional benchmark was included in order to ensure continued progress after 2020 towards the State's long-term GHG emission reduction goals; as indicated in the text of the 2009 and 2016 GGRA, which notes both reduction plans shall be designed "in recognition of the finding by the Intergovernmental Panel on Climate Change that developed countries will need to reduce greenhouse gas emissions by between 80 percent and 95 percent from 1900 levels by 2050".[93]

MDE is currently working on a draft of the 40 by 30 plan, which is due to be presented to the Governor and the General Assembly at the end of 2018. The final plan must be adopted in 2019, and has the same requirements as the 2012 plan, including consideration of the impacts implementation may have on all segments of the community (rural, low-income, minority) as well as various sectors of the economy (agriculture, manufacturing); ensuring reliable and affordable electrical service; producing a net economic benefit for Maryland and a net increase in jobs in the State; encouraging new "green jobs" in Maryland; and special provisions protecting the manufacturing industry. MDE will also submit a report in 2020 describing the State's progress toward achieving the required GHG reductions and an update on the state of science regarding emissions reductions needed by 2050 to avoid the most dangerous impacts of climate change.

An independent study on the economic impacts of these GHG reduction goals is to be performed by an institution of higher education in Maryland, and overseen by the Commission. This report is due to the Governor and General Assembly in 2022, and will supplement the MDE progress report to inform the General Assembly's decision regarding continuation of the 40 by 30 goals, as well as the special manufacturing provisions. The law will terminate in 2023 if not reauthorized.

3.2 Progress towards the 2020 Goals

In the 2015 GGRA Plan Update, MDE reported that the 2012 GGRA Plan was expected to result in an estimated $2.5 to $3.5 billion in increased economic output by 2020, and help create or maintain between 26,000 and 33,000 jobs. At that time, the State was projected to be on target to exceed the emission reduction goal of 34.66 million metric tons of CO_2 equivalent ($MMtCO_2e$, based on the global warming potential of other gases compared to CO_2) by nearly 4 $MMtCO_2e$. An updated estimate is expected to be developed during 2018, using the 2017 GHG Emissions Inventory data. At that time, the necessary information will be available to determine the current emissions trajectory and economic impacts for the State. This will allow for a decision regarding not only whether critical adjustments *need* to be made in order to ensure the required reductions are achieved, but also what adjustments *can* be made to achieve even deeper reductions while still maintaining net economic progress and jobs growth.

Programs listed in this chapter support the State's GHG reduction efforts or otherwise address climate change; and many are included in the annual reports submitted by State agencies regarding GGRA progress, and were more thoroughly discussed in the *2015 GGRA Plan Update* (Table 1). In addition to those programs noted here, there are many other State initiatives that directly and indirectly impact mitigation and adaptation efforts, whether designed for such purposes or as a co-benefit.

GGRA POLICY / PROGRAM
A. EmPOWER Maryland
B. The Maryland Renewable Energy Portfolio Standard (RPS)
C. The Regional Greenhouse Gas Initiative (RGGI)
D. Other Energy Programs
E. Transportation Technologies
F. Public Transportation
G. Pricing Initiatives
H. Other Innovative Transportation Strategies
I. Forestry and Sequestration
J. Ecosystems Markets
K. Building and Trade Codes in Maryland
L. Zero Waste
M. Leadership-By-Example
N. Maryland's Innovative Initiatives
O. Future or Developing Programs
P. Land Use Programs
Q. Outreach and Public Education

Table 1. Key strategies and programs listed in the *2015 GGRA Plan Update*.

3.2.1 EmPOWER Maryland

Enacted in 2008, the EmPOWER Maryland Energy Efficiency Act (EmPOWER) set a target to reduce both Maryland's per capita total electricity consumption and peak load demand by 15 percent below 2007 levels by 2015. The program includes numerous State and utility managed energy efficiency and conservation programs, some of which are noted later in this section. EmPOWER is funded in part by the Regional Greenhouse Gas Initiative, but also by a line-item on utility ratepayer bills. While the Maryland Energy Administration (MEA) is the lead on non-utility EmPOWER programs, the Public Service Commission (PSC) is responsible for ensuring that the utilities meet their goals. A 2015 order by the PSC extended the utility programs, and set new savings targets at two percent of gross sales annually for as long as cost-effective savings continue to be available. By increasing energy efficiency across the state, the GHG emissions from the electricity sector are reduced by decreasing the amount electricity required for the same activities.

3.2.2 The Maryland Renewable Energy Portfolio Standard

Recognizing the economic, environmental, fuel diversity, and security benefits of renewable energy resources, Maryland became one of the first states to adopt a Renewable Energy Portfolio Standard (RPS) in 2004. Requiring that power providers procure Renewable Energy Credits from renewable sources, the intent of this law is to establish support for development of renewable electricity generation within Maryland and the PJM footprint. The original legislation has been updated a number of times, most recently this past year to increase the goal to 25 percent of retail electricity sales by 2020, replacing the 20 percent by 2022 target.

This includes a 2.5 percent carve-out specifically for solar energy. This legislation has a clear and direct impact on GHG emissions from the electricity sector, by increasing the percentage of electricity that comes from zero emission generation sources.

3.2.3 The Regional Greenhouse Gas Initiative

The Regional Greenhouse Gas Initiative (RGGI) is a cooperative effort by Maryland and eight partner states to reduce CO_2 emissions from the electric generation sector. Maryland formally joined RGGI in 2007, and its participation is managed by MDE. The program is based on a "cap and invest" strategy, with a collective 91 million ton cap set for all participating states in 2014 declining by 2.5 percent annually until 2020, and then by another 30 percent from 2020 to 2030. The states are allocated a portion of the total cap, and sell most of their emission allowances at quarterly auctions. Auction proceeds fund various programs which promote energy efficiency, renewable energy or other consumer benefits. Maryland invests auction revenue in the Strategic Energy Investment Fund (SEIF), which is administered by MEA. SEIF is used in part to fund EmPOWER Maryland projects, including energy efficiency upgrades for low-to-moderate income families; and is also allocated for direct bill assistance and projects that promote affordable, reliable and clean energy across Maryland. According to the most recent update by MDE, the potential emissions reductions over the lifetime of the RGGI program are estimated to be 3.60 MMtCO2e by 2020; and the program is anticipated to continue driving emissions reductions into the future.[82]

After nearly two years of engagement in a program review which incorporated comprehensive feedback from stakeholders and experts, the RGGI states recently announced a series of improvements to the program that build on past successes and continue to reduce GHG emissions after 2020 through innovative approaches. Maryland played a leading role in forging this bipartisan consensus to strengthen and broaden the ground-breaking program with a number of proposed improvements, including establishing a 30 percent reduction in the carbon cap from 2020 to 2030 and adding a new, innovative mechanism, the Emissions Containment Reserve, which will secure additional environmental progress if emission reductions are less expensive than anticipated. In addition, the Cost Containment Reserve, which protects consumers by releasing additional allowances when costs are significantly higher than expected, will remain in effect. This program plays an important role in Maryland's statewide climate change efforts, and is a significant component of the GGRA program as it generates both environmental and economic benefits for the State.

Updates, including information on upcoming stakeholder meetings, news, and auction results, can be found at https://www.rggi.org/.

3.2.4 Other Energy Programs

The mission of the Maryland Energy Administration is to promote affordable, reliable and cleaner energy for the benefit of all Marylanders. MEA manages a portfolio of energy efficiency, renewable energy, and transportation programs that reduce energy consumption and produce cleaner energy for Maryland residents and businesses, many of which are linked to EmPOWER, the RPS, and RGGI. As many of these programs have broad reaches, the Administration often works in partnership with other agencies to accomplish the full scope. Furthermore, several agencies work through programs managed by the Federal government to provide energy efficiency and renewable energy benefits to Marylanders. The Maryland Department of Housing and Community Development (DHCD), for example, manages several energy conservation and retrofit programs that specifically reduce energy costs and address critical health and safety hazards for low-income Maryland residents. A number of State programs for energy efficiency and renewable energy are highlighted below.

Energy Efficiency

- The *Kathleen A. P. Mathias Agriculture Energy Efficiency Program* provides incentives on a competitive basis to farms/businesses in the agriculture sector to cover up to 50 percent of the cost of eligible energy efficiency upgrades and up to 25 percent of the cost of eligible renewable energy upgrades.
- The *Combined Heat and Power (CHP) Grant Program* provides incentives on a competitive basis to encourage the implementation of CHP technologies in Maryland.

- The *Commercial and Industrial Grant Program* provides incentives on a competitive basis to implement and showcase upgrades that reduce electricity usage by 15 percent or more with at least two measures.
- The *Clean Energy Communities Low-to-Moderate Income Grant Program* is designed to support energy efficiency and conservation programs, projects, or activities and demand response programs for low-to-moderate income Marylanders.
- The *Data Center Energy Efficiency Grant Program* is designed to support the robust and growing information technology sector in Maryland by providing grants on a competitive basis to encourage the implementation of cost-effective energy efficiency measures in data centers around the State.
- The *Weatherization Assistance Program*, managed by DHCD, helps eligible low-income households across the State of Maryland with the installation of energy conservation measures in their home. These measures reduce the consumption of energy, GHG emissions and the cost of maintenance for these homes. Funding is provided by the U.S. Department of Energy (DOE) and SEIF.
- The *EmPOWER Low Income Energy Efficiency Program and the Multifamily Energy Efficiency and Housing Affordability Program* help low income households with installation of energy conservation measures in their homes. Funding is provided by ratepayers of the five participating EmPOWER Maryland utility companies.
- The DHCD manages a *BeSMART Home Loan Program*, which offers financing to homeowners across the state for energy efficiency replacement and/or upgrade of appliances, heating, cooling and ventilation systems and whole house envelope improvements. The BeSMART platform grew in 2017 to support the energy efficiency upgrades at Perry Point – an affordable housing rehabilitation that will serve veterans – and further expansions are anticipated in the future.

Renewable Energy

- The *Parking Lot Solar PV Canopy with EV Charger Grant Program* combines Maryland's RPS goal for solar with the State's ongoing support of electric vehicle (EV) infrastructure by providing incentives for the installation of solar PV canopies in combination with EV charging stations at Maryland parking lots.

The Energy Water Infrastructure Program

The $24 million Energy Water Infrastructure Program launched by Governor Hogan continues to issue grants in 2017 throughout the State that save energy and reduce emissions.

- $3 million to the Easton Utilities Commission will help fund the construction of a solar power system designed to meet 100 percent of the plant's energy demands.
- $1 million to Anne Arundel County will help fund the purchase of high-efficiency presses at two treatment plants, expected to decrease electricity consumption by 51 percent.
- $129,720 to Kent County will fund upgrades to lighting systems at four water treatment plants and three wastewater treatment plants, expected to reduce energy consumption by 60 percent.
- $963,300 to Howard County and $132,000 to the City of Salisbury will help fund the replacement existing pumps with more efficient versions that reduce operating time and save energy.
- $379,568 to the Town of Sharpton will help fund a project that includes the construction of a solar panel system to generate electricity for the water treatment plant.
- $209,496 to the Town of Pittsville will help fund a project that includes the installation of a pressure-reducing valve which will conserve water and save energy.

- The *Clean Energy Grant Program* offers incentives to Maryland homeowners, businesses, nonprofits, State departments and agencies, and local governments for the installation of qualifying clean energy technologies to support the State RPS.
- The *Animal Waste Technology Fund*, managed by Maryland Department of Agriculture (MDA), provides incentives to companies that demonstrate new technologies on farms and provide alternative strategies for managing animal manure, including energy production.
- The *Offshore Wind Business Development Grant Program* and *Offshore Wind Workforce Development Grant Program* assist business owners, workers, researchers, and developers in preparing for the potential development of an Offshore Wind Industry in Maryland.

3.2.5 Transportation Initiatives

The proportion of GHG emissions that come from Maryland's transportation sector (36 percent in 2014) is above the nationwide average of 27 percent,[94, 95] This is partly attributable to extensive pass-thru transportation in the State, resulting in a higher emissions impact proportional to Maryland's economy. Within the transportation sector, 67 percent of emissions come from on-road gasoline vehicles (typical passenger cars and light-duty trucks); 19 percent of emissions come from on-road diesel vehicles (delivery trucks, combination trucks, and buses); and 14 percent of emissions are from the off-road sector (aviation, marine, rail, non-road gasoline and diesel, liquefied natural gas vehicles, and off-road equipment).[94]

State programs, many of which are managed by Maryland Department of Transportation (MDOT), focus on the GHG emissions from on-road vehicles. Levers to impact emissions from aviation, marine, rail, and non-road sources are indirect and primarily focused on operations within the boundaries of the Port of Baltimore and Maryland's airports; excluding the remainder of commercial operations. In addition to mitigation measures, the State has also begun taking steps to adapt to the expected impacts of climate change, including (but not limited to) the following recent initiatives:

- SHA completed a statewide coastal vulnerability assessment with the best available climate projections and LiDAR data to help inform all aspects of planning, programming and design to ensure resilient and reliable transportation.
- MTA's Environmental Planning Division completed a climate change focused Vulnerability Plan in 2016 and is continuing to utilize the results in development of adaptation measures and resiliency planning.

Transportation Technologies

A major part of initiative to reduce GHG emissions from the transportation sector includes increasing the use of electric vehicles (EVs). MDOT's leadership of the Electric Vehicle Infrastructure Council (EVIC), established in 2011, continues to build opportunities for and remove barriers to plug-in EVs in Maryland. This is accomplished through promoting and providing financial incentives for the purchase of EVs, as well as the installation of supply equipment. Last year, for example, MDOT led the effort to nominate EV charging

Maryland Port Administration: Wallenius Wilhelmsen Logistics

Wallenius Wilhelmsen Logistics works to deliver innovative and sustainable global shipping and logistics solutions for manufacturers of cars, trucks, heavy equipment and specialized cargo; and strives to maximize efficiency of energy and resources to minimize GHG emissions produced during their operations. The following key elements guide their work towards a zero emissions future:

1. Recognizing activities that impact the environment, and focusing on high impact changes;
2. Maintaining accountability and transparency in environmental commitments;
3. Seeking to exceed expectations today to reduce risk and cost tomorrow;
4. Investing in tomorrow's technologies by supporting early stage technology development today; and
5. Remaining humble before the challenges faced, seeking active partnerships with varied stakeholders to develop sustainable solutions.

corridors under the Federal FAST Act, and was successful at receiving designation for I-95, US 50, I-270, and I-70/I-68; building a critical infrastructure network to support both freight and passenger travel by EV. As of fall 2017, the total number of battery-electric and plug-in hybrid electric vehicles registered in Maryland is approaching 10,000.

Another large part of the mitigation strategy is reducing idling time, which can in part be accomplished by upgrading major commuting corridors with the latest and greatest in transportation technologies. In 2016, Governor Hogan invested $100 million in the I-270 Innovative Congestion Management Project which recently selected an innovative package that eliminates bottlenecks and adds new lane miles, real-time traffic communication signs, and intelligent signals that deliver dynamic traffic management along the corridor. While this project is still underway, it is expected to reduce the commute from Frederick by 30 minutes.[96] An ongoing program managed by State Highway Administration (SHA) called CHART continues to yield substantial GHG reductions associated with the efficient management of incidents, traveler information, and other on-road infrastructure technologies that reduce delay.

Public Transportation

Increasing public transportation use is one of the many ways to reduce vehicle miles traveled, as well as congestion by reducing the number of cars on the road. The following represent a number of recent and ongoing initiatives to improve public transportation efficiency and increase ridership.

- The multi-year planning process and successful start-up of BaltimoreLink in 2017 was a major effort resulting in the reconfiguration of local and commuter bus service throughout Baltimore. BaltimoreLink creates a more efficient and accessible system, including an estimated 32 percent increase in the population within a quarter mile of transit service.
- Supported by two TIGER Grant awards from the U.S. Department of Transportation, Maryland Transit Authority (MTA) is working with Baltimore City to deliver the North Avenue Rising project, and with Montgomery County to deliver the US 29 Bus Rapid Transit project. Both projects were added to the construction program in the 2017 to 2022 CTP, and will provide enhanced and more efficient transit options in these critical corridors.
- Groundbreaking occurred for the Purple Line in August 2017 after securing $900 million from the Federal Transit Administration to match State, local, and private funding.

Photo 10. Baltimore light rail after the 2017 BaltimoreLink redesign of the area's core transit system *{Photo by BeyondDC}*

The relationships and priorities of policies and investments that advance public transportation and those that promote roads and vehicular traffic will remain an area of active public debate. Requirements to substantially reduce our GHG must be incorporated into existing considerations for personal convenience and choice, growth and development, and congestion and efficiency.

Maryland Clean Cars Program

Maryland's Clean Cars Program is designed to lower emissions from vehicles and is implemented by MDE. The program adopted California's strict vehicle emission standards in November 2007, implementing the California Low Emission Vehicle Standards II (CALEV II) for all model year 2011 vehicles. It works on a macro level; rather than applying to individuals it sets a standard based on fleet-wide emission averages. The purpose of the Clean Cars Program is to reduce a number of vehicle emissions, including volatile organic compounds (VOCs) and nitrogen oxides (NO_x); but it directly regulates CO_2 emissions as well. The Clean

Cars Program is mandated by the Maryland Clean Cars Act of 2007 and has been fully implemented through regulations codified in COMAR 26.11.34, the Low Emissions Vehicle Program, adopted and enforced by MDE. In 2017, the program was updated to maintain consistency with the California Program, adopting changes designed to:

- Streamline testing for the alternative fuel conversion certification procedure and reduce the burden for small volume manufacturers;
- Provide greater flexibility to intermediate volume manufacturers to meet the Zero Emission Vehicle (ZEV) requirement;
- Align the CALEV III program and test procedures with the Federal Tier 3 program;
- Align the medium and heavy-duty GHG regulations with EPA's Phase 1 GHG regulations; and
- Improve compliance flexibility and strengthen the performance requirements of the On-Board Diagnostics II (OBD II) regulation.

3.2.6 Zero Waste

Sustainable materials management (SMM) is another important part of improving the efficiency with which resources and energy are used, which in turn reduces GHG emissions from life-cycle processes such as the extraction of natural resources, and production, transportation and disposal of food and goods. A 2009 analysis by the EPA showed that materials management accounted for 42 percent of GHG emissions nation-wide.[97] On June 27, 2017, Governor Hogan signed Executive Order 01.01.2017.13, Waste Reduction and Resource Recovery Plan for Maryland. The Order adopts a first-ever SMM policy for Maryland that aims to minimize the environmental impacts of the materials' use throughout the entire lifecycle. The policy emphasizes environmentally and economically sustainable methods to capture and reinvest resources into our economy, rather than simply dispose of them – including everything from metals and plastics to energy, nutrients, and soil.

Specifically, the Order contains the following initiatives:

- A stakeholder consultation process to improve MDE's methodology for tracking waste generation, source reduction, and recycling, including recommendations to better account for business recycling activities and new voluntary statewide goals for continuous improvement in SMM;
- A technical assistance partnership between the Department of Commerce and MDE to help establish new recycling businesses in Maryland;
- A partnership between MDA and MDE to provide research and demonstration of innovative nutrient recovery technologies in order to facilitate adoption of these technologies;
- A partnership between the MEA and MDE to research and promote adoption of energy recovery technologies such as anaerobic digestion;
- A partnership between MDOT and MDE to provide guidance to increase the reuse of dredged materials, including by State agencies; and
- Outreach partnerships to increase awareness of the benefits of and opportunities for waste diversion.

3.2.7 Managing Forestry and Agricultural Lands

Land conservation and sustainable management offers an important mechanism for mitigating and adapting to climate change. Healthy and vigorous forests and grass lands not only provide direct benefits in GHG reduction but keeping them intact also helps to avoid or diminish additional GHG emissions which would be

associated with development. Climate change is projected to have multiple and potentially severe impacts to the agricultural and forestry sectors; shifting the optimum growth ranges for various species, and increasing direct and indirect stressors such as heat and pests. The State's programs in land management work on all these fronts – to mitigate by increasing sequestration capacity and avoiding future emissions, and also take steps that make Maryland more resilient to direct and indirect climate change impacts.

Sustainable Forestry Management

There are an estimated 2.5 million acres of forest land in Maryland. Though long-term data show decreases since the 1963 inventory, estimates of aboveground biomass and net volume on forest land have increased since 2011, and in 2016, the total annual growth of all live trees on timberland outpaced total removals by a ratio of 1.9:1.[98] The Maryland DNR acts as state lead to manage forests to capture carbon. This program promotes sustainable forestry management practices which enhance productivity and increase carbon sequestration in existing Maryland forests on both public and private lands. The goals of this program are to improve sustainable forest management on 30,000 acres of private land annually and on 100 percent of State-owned resource lands, and ensure 50 percent of State-owned forest lands will be third-party certified as sustainably managed.

Photo 11. Healthy diverse forest being inspected by a Chesapeake Watershed Forester on the Eastern Shore of Maryland. *{Photo by Jane Hawkey, IAN/UMCES}.*

Enhanced forestry management in Maryland should contribute a total 1.8 $MMtCO_2e$ reduction in the State's GHG emissions in 2020. In addition, planting trees expands forest cover and associated carbon stocks by regenerating or establishing healthy, functional forests through practices such as soil preparation, erosion control, and supplemental planting, to support optimum forest growth. By 2020, the implementation goal of this program is to achieve the afforestation and/or reforestation of 43,030 acres in Maryland; and over 35,000 acres have been planted thus far (between 2006 and 2016). This is expected to achieve 1.79 $MMtCO_2e$ of cumulative sequestration in 2020. To help protect existing forests, MDA is also working on an integrated pest management program for gypsy moths – the "most destructive pest of forest and shade trees in Maryland"[99] – and one of the pests expected to thrive in a changing climate. It will be important to continue sustainable maintenance of forested lands and ensure net growth of biomass to retain sequestration benefits into the future.

Agriculture and Land Conservation

MDA seeks to safeguard Maryland's network of natural areas, agricultural lands, and coastal zones through its established conservation programs and practices. MDA has pursued policies and programs that curb the conversion of agricultural lands and encourage the conservation of natural resources while working with its partners at DNR and Maryland Department of Planning (MDP) to promote the preservation and restoration of forested, grassed, and wetland areas on agricultural lands. Two MDA programs key to these efforts are the Maryland Agricultural Land Preservation Foundation (MALPF) and the USDA's Conservation Reserve Enhancement Program (CREP). MALPF, which purchases permanent preservation easements, was established in 1977 and is one of the most successful programs of its kind in the country. Besides maintaining prime farmland and woodland as a viable local base of food and fiber production, the protection of agricultural land reduces random urban development, safeguards wildlife habitat, and enhances the ecology of the Chesapeake Bay and its tributaries. Maryland has participated in CREP since 1997 to target high-priority conservation concerns by offering rental payments for 10 to 15-year set-aside contracts and other incentives to agricultural producers to protect environmentally sensitive lands, improve wildlife habitat, and reduce nutrient and sediment loss. While enrollment is down in recent years, most of the funded areas have maintained their program measures. Furthermore, these CREP areas are being targeted for *permanent* protection under DNR's Easement Program, and nearly 10,000 acres have been converted so far.

3.2.8 Land Use Development

Maryland's GGRA Plan includes two programs designed to minimize GHG emissions through the management of future land development: (1) Reducing Emissions through Smarter Growth; and (2) Land Use/Location Efficiency and Priority Funding Area Related Benefits. MDP is the lead agency for these efforts, which involve the private sector as well as various agencies and commissions at all levels of government within the State. Overall, land use development trends in Maryland have moved in the direction of more compact development, with 75 percent compact development from 2011 through 2016, a marked improvement from 62.5 percent compact development between 2001 and 2010. Despite implementation of the land use programs, market, economic, and other forces invariably have an impact on the location and intensity of new development. This, in turn, impacts the GHG emissions prevented.

MDP provides data analysis and forecasting as part of its technical assistance to State and local governments, utilizing a variety of data sets and analytical tools, such as MDP's parcel database, U.S. Census information, land use/land cover data, and the Growth Simulation Model. By actively managing growth, local communities can maximize the efficiency of their development patterns and contribute to a reduction in Maryland's GHG emissions. Smart growth promotes compact, mixed-use development that maximizes mobility and housing choices; and encourages new development (or redevelopment) in areas with existing or planned infrastructure, to reduce sprawl. This helps the State meet its forestry management and land conservation goals, while helping to increase the economic competitiveness and fiscal performance of local communities. Many local governments in Maryland are increasingly implementing these kinds of land use and transportation policies and programs. The following are a few examples of programs and initiatives managed by MDP which support these efforts.

- In 2010, the "Sustainable Communities" designation was established, in order to strengthen reinvestment and revitalization in designated areas. It simplified the framework for the Community Legacy and Neighborhood BusinessWorks programs, and requires MDOT to consider Sustainable Communities in its annual examination of the Consolidated Transportation Program.
- Maryland has designated Priority Funding Areas to influence smarter, more sustainable growth and development; and legislation directs the use of State funding for roads, water and sewer plants, economic development and other growth-related needs toward these areas.

Healthy Soils

Healthy soils are defined by their ability to function as a biological system, as well as having a composition with substantial organic matter and a structure which promotes water- and nutrient-holding capacity. Healthy soils are beneficial for both the farmer (e.g., increasing agricultural yields) and the environment (e.g., increasing carbon sequestration ability). While there is still much to learn about the co-benefits, healthy soils hold substantial promise as an important part of the climate solution, and the State is moving forward with a variety of initiatives:

- During the 2015/2016 season, a record-breaking 501,204 acres of cover crops were planted, thanks in part to almost $25 million in grants.[64] Another $22.5 million provided for the 560,000 acres of cover crops planted over the 2016/2017 season.[114]
- Over the spring of 2017, two Healthy Soils Workshops (focused on soil science and soil health) were sponsored by the Commission's ARWG.
- Effective October 2017, HB1063 enacts the Maryland Healthy Soils Program, which will promote the adoption of best management practices that improve the health of the soil and increase its capacity for carbon sequestration.[115]

- The Maryland Smart Growth Cabinet makes recommendations to the Governor regarding changes in State law, regulations, and procedures needed to create, enhance, support, and revitalize Sustainable Communities across Maryland.
- The Maryland Sustainable Growth Commission identifies regional growth and development issues for the Governor's Smart Growth Subcabinet, and recommends opportunities for collaboration on these issues between the State and local governments. It also reviews statewide efforts to implement the State Growth Plan and the state plans for transportation and housing.

3.3 Long-Term Goals: Beyond 2020

Many of the control programs in Maryland's 25 percent by 2020 Plan are not tailored to a 2020 endpoint, but designed to generate deeper reductions as they are implemented through 2030 and into the future. For example, mobile source emission reductions will occur as fleets turn over and older vehicles are replaced by newer models with more stringent requirements and updated technology, decreasing the total pollution burden. Energy sector reductions related to RGGI, Maryland's RPS, and supply and demand-side energy efficiency measures should also continue to decrease total GHG emissions. Recent initiatives include a $24 million Energy Water Infrastructure Program launched by Governor Hogan, of which $4 million has been granted to fund a photovoltaic solar array at the Easton Wastewater Treatment plant, and $1 million to purchase high-efficiency upgrades in several Anne Arundel Country wastewater treatment plants.[100] At the grid-level, the Maryland PSC awarded offshore wind renewable energy credits (ORECs) to two projects with a combined 368 MW of capacity, expected to come online in 2020 and 2022.[101] In addition to existing efforts and emerging strategies being considered by the State, MDE is keeping track of broader trends such as energy demand, fuel usage, and travel trends which are expected to impact the additional reductions needed. The complete suite of proposed programs and initiatives will be drafted and available to stakeholders for review in MDE's Draft Plan at the end of 2018, in conjunction with the most recent update of the GHG Inventory. Program evaluation will include the full scope of expected reductions into the future, in recognition of the finding by the IPCC that developed countries will need to reduce GHG emissions by between 80 percent and 95 percent from 1990 levels by 2050, as required by the legislation. The Plan will be finalized in 2019, with careful consideration for inventory data, modeling, and stakeholder input, to ensure that Maryland has everything in place to meet or, as feasible, to exceed its ambitious reduction goals while at the same time creating jobs and benefiting the State economy.

3.3.1 Emerging Technologies

Energy Storage

Constant improvements to the technology of energy storage have important implications for GHG reduction. As the use of variable renewable energy sources, specifically solar and wind, have massively increased, so has the need for a reliable way to store the energy produced. Recent improvements to energy storage allow for renewable energy to be generated in excess when it is available (when the sun is shining, or the wind is blowing), but utilized when it is needed instead of immediately (and potentially at times when it could not be generated). Energy storage is also important to reduce or eliminate reliance on power plants that operate only during peak energy demand, which are often more polluting and expensive than regular plants. In addition to energy storage connected to the grid, home energy storage is also emerging with the release of the Tesla Powerwall, which will allow consumers the option to store their own renewable or off-peak energy to power their homes.

Smart Grid Technology

A smart grid is an electrical grid that has the ability to gather information and then act on it. It integrates both the generator's and consumer's information, such as usage or behaviors, and uses it to create the most efficient, economical, and sustainable system possible. Through increasing efficiency and conservation, renewable energy integration, and plug-in electric vehicle integration, smart grids can greatly reduce GHG emissions. Smart grids also have numerous benefits in addition to lower GHG emissions, such as: reduced operating costs

for utilities, increased ability to use all available infrastructure, better coordination of plug-in electric vehicles, and easier installation of new technologies into the grid. Smart grids reduce the power outages, inefficiencies, and lack of information problems for which the complex U.S. electrical grid is infamous; thus creating a system that is much more reliable and responsive.

Electric Vehicles

Since a large portion of GHG emissions are generated by the transportation sector, replacing gasoline-fueled vehicles with EVs would have a significant impact on the climate. EVs are vehicles that are powered by electricity that is usually stored in the vehicle in a battery, but can also be connected directly to generator plants (i.e., electric trains or trolleys). This technology is obviously very closely linked to small-scale energy storage technology in general, with improvements concentrating on increasing the storage capacity of onboard batteries which provide a greater range for the vehicle. As EV technology improves, the distance a vehicle can travel on a single charge goes up and the prices go down, making them both more desirable and more affordable for the average consumer. While EVs do not emit GHGs themselves, they do shift the source of pollution to the power plant generating the extra electricity used. This still has a net positive impact, since it is more efficient, but the benefits could be increased by using electricity generated with renewable sources. EVs which run on solar or wind generation would be the most effective way of decreasing transportation emissions. Some EVs have even been designed with solar panels on the roof to produce electricity for some basic processes in the vehicles, and as solar panels become more efficient this could be expanded to accommodate most of the vehicle's functions. EVs used in tandem with a smart grid that provides significant charging infrastructure for the vehicles would also greatly encourage their use.

Fuel Cell Vehicles

As an alternative to fossil fuel hybrids or electric vehicles, fuel cell vehicles are an emerging technology that shows a lot of promise. Fuel cells are used to directly produce electricity inside the vehicle using hydrogen or natural gas, as opposed to batteries which must be charged for a long time from an external source. Hydrogen fuel cells are remarkable due to their only emission being pure liquid or gaseous water. Fuel cell vehicles can also travel much further than battery powered electric vehicles, with a current range of up to 400 miles on a tank of compressed hydrogen gas. Hydrogen fuel cells have gotten some controversy due to the fact that it requires a lot of energy to electrolyze water, which is how the hydrogen fuel is produced. Therefore it releases a lot of CO_2 into the air when the hydrogen gas is created, which can make the whole usage of hydrogen cells carbon positive despite the lack of emissions from the vehicle itself. In order to avoid this, wind or solar power could be used to power electrolysis, but these power sources are still relatively inefficient compared to fossil fuels. If fossil fuels are utilized, CCS (another emerging technology, discussed below) may be used to capture and store/sequester the CO_2 that is produced to prevent it from entering the atmosphere.

Photo 12. New electric vehicle charging stations at M&T Bank Stadium in Baltimore, funded in part through MEA's Alternative Fuel Infrastructure Program. *(Photo by Maryland Energy Administration)*

Innovative Biofuels

The category of biofuels includes liquid or gaseous fuels produced from biomass (plant or animal matter) and typically used as a replacement for - or blended with - fossil fuels, such as corn ethanol in automobile gasoline. *Carbon-neutral* biofuels are the topic of very active research and development. Although biofuels do emit CO_2 when combusted, this carbon was removed from the atmosphere recently during the biomass growth

process, and therefore results in no net GHG emissions. Particularly attractive is the potential for biofuels produced by algae that utilize waste streams during photosynthesis, such as the nutrients and organic matter in wastewater or industrial CO_2 emissions. These wastes would be diverted from what were additional energy-consuming processes to one that actually produces useable energy. This is a topic of substantial research, industrial process development and commercialization in Maryland.

The Water-Energy Nexus

The water-energy nexus refers to the connection between how much water is evaporated in energy production, and how much energy is consumed in the human use of water, such as the collection, purification, and transportation/distribution. It is estimated that on average, 2 gallons of water is evaporated in order to create 1 kilowatt hour of energy; equivalent to 3,000 to 6,300 gallons of water to power one 60 watt light bulb for one year. This results in water shortages as the energy industry must also compete with other major water consumers, especially the ever-growing agricultural sector. Additionally, a large amount of energy is needed to utilize water in many industrial and residential processes. Decreasing the amount of water used in these processes decreases the energy needed, and also means less methane-producing wastewater is generated. Therefore, maximizing the efficiency of the water-energy nexus – using both less water and less energy in water use – has the potential to significantly decrease GHG emissions.

Carbon Capture and Sequestration (CCS)

Multiple entities are currently engaged in research to develop technology that captures CO_2 generated by fossil fuel combustion before it enters the atmosphere, and either transforms it for an alternative use, or stores (sequesters) it indefinitely. Maryland is a part of the Midwest Regional Carbon Sequestration Partnership (MRCSP), one regional segment of a national (DOE) effort to study CCS options for mitigating climate change. Partners in this effort include the University of Maryland, Maryland Energy Administration, and Maryland Geological Survey.

Private efforts are underway as well. Integrated Environmental Services, Inc., for example, has developed CO_2 Reduction Technology that breaks down CO_2 into graphite and oxygen. This process used to be inefficient, emitting more CO_2 when generating the energy utilized during the breakdown than was removed by it. However, IES has developed a method of pre-processing CO_2 which reduces the energy required to break the molecular bonds. This technology can be used in power plants to reduce their CO_2 emissions and allow them to produce graphite that can then be used in other industrial processes such as battery, hybrid electric vehicle, and solar panel production.

Bio-Energy with Carbon Capture and Storage (BECCS)

A related emerging technology is BECCS, or bioenergy with carbon capture and storage. This is the process of generating electricity from biomass and then capturing and storing the resulting CO_2 emissions. This technique is carbon negative, since CO_2 is removed from the atmosphere during biomass growth, and none is released during generation. However, there are still issues with the technology that must be resolved before it is considered viable. First, the methods of carbon capture and storage underground are incredibly expensive and there are a

The Baltimore Convention Center

The Chilled Water Plant 1 at the Baltimore Convention Center reached commissioning completion in July 2017. Through equipment efficiencies and the elimination of 60,000 lbs. of R-22 refrigerant (and ozone-depleting refrigerant), the plant is helping Baltimore and Maryland to achieve our environmental goals. The plant will reduce 6,137 tons of greenhouse gas emissions annually (the carbon reduction equivalent of removing 1,097 cars from the roads each year), and save $189,172 in electricity costs each year. Through successful pre-planning, bidding, local sourcing and close project management, $2.1 million in construction cost savings was achieved.

The Chilled Water Plant 1 has a total chilled water capacity of 5,400 tons, with an ice storage capacity of 48,000 ton-hours. 32.5 percent of the total chilled water capacity is dedicated to the Baltimore Convention Center for its cooling needs.

lot of technological gaps to be filled in about it. The compression and transport of CO_2 leaves a lot of room for potential leaks and spills that would release large amounts of CO_2 right back into the atmosphere, and the same can happen when it is stored underground. One method that MIT has determined is geologically viable is injecting and storing the captured CO_2 in deep saline aquifers. Another option that is being considered is injecting the CO_2 into depleted oil and gas fields. The Department of Energy currently has a BECCS project at a corn ethanol facility in Illinois that captures about 1,000 metric tons of CO_2 and stores it in a sandstone formation 7,000 feet underground.

Biochar

A technology similar to BECCS is biochar, a carbon-negative plant byproduct that resembles charcoal. Electricity can be produced from the energy released via pyrolysis (heating slowly without oxygen) of lumber waste, dried corn stalks and other plan residues. The resulting biochar is very carbon rich and can be placed in the soil as fertilizer, allowing the carbon to be locked underground instead of emitted into the atmosphere. However, to ensure that this process remains carbon negative, the source of the biomass used is important. Biochar made from waste biomass, sustainably harvested crop residues, or crops grown on non-forested abandoned land will be carbon negative. If the biochar is made from forest ecosystems, the result could be a net increase in GHGs. Additionally, biochar must be used in soils of similar pH or it can negatively affect soil fertility.

Green Cement

In 2014, the process of creating clinker for cement mix released CO_2 that accounted for 1.6 $MMtCO_2e$ of the State's GHG emissions. Several different companies are working to develop new technologies and methods that reduce the resource use and process CO_2 emissions generated, even making it a carbon neutral process. One particularly viable method uses fly ash as a component of the mixture, which contributes to the State's zero waste initiative by diverting the bi-product from landfills. The mixture also requires only half the amount of water that is typically required to mix normal concrete, improving the efficiency of the water-energy nexus. Finally, the unique curing process actually *consumes* CO_2 as the cement sets. This results in the process being carbon negative since it reduces the amount of CO_2 in the atmosphere.

Geoengineering

Geoengineering is a broad term for deliberate, large-scale manipulations of Earth's environment that have been proposed as a way to potentially offset some of the consequences of climate change. In general, geoengineering techniques fall into two categories: (1) solar radiation management approaches that aim to change the incoming solar radiation balance; and (2) CO_2 removal approaches that would reduce the amount of CO_2 in the atmosphere. The National Academies of Sciences completed their *Geoengineering Climate: Technical Evaluation of Selected Approaches* study and released two reports in February 2015*; Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration*, and *Climate Intervention: Reflecting Sunlight to Cool Earth*. These reports cautioned that such interventions are not a substitute for reducing GHG emissions, and that additional research is needed to fully assess the potential environmental and other risks to determine whether large-scale deployment is viable. The reports can be found in the *2015 GGRA Plan Update* as Appendices F and G, respectively.

Maryland Energy Innovation Institute

New legislation in 2017 created the Maryland Energy Innovation Institute[102] as part of the University of Maryland's School of Engineering; a collaboration between the University of Maryland Energy Research Center (UMERC) at College Park and the Maryland Clean Energy Center (MCEC). UMERC promotes energy research and education and MCEC is an existing corporate instrumentality of the State to advance clean energy and energy efficiency products, services, and technologies for economic development. Creation of the Institute is expected to allow greater integration of energy research and education with policy innovation, and commercialization of clean energy technologies in Maryland.

3.4 The Role of the Maryland Commission on Climate Change

The Maryland Commission on Climate Change has been actively involved in efforts to mitigate, adapt to, enhance local scientific knowledge of, and educate on climate change for almost a decade. As has been noted, the 2008 Climate Action Plan produced by the Commission was instrumental to informing the development and passage of the 2009 GGRA. More recently, the 2015 MCCC Report supported the new 40 by 30 goals, and helped to inform the decision of the Governor and General Assembly, explicitly recommending "that the State adopt a goal and develop a plan to reduce Maryland's GHG emissions 40 percent from 2006 levels by 2030, with continued inclusion of safeguards, exemptions... and other relevant language contained in the 2009 Act".[32] This endorsement by the Commission was informed by STWG calculations which were based on the IPCC's conclusion that global emissions must be reduced 40 to 70 percent from 2010 levels by 2050 in order to minimize the impacts of climate change.[E, 1,32]

Next year, the Commission is expected to be a major stakeholder involved in creating recommendations for the 40 percent by 2030 Draft Plan, as well as its subsequent review and finalization in 2019.

The full Commission meets at least four times per year, and in 2017 it convened in April, June, September, October, and November. These meetings are open to the public, and a portion of each meeting is set aside for public comment. The Steering Committee for the MCCC met regularly to review and guide Working Group progress in the interim. The four Working Groups held numerous meetings in 2017 to advance each of their contributions to the Commission goals. Details of the meetings and activities of the MCCC and its working groups can be found at: http://mde.maryland.gov/programs/Marylander/Pages/mccc.aspx

3.5 Federal Efforts

A large portion of climate change action at the Federal level had been developed and implemented under executive orders, most notably *Preparing the United States for the Impacts of Climate Change*, which was expected to cut Federal GHG emissions by 40 percent over the next decade (from 2008 levels).[103, 104] This order included requirements for the agencies to make plans for and take internal action related to mitigation and adaptation, and also to provide support (incentives, information, data, and tools) for State and local government assessment, planning, and action in resiliency; establishing a Council and Task Force to oversee these efforts. Significantly for Maryland, it called for agencies to ensure regional actions "consider and are consistent with, sustainability and climate preparedness priorities of States, local governments, and tribal communities where agency facilities are located", and to coordinate climate change preparedness and resilience planning with the states.[103] With the transition to a new Federal administration in 2017, however, several policies that limit global climate change and adapt to its consequences have been altered, set aside, or challenged, and future Federal roles are uncertain. In March of 2017, Executive Order 13783 (*Promoting Energy Independence and Economic Growth*) rescinded the previous EO and several other energy and climate-related policies, additionally directing the EPA to review the Clean Power Plan[105] which the EPA administrator has since proposed to repeal.[106] In August, a new Executive Order 13807 revoked the 2015 EO 13690 which had created a new Federal Flood Risk Management Standard intended to improve resiliency to flood risk by updating floodplain determinations to account for, among other things, the impacts of climate change.[107, 108] Furthermore, in June, President Trump announced his intent to withdraw the United States from the Paris Climate Agreement.[109]

With 3,100 miles of shoreline, Maryland is one of the states potentially most vulnerable to sea-level rise associated with climate change. For this reason, and for those noted in the preceding chapters, the Maryland Commission on Climate Change is concerned that the President has announced his intent for the United States to withdraw from the Paris Climate Agreement. This agreement aims to strengthen both the global response to climate change and adaptive capabilities to its impacts through a standard commitment, which as of October 2017 has been ratified by 166 of 195 signatories.[110] In his opening statement during the signature ceremony,

E The STWG utilized the upper end of the reduction range for their calculations, in consideration of the large per capita emissions in the U.S.

United Nations Secretary-General Ban Ki-moon noted the urgency of the call for action, stating that "we are in a race against time", and "the window for keeping global temperature rise well below 2 degrees Celsius, let alone 1.5 degrees, is rapidly closing". He urged all countries to commit to actions "on behalf of this generation and all future generations… that reduce climate risk and protect communities… [and] that place us on a safer, smarter path".[111]

While the noted Federal actions do not prevent Maryland from moving forward with its own efforts to limit climate change, they do make state-based efforts more difficult. For example, while Maryland is working to reduce emissions from power plants in-state under the RGGI program, the GGRA also requires an accounting of emissions from imported electricity (which supplied approximately 42 percent of consumption in 2014)[94]. As noted in the 2016 Annual Report, the Federal Clean Power Plan (CPP) helps Maryland meet its GGRA goals by requiring similar emission reductions from neighboring states which supply this electricity, reducing the overall emissions from this sector. Furthermore, the CPP improves the economic prospects of in-state power plants, since all generators selling electricity into the regional market will be following similarly stringent regulations. This was recognized in the 2016 GGRA, which notes among the legislative findings that "cap and trade regulation of greenhouse gas emissions is most effective when implemented on a Federal level", and similarly that "because of the need to remain competitive with other states", so are GHG emissions from the manufacturing and certain other commercial and service sectors.[93] Several measures in the proposed Federal FY 2018 Budget, if passed by Congress, may also be of particular consequence to the State, both economically and environmentally. These include cuts in funding targeted for research on global change, food-energy-water systems and risk and resilience at the National Science Foundation (NSF); climate research and mid-range weather forecasting at NOAA; earth science research and satellite missions and education at NASA; and research on climate and energy by the EPA.[112] Many of the NOAA and NASA activities are based in the State, and Maryland's universities and research laboratories perform significant portions of this Federal research and development. For example, one of the research and development programs proposed for elimination is the DOE's *Advanced Research Projects Agency – Energy* (ARPA-E). Since its inception in 2009, UMERC has received $50 million in ARPA-E funding to develop multiple projects in energy storage, and dry cooling technology for power plants.[113] Furthermore, these investments yield results that are necessary to inform the country's mitigation and adaptation efforts, and critical to ensuring Maryland's efforts to reduce its GHG emissions and adapt to the changing climate are based on the strongest and most complete scientific information possible.

The need for continued aggressive action has been made clear throughout this report, and regardless of the status of official national commitments, the goals which Maryland has set through the GGRA of 2009 and 2016 place the State on a pathway to not only meet but exceed its anticipated proportional contribution to the goals of the Paris Agreement. Support at the regional and ideally the Federal level will assure the success of these ambitious interim goals and the State's long-term goal of even deeper reductions, especially during the critical final phases. As surrounding states also begin to internalize the environmental costs of electricity generation, for example, it will become more practicable for Maryland to make even deeper reductions while remaining competitive in this market. As with other issues of interstate commerce, a Federal standard will likely become essential as we move forward with decarbonization. The Commission fully recognizes the need for regional and national leadership and action on the global challenge of climate change, and encourages the Federal government to take note of the proactive and economically beneficial approach taken by Maryland to address this substantial and pressing issue.

4 Recommendations

The recommendations in this year's report demonstrate efforts made by the working groups to continue building on the progress towards our 2020 and 2030 interim goals, while maintaining a broader and longer-term focus on what must be achieved in the decades to follow. Although next year's report is expected to be far more substantial, coinciding with the release of the most recent Greenhouse Gas Inventory and the Draft 40 by 30 Plan from MDE, it is the expectation of the Commission that the contents of this year's report will provide the Governor and General Assembly, in the interim, with guidance to aid in making informed policy and program decisions which benefit all Marylanders now and in the future.

After significant discussion and effort at both the Working Group and Commission levels, it was determined that, while each Working Group would put forth their own set of recommendations and goals for the upcoming 2018 year (as they have in the past), the Commission would also distill a set of recommendations which are outward-facing, addressed to specific parties, and request timely and measurable responses.

4.1 Commission Recommendations

The Commission has unanimously decided to provide the following recommendations to the parties identified in each. These recommendations are based on those provided by the Working Groups, as distilled and refined by the group chairs and Commission members.

GGRA/Programmatic

- The Commission recommends that MDE identify the capacity of water infrastructure facilities and assess ways to increase their resiliency and effectiveness. MDE should report back to DNR for consideration and discussion at ARWG meetings in 2018.
- In developing the final Plan that reduces statewide GHG emissions by 40 percent from 2006 levels by 2030 as required by the GGRA of 2016, MDE should consider not only actions to close the gap to achieve the 40 percent reduction, but should identify and consider longer-term strategies needed to achieve zero net emissions over the subsequent two to three decades.
- In developing the final 40 by 30 Plan, the MDE should fully take into account the changes in GHG emissions associated with population growth and expanded land development in projecting growth in emissions that must be offset to achieve the GGRA mandated reductions.
- The Commission encourages and supports collaboration among State agencies and researchers in forecasting future emissions through approaches that provide a more dynamic basis for evaluating future public policy options that achieve the needed GHG emission reductions together with other important objectives.
- The Commission recommends that MDE continue to work with the STWG, the University of Maryland, and the Departments of Natural Resources and Agriculture to ensure that MDE's Greenhouse Gas Emission Inventory is locally relevant and complete. Specifically MDE should continue to examine improvements to: life cycle emissions of fossil fuels extracted out of state but burned in state, and emissions sink methodologies for in-state forests, wetlands, and agriculture. As required by law, this work will be completed by the end of 2018 as part of the final publication of the 2017 emissions inventory.
- The Commission recommends that the Department of General Services (DGS) investigate the possible inclusion of climate goals into the State procurement policy. DGS should report back to the Commission in advance of the draft 40 by 30 Plan release.
- The Commission recommends that the State continue the promotion of in-state green manufacturing, "Buy Maryland/Buy USA and Hire Maryland" whenever possible.

- The Commission recommends that MDE work with the Commission and the MWG on the manufacturing study required by the GGRA law in 2020, and that any economic analysis performed for the GGRA plan include: workforce and economic considerations surrounding various technologies in electricity generation/storage and advanced management strategies that decrease the total GHG burden of the electric grid; numbers for actual expected displacement of workers, and geographic location; how the future climate may impact worker productivity and construction seasons; the quality of jobs that may replace fossil fuel industry work; and the potential impacts of combined heat and power (CHP) on industrial operational costs and job retention. MDE will discuss the scope of work for GGRA related economic analysis with the MWG when it is available.

- The Commission strongly supports efforts of the State to advance the responsible development of offshore wind energy and is encouraged by recent actions of the Public Service Commission to approve two proposed projects that could produce 368 megawatts of electricity, reducing carbon emissions by 19,000 metric tons per year for 20 years. The Commission appreciates the continuing debate over localized impacts but would strongly caution against State or Federal efforts to push the projects farther offshore if such actions would add costs, reduce environmental benefits, or put at risk the responsible development of offshore wind.

- The Commission recommends that MDOT and MDE continue their participation in the work of the Transportation and Climate Initiative to develop a regional clean and equitable transportation policy. MDOT and MDE should regularly report back to and engage with the Commission and Working Groups as appropriate.

Transportation Sector Emissions

- The Commission recommends that MDOT continue to work with the MWG to better estimate emissions reductions that result from a combination of multiple mitigation programs. MDOT should also work with MDP to ensure that the best possible land use and development assumptions are being used in all state wide modeling for GHG mitigation.

- The Commission recommends that MDOT, MDE, MEA, and DGS review state fleet procurement procedures with respect to Alternate Fuel Vehicles and report back to the Commission at the end of 2018 the potential emission benefits and economic data for an enhanced Alternate Fuel Vehicle procurement program. MDOT should report back to the Commission in advance of the draft 40 by 30 plan release.

- The Commission recommends that MDOT and the MWG report on the costs and benefits of a program aimed at the rapid deployment of ZEV, propane, and compressed natural gas transit and school buses (acknowledging that MDOT does not have jurisdiction over local bus purchases) in Maryland. MDOT should report back to the Commission in advance of the draft 40 by 30 plan release.

- The Commission recommends that MDOT and MDP report back on the costs and benefits (economic and emissions) of applicable and effective strategies and strategy bundles geared towards decreasing vehicle miles traveled, including increasing public transportation ridership, providing transit access through first and last mile linkages, facilitating the integration of autonomous vehicles, increasing ride-sharing, and integrated land-use planning. MDOT should report back to the Commission in advance of the draft 40 by 30 Plan release.

Healthy Soils

- The Commission recommends that MDA, through collaboration with ARWG, MWG and STWG, provide adequate and reliable information to MDE for inclusion of the Healthy Soils Program in the 40 by 30 Plan. This information should include expected GHG emissions reductions; climate change adaptation benefits; economic factors affecting its implementation; and legal, regulatory and fiscal requirements.

Environmental Justice

- The Commission recommends that the State continue to incorporate considerations of environmental justice as it relates to climate change into its 40 by 30 Plan. Specifically, MDE should continue working with DNR and the ARWG on tools that will help this cause. MDE should share specific ways in which environmental justice will be incorporated in the Draft 40 by 30 Plan with the Commission during the summer 2018 Commission meeting.
- In terms of adaptation, the CESJC, DNR, and MDE should clarify the types and definitions of vulnerable populations that would most benefit from coastal resiliency projects and other climate adaptation work and identify the data or tools that will help to meet this need.
- The Maryland State Legislature and the Commission's stakeholders should incorporate considerations for vulnerable communities (as defined in the 2016 MCCC Annual Report), environmental justice and underserved communities as it relates to climate change in its recommendations for the State's 40 by 30 Plan.

Federal

- The Commission recognizes the impact of Federal actions regarding climate change on the ability of the State to meet its climate goals. MDE and other State agencies (as applicable) should communicate and educate stakeholders as identified by the Commission on equity, economic, and environmental implications of Federal actions on Maryland climate change goals.
- The Commission urges the Maryland Congressional delegation to place a high priority on ensuring that climate change science and research and development of energy technologies are adequately funded and implemented by the Federal government.

Outreach

- The Commission recommends that DNR and MDP convene regional meetings by the end of 2018 to solicit local and regional climate adaptation priorities and support local adaptation efforts. The Commission intends that these regional meetings offer scientific, technical, logistical and planning resources that provide climate change adaptation planning assistance and that capitalize on existing engagement efforts and regional bodies or organizations.
- The Commission recommends that the Secretary of MDE provide information and updates to the Maryland General Assembly around the 40 by 30 plan and the Annual Report.
- The Commission requests that state agencies make materials on climate change initiatives and programs publicly accessible and available and strive to make such materials available as bilingual resources, with consideration to multiple literacy levels and keep the Commission informed as to opportunities and challenges of such an effort.
- The Commission asks MDE, DNR, and other state agencies to consult with the Education, Communication and Outreach Working Group regarding best practices and messaging around climate change outreach and public meetings. Those agencies identified with capacity for outreach should engage with appropriate organizations in vulnerable communities, the business community, and other non-government organizations to broaden the audience involved in climate change discussions and considerations.
- The Commission seeks to continue and further develop partnerships within the Commission's diverse sectors. MDE should implement (1) a Climate Ambassadors program to enable members of the public to educate on climate change and (2) a Climate Champions program that recognizes companies or groups engaged in efforts meet the State's climate goals. Other state agencies should suggest additional efforts and collaborations that may supplement this goal.

4.2 2017 Working Group Recommendations

The following section contains a summary of statements, priorities, and recommendations which were developed by the members of each working group. They reflect the discussions and activities of the groups during 2017, as well as expectations for 2018. The goals and priorities which the groups have established for themselves represent the basis of each working group's 2018 Work Plan, which will contain additional detail and more specific targets for the upcoming year. These plans will be presented to the Commission for approval during the first quarter of 2018.

4.2.1 Adaptation and Response Working Group

The Adaptation and Response Working Group (ARWG) is chaired by the Secretary of the Maryland Department of Natural Resources with administrative support provided by DNR staff. The ARWG is charged with developing a comprehensive strategy for reducing Maryland's climate change vulnerability, as well as providing the State and local governments with tools to plan for and adapt to the more extreme weather and rise in sea levels anticipated as a consequence of climate change. The working group advances its work through the active involvement of and leadership from other working group members, agencies and stakeholders.

The ARWG and its members are actively implementing work on recommendations that have been adopted since the group began its early work nearly a decade ago. The ARWG members are squarely in implementation mode – working to ensure that a broad variety of Phase I and II Strategy recommendations about sea-level rise and climate impact are advancing. The working group has relied upon and recommends continued collaboration and conversations with stakeholders to determine when, how and if implementation of adaptation measures move forward. The recommendations and statements of support set forth below will continue to be guided and informed in this manner as they move forward.

The complete recommendations can be found in Appendix A.

The group's recommendations are based on and draw from (1) discussions, actions and suggestions made at quarterly ARWG meetings; (2) ARWG staff dialogue with individual ARWG members during 2017; and (3) suggested items recommended for consideration from MCCC members and partners.

In 2016 - 2017, progress was made establishing a Healthy Soils Consortium to address the role of agriculture in carbon sequestration. Within their respective roles and charges, the Commission and its four working groups should support the efforts of the Consortium to inform Maryland farmers of not only the benefits of soil health, but also the programs and incentives that can be accessed to further the adoption of such practices. Furthermore, the ARWG recommends an analysis to identify practices (and their co-benefits) appropriate to Maryland that increase soil health, and tools/metrics available for quantification of carbon sequestration and GHG reduction which can be achieved through the adoption of healthy soils practices. The group also supports incentivizing a menu of Best Management Practices that improve soil health, and conducting an inventory of existing State programs which could prioritize and incentivize these practices for all scales of farming.

For the upcoming year, the ARWG proposes a review of its Phase I and II Comprehensive Strategy recommendations to identify progress, highlight any gaps or needs, and revise as appropriate. The ARWG will continue to incorporate equity and environmental justice considerations into its implementation work addressing adaptation actions, including both Phase I and II strategies for reducing vulnerability to climate change. Supporting Phase I, the working group encourages DNR and its inter-agency review team to understand and further clarify the types of vulnerable populations that would most benefit from coastal resiliency projects addressing climate impacts. In accordance with Phase II of the plan, the group recognizes that an increasing amount of adaptation work is beginning to develop approaches to non-coastal populations and proposes that the Commission and Working Groups increase their efforts to understand, identify and communicate specific non-coastal strategies. In general, the ARWG proposes that existing regional meetings be used to identify the needs of and provide support to local partners, recognizing that their climate adaptation challenges are as diverse as the communities themselves.

Finally, in achieving the State's adaptation goals, the ARWG acknowledges the importance of engaging the business and engineering communities; Maryland's academic and research communities; and health equity and environmental justice efforts; and supports an approach by the Commission and other adaptation actors that coordinates with and seeks input from these partners.

4.2.2 Education, Communication and Outreach Working Group

The Education, Communication and Outreach (ECO) Working Group assists with the Commission's public outreach and public meetings on climate change, as well as educating Marylanders on what the State is doing to address its causes and impacts.

In 2017, the Education Communication and Outreach (ECO) Working Group made concrete progress in many of the 2017/2018 Work Plan goals. ECO members worked to increase stakeholder awareness and participation in climate-related events in Maryland by continually enhancing the Maryland Department of Health's (MDH) "Environment, Public Health and Climate Change in Maryland" calendar with relevant events and directing traffic to the calendar. The working group developed and began enacting an Outreach Plan, (1) collaborating with partners to both expand and enhance outreach and education by increasing the climate literacy of existing environmental outreach, through development and implementation of the Climate Ambassador pilot; (2) building the Toolkit of climate education resources; and (3) building the list of Climate Communicators. ECO proposed and developed a statement from the Commission regarding President Trump's decision to withdraw from the Paris Climate Agreement. ECO members also worked to produce five one-pagers on the topics of: The Commission, The Greenhouse Gas Reduction Act, Resiliency to Climate Change, Sea-Level Rise and Flooding, and the Health Impacts of Climate Change.

The complete recommendations can be found in Appendix B.

ECO's 2017 recommendations continue to expand upon ECO's Work Plan and the 2016 recommendations; and reflect proposed best practices regarding education, communication and outreach. In general, they are related to three specific charges which the legislation notes as working group actions: (1) communicating with and educating citizens about the urgency of acting to reduce the impacts of climate change; (2) addressing any disproportionate impacts of climate change on low-income and vulnerable communities; and (3) developing broad public and private partnerships with local, State, and Federal agencies.

ECO seeks contributions from all Commission stakeholders to the resources the group is engaged in developing, including the calendar of climate events maintained by the Department of Mental Health, the ToolKit of climate resources, and other platforms and initiatives as requested. While ECO intends to keep the Commission up to date with best practices for communication, education and outreach, it also encourages working group and Commission members to seek the expertise of the group in this area as relevant to their activities. Furthermore, the Commission (inclusive of working groups) should continue to formalize partnerships with its diverse sectors to support a broader network of information and engagement regarding communities vulnerable to climate change.

The ECO Working Group will continue to provide advisement and additional capacity as applicable to identify communities especially vulnerable to the impacts of climate change (as defined in the 2016 Annual Report), what these impacts may be, and how they may be addressed in the work of the Commission and the State. With ECO's support, the Commission should continue to incorporate considerations for environmental justice and vulnerable/underserved communities in its recommendations for the State's 40 by 30 Plan.

In 2018, ECO plans to continue its effort to increase collaboration with the Commission's other working groups, in order to ensure that each group's network, knowledge and capacity are being fully utilized. The group also plans to provide support for dissemination and utilization of the fact sheets and other products as they are completed and approved; and provide expertise in the identification, development and collation of additional resources relevant to a variety of communities and outreach activities. ECO plans to continue its support of the effort to raise awareness of this Annual Report and the work of the Commission, particularly

regarding best practices for education and outreach surrounding the 2018 Annual Report and 40 by 30 GGRA Draft Plan, in order to increase stakeholder involvement. The group also plans to identify and support efforts for more general climate change education and related environmental literacy.

4.2.3 Mitigation Working Group

The Mitigation Working Group (MWG) is co-chaired by three balanced commission members (State agency, business representative, and environmental advocate), with administrative support provided by MDE staff. The MWG focuses on regulatory, market-based and voluntary programs to reduce GHG emissions while supporting economic development and job creation.

This year, the group heard from expert panels on a number of topics as determined by the 2017 Work Plan, followed by discussions to develop recommendations for the 40 by 30 Plan, including the identification of areas which may be pertinent to the Plan but require additional research. A sub-group was also developed this year on innovative financing (PACE and QECB), lead by MEA, which will continue its activity into 2018. The MWG is continually engaged in identifying new emission reduction/mitigation strategies to be analyzed for inclusion in the State's draft of this Plan, and continues to seek input on any recommendations for additional programs or considerations while there is still sufficient time for analysis and incorporation into the drafting process.

The complete recommendations can be found in Appendix C.

Regarding the State's GHG Emissions Inventory, due in 2018, the MWG recommends that MDE continue to work with the STWG, the University of Maryland, and the Departments of Natural Resources and Agriculture to ensure that the Inventory is both locally relevant and complete. This includes consideration of life-cycle emissions generated by out-of-state extraction, processing, and transportation of fossil fuel energy consumed in-state; and applying advanced methods to generate a more accurate accounting of emissions sinks such as agricultural soil and forestry management.

The MWG plans to continue incorporating considerations for environmental justice in its recommendations for the State's 40 by 30 Draft Plan, due in 2018, and encourages the State to also use this lens. The MWG also supports the work of the Healthy Soils initiative and recommends that relevant State agencies continue work to confirm potential emissions reductions and economic benefits from the program which may be incorporated into the 40 by 30 Draft Plan. The MWG supports the promotion of green-energy manufacturing in-state that will directly provide sustainable, high quality jobs and generate additional jobs along the supply chain. By meeting both criteria, this can potentially improve Maryland's jobs and economic prospects, and also reduce life-cycle emissions for renewable energy projects.

The MWG has laid out a number of items which should be considered for analysis, if feasible, regarding potential impacts to manufacturing and other jobs in the State, as well as policies that may benefit both the economy and the environment. These are recommended to be considered during the drafting of the 40 by 30 Plan as well as the manufacturing study due in 2020. Similarly, a number of items were identified for further consideration regarding emissions reductions from the transportation sector, including improvements to estimation of the impacts of strategies and modeling processes; incorporation of electric and alternative fuel vehicles into the state fleets; and strategies geared towards decreasing vehicle miles traveled.

4.2.4 Scientific and Technical Working Group

The Scientific and Technical Working Group (STWG) is responsible for updating and informing the Commission on the science of climate change. During 2017, one of the STWG's undertakings was an examination of the procedures used by the Department of the Environment (MDE) in developing periodic GHG inventories needed to track progress in achieving GGRA reduction goals and in projecting future

trends.[F] In 2018, the group plans to focus more attention on the methods of estimation for items which may be considered sinks, including forests, agriculture, wetlands and waterways, as well as to begin exploring energy alternatives to achieve emissions reductions beyond 2030 that move towards long-term goals.

The complete recommendations can be found in Appendix D.

The STWG urges the Maryland Congressional delegation to place a high priority on ensuring that climate change science and research and development of energy technologies are adequately funded and implemented by the Federal government.

The Climate Action Plan required by the GGRA of 2016 should not only include actions to close the gap to achieve a 40 percent reduction in emissions, but should be based on longer-term strategies needed to achieve carbon neutrality over the decades subsequent to 2030.

Through the STWG, the Commission should identify critical uncertainties in and methods to improve the estimation of greenhouse emissions from forests, agriculture, wetlands and waterways.

Changes in GHG emissions associated with population growth and expanded land development should to be better taken into account in projecting growth in emissions that must be offset to achieve the GGRA goal.

The Commission on Climate Change encourages and supports collaborative efforts in forecasting future emissions in order to provide a more dynamic basis for evaluating public policy options that achieve the needed GHG emission reductions together with other social and economic objectives.

F The summary of these findings can be found in Appendix D with the complete recommendations

Works Cited

1 Intergovernmental Panel on Climate Change, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, R. Pachauri and L. Meyer, Eds., Geneva, 2014.

2 Maryland Commission on Climate Change Scientific and Technical Working Group, "Appendix 1 of 2015 Maryland Commission on Climate Change Report: Reducing Emissions of Greenhouse Gases Beyond 2020," in 2015 Maryland Commission on Climate Change Annual Report, 2015.

3 J. Walsh, D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis and D. Anderson, "Chapter 2: Our Changing Climate," in Climate Change Impacts in the United States: The Third National Climate Assessment, J. Melillo, T. Richmond and G. Yohe, Eds., U.S. Global Climate Change Research Program, 2014, pp. 19-67.

4 D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, B. DeAngelo, S. Doherty, K. Hayhoe, R. Horton, J. P. Kossin, P. C. Taylor, A. M. Waple and C. P. Weaver, "Executive Summary," in Climate Science Special Report: Fourth National Climate Assessment, Volume I, D. Wuebbles, D. Fahey, K. Hibbard, D. Dokken, B. Stewart and T. Maycock, Eds., Washington, DC, U.S. Global Change Research Program, 2017, pp. 12-34.

5 American Chemical Society, "Global Climate Change: ACS Position Statement," 2014. [Online]. Available: https://www.acs.org/content/acs/en/policy/publicpolicies/sustainability/globalclimatechange.html?_ga=2.78158420.173778942.1502223826-1730421612.1502223826. [Accessed 9 August 2017].

6 American Geophysical Union, "Human-Induced Climate Change Requires Urgent Action," 2014. [Online]. Available: http://sciencepolicy.agu.org/files/2013/07/AGU-Climate-Change-Position-Statement_August-2013.pdf. [Accessed 9 August 2017].

7 American Meteorological Society, "Climate Change: An Information Statement of the American Meteorological Society," 2012. [Online]. Available: https://www.ametsoc.org/ams/index.cfm/about-ams/ams-statements/statements-of-the-ams-in-force/climate-change/. [Accessed 9 August 2017].

8 American Physical Society, "National Policy 07.1 Climate Change," 2010. [Online]. Available: http://www.aps.org/policy/statements/07_1.cfm. [Accessed 09 August 2017].

9 U.S. Global Change Research Program, Global Climate Change Impacts in the United States, T. Karl, J. Melillo and T. Peterson, Eds., Cambridge University Press, 2009.

10 National Aeronautics and Space Administration, "Scientific Consensus: Earth's climate is warming," 2017. [Online]. Available: http://climate.nasa.gov/scientific-consensus. [Accessed 8 August 2017].

11 American Association for the Advancement of Science, "What We Know: The reality, risks, and response to climate change," 2014. [Online]. Available: http://whatweknow.aaas.org/get-the-facts/. [Accessed 8 August 2017].

12 The Geological Society of America, "Climate Change," 2015. [Online]. Available: https://www.geosociety.org/gsa/positions/position10.aspx. [Accessed 09 August 2017].

13 Royal Society and U.S. National Academy of Sciences, "Climate Change: Evidence & Causes," 2014. [Online]. Available: http://dels.nas.edu/resources/static-assets/exec-office-other/climate-change-full.pdf.

14 U.S. Global Change Research Program, Climate Change Impacts in the United States: The Third National Climate Assessment, J. Melillo, T. Richmond and G. Yohe, Eds., 2014.

15 J. Cook, N. Oreskes, P. T. Doran, W. R. L. Anderegg, B. Verheggen, E. W. Maibach, J. S. Carlton and S. Lewandowsky, "Consensus on consensus: A synthesis of consensus estimates on human-caused global warming," Environmental Research Letters, vol. 11, no. 4, 2016.

16 National Oceanic and Atmospheric Administration, "What is the difference between weather and climate?," 2014. [Online]. Available: http://oceanservice.noaa.gov/facts/weather_climate.html. [Accessed 17 April 2017].

17 A. P. Schurer, M. E. Mann, E. Hawkins, S. F. B. Tett and G. C. Herger, "Importance of the pre-industrial baseline for likelihood of exceeding Paris goals," Nature Climate Change, vol. 7, pp. 563-567, 2017.

18 A. E. Rafferty, A. Zimmer, D. M. W. Frierson, R. Startz and P. Liu, "Less than 2°C warming by 2100 unlikely," Nature Climate Change, vol. 7, pp. 637-641, 2017.

19 C. Figueres, H. Schellnhuber, G. Whiteman, J. Rocostrom, A. Hobley and S. Rahmstorf, "Three years to safeguard our climate," Nature, vol. 546, pp. 593-595, 2017.

20 U.S. Environmental Protection Agency, "Climate Change in the United States: Benefits of Global Action," United States Environmental Protection Agency, Office of Atmospheric Programs, 2015.

21 J. Hansen, L. Nazarenko, R. Ruedy, M. Sato, J. Willis, A. Del Genio, D. Koch, A. Lacis, K. Lo, S. Menon, T. Novakov, J. Perlwitz, G. Russell, G. A. Schmidt and N. Tausnev, "Earth's Energy Imbalance: Confirmation and Implications," Science, vol. 308, pp. 1431-1435, 2005.

22 H. B. Dieng, A. Cazenave, B. Meyssignac and M. Ablain, "New estimate of the current rate of sea level rise from a sea level budget approach," Geophysical Research Letter, vol. 44, pp. 3744-3751, 2017.

23 R. Horton, G. Yohe, W. Easterling, R. Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe and a. F. Lipschultz, "Chapter 16: Northeast," in Climate Change Impacts in the United States, 2014, pp. 371-395.

24 J. L. Davis and N. T. Vinogradova, "Causes of accelerating sea level on the East Coast of North America," Geophysical Research Letters, vol. 44, no. 10, pp. 5133-5141, 2017.

25 National Oceanic and Atmospheric Administration, "Global Climate Report - September 2017," 2017.

26 Z. Hausfather, K. Cowtan, D. C. Clarke, P. Jacobs, M. Richardson and R. Rohde, "Assessing recent warming using instrumentally homogenous sea surface temperature records," Science Advances, vol. 3, no. 1, 2017.

27 B. D. Santer, S. Solomon, F. J. Wentz, Q. Fu, S. Po-Chedley, C. Mears, J. F. Painter and C. Bonfils, "Tropospheric warming over the past-two decades," Scientific Reports, vol. 7, 2017.

28 K. E. Kunkel, L. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, J. Rennells, A. DeGaetano and J. G. Dobson, "Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 1. Climate of the Northeast U.S.," National Oceanic and Atmospheric Administration, 2013.

29 J. Runkel, K. Kunkel, D. Easterling, B. Stewart, S. Champion, R. Frankson and W. Sweet, "Maryland State Summary," National Oceanic and Atmospheric Administration, 2017.

30 National Academies of Sciences, Engineering, and Medicine, "Attribution of Extreme Weather Events in the Context of Climate Change," The National Academies Press, Washington, DC, 2016.

31 B. B. Sarojini, P. A. Scott and E. Black, "Detection and attribution of human influence on regional precipitation," Nature Climate Change, vol. 6, pp. 669-675, 2016.

32 Maryland Commission on Climate Change, "2015 Maryland Commission on Climate Change Annual Report," 2015.

33 Maryland Commission on Climate Change, "2016 Maryland Commission on Climate Change Annual Report," 2016.

34 U.S. Environmental Protection Agency, "Climate Change Indicators in the United States," Washington DC, 2016.

35 U.S. Geological Survey, "California's Central Valley," 20 March 2017. [Online]. Available: https://ca.water.usgs.gov/projects/central-valley/about-central-valley.html. [Accessed 18 September 2017].

36 G. Garfin, G. Franco, H. Blanco, A.Comrie, P. Gonzalez, T. Piechota, R. Smyth and R. Waskom, "Chapter 20: Southwest," in Climate Change Impacts in the United States: The Third National Climate Assessment, 2014, pp. 462-486.

37 Maryland Commission on Climate Change Adaptation and Response Working Group, " Adaptation and Response Working Group Annual Report," in Appendix E of 2016 Maryland Commission on Climate Change Annual Report, 2016.

38 P. M. Groffman, P. Kareiva, S. Carter, N. B. Grimm, J. Lawler, M. Mack, V. Matzek and H. Tallis, "Chapter 8: Ecosystems, Biodiversity, and Ecosystem Services," in Climate Change Impacts in the United States: The Third National Climate Assessment, J. Melilo, T. Richmond and G. Yohe, Eds., U.S. Global Change Research Program, 2014, pp. 195-219.

39 I.-C. Chen, J. K. Hill, R. Ohlemuller, D. B. Roy and C. D. Thomas, "Rapid Range Shifts of Species Associated with High Levels of Climate Warming," Science, vol. 333, no. 6045, pp. 1024-1026, 2011.

40 J. Lenoir, J. C. Gegout, P. A. Marquet, P. de Ruffray and H. Brisse, "A significant upward shift in plant species optimum elevation during the 20th century," Science, 2008.

41 J. VanDerWal, H. T. Murphy, A. S. Kutt, G. C. Perkins, B. L. Bateman, J. J. Perry and A. E. Reside, "Focus on poleward shifts in species' distribution underestimates the fingerprint of climate change," Nature Climate Change, vol. 3, 2012.

42 S. M. Crimmins, S. Z. Dobrowski, J. A. Greenberg, J. T. Abatzoglou and A. R. Mynsberge, "Changes in climatic water balance drive downhill shifts in plant species' optimum elevations," Science, vol. 331, 2011.

43 J. S. Dukes, J. Pontius, D. Orwig, J. R. Garnas, V. L. Rodgers, N. Brazee, B. Cooke, K. A. Theoharides, E. E. Stange, R. Harrington, J. Ehrenfeld, J. Gurevitch, M. Lerdau and K. Stinson, "Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict?," Canadian Journal of Forest Research, vol. 39, no. 2, pp. 231-248, 2009.

44 B. Huang, P. W. Thorne, V. F. Banzon, T. Boyer, G. Chepurin, J. H. Lawrimore, M. J. Menne, T. M. Smith, R. S. Vose and H. Zhang, NOAA Extended Reconstructed Sea Surface Temperature (ERSST), Version 5, National Oceanic and Atmospheric Administration, 2016.

45 R. K. Shearman and S. J. Lentz, "Long-Term Sea Surface Tempreature Variability along the U.S. East Coast," Journal of Physical Oceanography, vol. 40, pp. 1004-1017, 2010.

46 Ecosystem Assessment Program, "Ecosystem Assessment Report for the Northeast U.S. Continental Shelf Large Marine Ecosystem," National Oceanic and Atmospheric Administration, 2009.

47 H. Ding and A. J. Elmore, "Spatio-temporal patterns in water surface temperature from Landsat time series data in the Chesapeake Bay, U.S.A.," Remote Sensing and Environment, vol. 168, pp. 335-348, 2015.

48 Chesapeake Environmental Communications, "The Changing Chesapeake," 2017. [Online]. Available: http://www.chesapeake-data.com/changingchesapeake/. [Accessed 21 August 2017].

49 National Oceanic and Atmospheric Administration, "Climate Change and the Chesapeake Bay," 2011.

51 Maryland Department of the Environment, "2015 Greenhouse Gas Emissions Reduction Act Plan Update," 2015.

52 U.S. Environmental Protection Agency, "Climate Adaptation and Estuaries," October 4 2016. [Online]. Available: https://www.epa.gov/arc-x/climate-adaptation-and-estuaries. [Accessed September 21 2017].

53 Maryland Ocean Acidification Task Force, "Task Force to Study the Impact of Ocean Acidification on State Waters Report to the Governor and the Maryland General Assembly," 2015.

54 S. C. Moser, M. A. Davidson, P. Kirshen, P. Mulvaney, J. F. Murley, J. E. Neumann, L. Petes and D. Reed, "Chapter 25: Coastal Zone Development and Ecosystems," in Climate Change Impacts in the United States: The Third National Climate Assessment, J. Melillo, T. Richmond and G. Yohe, Eds., U.S. Global Change Research Program, 2014, pp. 579-618.

55 S. L. Cutter, W. Solecki, N. Bragado, J. Carmin, M. Fragkias, M. Ruth and T. J. Wilbanks, "Chapter 11: Urban Systems, Infrastructure, and Vulnerability," in Climate Change Impacts in the United States: The Third National Climate Assessment, J. Melillo, T. Richmond and G. Yohe, Eds., U.S. Global Change Research Program, 2014, pp. 282-296.

56 H. G. Schwartz, M. Meyer, C. J. Burbank, M. Kuby, C. Oster, J. Posey, E. J. Russo and A. Rypinski, "Chapter 5: Transportation," in Climate Change Impacts in the United States: The Third National Climate Assessment, J. Melillo, T. Richmond and G. Yohe, Eds., U.S. Global Change Research Program, 2014, pp. 130-149.

57 Maryland State Archives, "Maryland at a Glance: Waterways," 2017. [Online]. Available: http://msa.maryland.gov/msa/mdmanual/01glance/html/port.html. [Accessed 14 September 2017].

58 A. Georgakakos, P. Flemming, M. Dettinger, C. Peters-Lidard, T. Richmond, K. Reckhow, K. White and D. Yates, "Chapter 3: Water Resources," in Climate Change Impacts in the United States: The Third National Climate Assessment, M. Melillo, T. Richmond and G. Yohe, Eds., U.S. Global Change Research Program, 2014, pp. 69-112.

59 Maryland General Assembly, Environment - Emergency Action Plans for Dams (HB0125), 2017.

60 D. Hales, W. Hohenstein, M. D. Bidwell, C. Landry, D. McGranahan, J. Molnar, L. W. Morton and M. Vasquez, "Chapter 14: Rural Communities," in Climate Change Impacts in the United States: The Third National Climate Assessment, J. Melillo, T. Richmond and G. Yohe, Eds., U.S. Global Change Research Program, 2014, pp. 333-349.

61 University of Maryland Center for Environmental Science, "Land Management: Farming in a Changing Climate," 2014. [Online]. Available: https://climatechange.maryland.gov/wp-content/uploads/sites/16/2014/12/ian_newsletter_4061.pdf. [Accessed 11 September 2017].

62 J. Hatfield, G. Takle, R. Grotjahn, P. Holden, R. C. Izaurralde, T. Mader, E. Marshall and E. Liverman, "Chapter 6: Agriculture," in Climate Change Impacts in the United States: The Third National Climate Assessment, J. Melillo, T. Richmond and G. Yohe, Eds., U.S. Global Change Research Program, 2014, pp. 150-174.

63 Maryland Department of Planning, "2012 Census of Agriculture For Maryland and its Jurisdictions," U.S. Department of Agriculture, National Agricultural Statistics Service, 2012. [Online]. Available: http://planning.maryland.gov/msdc/S6_Econ_Agri_Census.shtml. [Accessed 12 September 2017].

64 Maryland State Archives, "Maryland at a Glance: Agriculture," [Online]. Available: http://msa.maryland.gov/msa/mdmanual/01glance/html/agri.html. [Accessed 08 September 2017].

65 U.S. Department of Agriculture, "2016 State Agriculture Overview: Maryland," [Online]. Available: https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=MARYLAND. [Accessed 08 September 2017].

66 Maryland State Archives, "Maryland at a Glance: Forests," [Online]. Available: http://msa.maryland.gov/msa/mdmanual/01glance/html/forests.html. [Accessed 11 September 2017].

67 Maryland Department of Natural Resources, "Forestry Facts," [Online]. Available: http://dnr.maryland.gov/forests/Pages/mdfacts.aspx. [Accessed 11 September 2017].

68 W. H. McNab, M. A. Spetich, R. W. Perry, J. D. Haywood, S. G. Laird, S. L. Clark, J. L. Hart, S. J. Torreano and M. L. Buchanan, "Climate-Induced Migration of Native Tree Populations and Consequences for Forest Composition," in Climate change adaptation and mitigation management options: A guide for natural resource managers in southern forest ecosystems, 2014, pp. 307-378.

69 A. P. Kirilenko and R. A. Sedjo, "Climate change impacts on forestry," Proceedings of the National Academy of Sciences of the United States of America, vol. 104, no. 50, pp. 19697-19702, 2007.

70 H. D. Jacoby, A. C. Janetos, R. Birdsey, J. Buizer, K. Calvin, F. de la Chesnaye, D. Schimel, I. Sue Wing, R. Detchon, J. Edmonds, L. Russell and J. West, "Chapter 27: Mitigation," in Climate Change Impacts in the United States: The Third National Climate Assessment, J. Melillo, T. Richmond and G. Yohe, Eds., U.S. Global Change Research Program, 2014, pp. 648-669.

71 Maryland State Archives, "Maryland at a Glance: Economy," [Online]. Available: http://msa.maryland.gov/msa/mdmanual/01glance/economy/html/economy.html.

72 National Marine Fisheries Service, "Fisheries Economics of the United States, 2015," U.S. Department of Commerce, 2017.

73 Chesapeake Bay Program, "Oysters," [Online]. Available: http://www.chesapeakebay.net/issues/oysters. [Accessed 21 September 2017].

74 A. H. Hines, E. G. Johnson, M. Z. Darnell, D. Rittschof, T. J. Miller, L. J. Bauer and P. Rodgers, "Predicting Effects of Climate Change on Blue Crabs in the Chesapeake Bay," in Biology and Management of Exploited Crab Populations under Climate Change, G. Kruse, G. Eckert, R. Foy, R. Lipcius, B. Sainte-Marie, D. Stram and D. Woodby, Eds., Alaska Sea Grant, University of Alaska Fairbanks, 2010.

75 The Maryland Tourism Development Board and The Maryland Department of Commerce, "FY2016 Tourism Development Annual Report," 2017.

76 Maryland Office of Tourism Development, "FY2015 Tourism Devleopment Annual Report," 2015.

77 Maryland Office of Tourism Development, "Visit Maryland," 2017. [Online]. Available: http://www.visitmaryland.org/. [Accessed 22 September 2017].

78 M. Nicholls, "Climate Change: Implications for Tourism," University of Cambridge, 2014.

79 Maryland Department of Commerce, "Brief Economic Facts: Garrett County, Maryland," 2017.

80 S. Loss, "Balmy December weather keeping trails closed at area ski resorts," WTOP, 24 December 2015.

81 Wisp Resort, "Mountain Message Blog," [Online]. Available: http://www.wispresort.com/Blog/. [Accessed 22 September 2017].

82 Maryland Department of Tourism, "Ocean City Maryland Tourism Metrics Report," [Online]. Available: http://ococean.com/media/metrics-reports. [Accessed 22 September 2017].

83 Maryland Department of the Environment, "Maryland's Greenhouse Gas Reduction Act Plan," 2013.

84 U.S. Environmental Protection Agency, "Climate Impacts on Energy," [Online]. Available: https://www.epa.gov/climate-impacts/climate-impacts-energy. [Accessed 20 October 2016].

85 J. Dell, S. Tierney, G. Franco, R. G. Newell, R. Richels, J. Weyant and T. J. Wilbanks, "Chapter 4: Energy Supply and Use," in Climate Change Impacts in the United States: The Third National Climate Assessment, J. Melillo, T. Richmond and G. Yohe, Eds., U.S. Global Change Research Program, 2014, pp. 113-129.

87 U.S. Global Change Research Program, The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment, A. Crimmins, J. Balbus, J. Gamble, C. Beard, J. Bell, D. Dodgen, R. Eisen, N. Fann, M. Hawkins, S. Herring, L. Jantarasami, D. Mills, S. Saha, M. Sarofim, J. Trtanj and L. Ziska, Eds., 2016.

88 U.S. Environmental Protection Agency, "Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act," Federal Register, vol. 74, no. 239, 2009.

89 Maryland Institute for Applied Environmental Health and University of Maryland School for Public Health College Park, "Maryland Climate and Health Profile Report," 2016.

90 Johns Hopkins Center for a Livable Future, Maryland Grown: How What We Grow Compares with What We Eat, Baltimore, 2015.

91 U.S. Department of Agriculture, "USDA Economic Research Service: Data Products," [Online]. Available: https://www.ers.usda.gov/data-products/. [Accessed 14 September 2017].

92 U.S. Department of Agriculture, "Household Food Security in the United States in 2016," 2017.

93 Maryland General Assembly, Greenhouse Gas Emissions Reduction Act - Reauthorization (SB0323), 2016.

94 Maryland Department of the Environment, "Maryland 2014 Periodic GHG Emissions Inventory," 2015.

95 U.S. Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks," 14 April 2017. [Online]. Available: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks. [Accessed 16 October 2017].

96 Maryland Department of Transportation, "News Release: Governor Larry Hogan Announces Advancement of I-270 Congestion Relief Project," 19 April 2017. [Online]. Available: http://www.roads.maryland.gov/Pages/release.aspx?newsId=2821.

97 U.S. Environmental Protection Agency, Region 10, "Reducing Greenhouse Gas Emissions through Recycling and Composting," 2011.

98 U.S. Department of Agriculture, "Forests of Maryland, 2016," 2016.

99 Maryland Department of Agriculture, "Gypsy Moth Program," [Online]. Available: http://mda.maryland.gov/plants-pests/pages/gypsy_moth_program.aspx. [Accessed 20 October 2017].

100 J. Apperson, Board of Public Works Approves Funding for Clean Water, Energy and Chesapeake Bay Progress, Maryland Department of the Environment, 2017.

101 The Maryland Public Service Commission, Maryland PSC Awards ORECS to Two Offshore Wind Developers Projects to Create Jobs, Economic Development in New Industry, 2017.

102 Maryland General Assembly, Economic Development - Maryland Energy Innovation Institute (HB0410), 2017.

103 President Barack Obama, Exec. Order No. 13653 (78 FR 66817), 2013, pp. 66817-66824.

104 The White House Council on Environmental Quality, "Federal Leadership on Climate Change and Environmental Sustainability - EXECUTIVE ORDER 13693," [Online]. Available: https://obamawhitehouse.archives.gov/administration/eop/ceq/initiatives/sustainability. [Accessed 3 October 2017].

105 President Donald J. Trump, Exec. Order No. 13783 (82 FR 16093), 2017, pp. 16093-16097.

106 U.S. Environmental Protection Agency, "EPA Takes Another Step to Advance President Trump's America First Strategy, Proposes Repeal of "Clean Power Plan"," 10 October 2017. [Online]. Available: https://www.epa.gov/newsreleases/epa-takes-another-step-advance-president-trumps-america-first-strategy-proposes-repeal. [Accessed 31 October 2017].

107 President Donald J. Trump, Exec. Order No. 13807 (82 FR 40463), 2017.

108 President Barack Obama, Exec. Order No. 13690 (80 FR 6425), 2015, pp. 6425-6428.

109 The White House, Office of the Press Secretary, "Statement by President Trump on the Paris Climate Accord," 01 June 2017. [Online]. Available: https://www.whitehouse.gov/the-press-office/2017/06/01/statement-president-trump-paris-climate-accord.

110 United Nations Framework Convention on Climate Change, "The Paris Agreement," [Online]. Available: http://unfccc.int/paris_agreement/items/9444.php. [Accessed 10 August 2017].

111 United Nations Framework Convention on Climate Change, Paris Climate Agreement Signing Ceremony, 2016.

112 Office of Management and Budget, "Appendix, Budget of the U.S. Government Fiscal Year 2018," 2017. [Online]. Available: https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/appendix.pdf.

113 Maryland Energy Innovation Institute, "UMERC exhibits large presence at 2017 DOE ARPA-E Energy Summit," 16 March 2017. [Online]. Available: https://energy.umd.edu/news/story/umerc-exhibits-large-presence-at-2017-doe-arpae-energy-summit.

114 Breakthrough Strategies & Solutions, "Summary of State Efforts to Promote Healthy Soils and Soil Carbon Sequestration," Regeneration International, 9 August 2017. [Online]. Available: http://regenerationinternational.org/2017/08/09/summary-state-efforts-promote-healthy-soils-soil-carbon-sequestratio/.

115 Maryland General Assembly, Maryland Healthy Soils Program (HB1063), 2017.

116 National Oceanic and Atmospheric Administration, "Climate Models," 2017. [Online]. Available: https://www.climate.gov/maps-data/primer/climate-models. [Accessed 18 August 2017].

Appendices

Adaptation and Response Working Group

These recommendations are based on and draw from (1) discussions, actions and suggestions made at quarterly ARWG meetings; (2) ARWG staff dialogue with individual ARWG members during 2017; and, (3) suggested items recommended for consideration from MCCC members.

The Maryland Commission on Climate Change's (MCCC) Adaptation and Response Work Group (ARWG) is chaired by the Secretary of the Maryland Department of Natural Resources with support provided by Department staff. The ARWG and its members advance their work through the active involvement of and leadership from other work group members, agencies and stakeholders.

The ARWG and its members are actively implementing work on recommendations that have been adopted since the group began its early work nearly a decade ago. The ARWG members are squarely in implementation mode – working to ensure that a broad variety of Phase I and II Strategy recommendations about sea-level rise and climate impact are advancing.

The work group has relied upon and recommends continued collaboration and conversations with stakeholders to determine when, how and if implementation of adaptation measures move forward. The recommendations and statements of support set forth below will continue to be guided and informed in this manner as they move forward.

Evaluating Adaptation Strategies and Supporting Local Partners

1. Evaluation of Adaptation Strategies

   The ARWG proposes a 2018 review of its Phase I and II Comprehensive Strategy recommendations[1] to identify progress on the existing suite of recommendations, highlight any gaps or needs that may exist and remove or revise recommendations as appropriate. The ARWG recommends that this review guide future priorities and that the review be presented to the MCCC and/or other work groups.

2. Regional Adaptation Meetings

   The climate adaptation challenges facing local communities are as diverse as the communities themselves. The ARWG is proposing the use of regional meetings to understand and share priorities and assistance opportunities; support local partners in their own adaptation efforts; ensure data consistency across boundaries; and, identify future opportunities to incentivize local action. The ARWG proposes to define these regions in a manner consistent with other region-specific climate work (e.g., MDH, MEMA or the Resiliency Partnership efforts).

The workgroup recommends that the MCCC, ARWG and other work groups provide scientific, technical, logistical and planning support for regional meetings to provide optional climate change adaptation planning assistance to local governments. The meetings may cover the development of geographically relevant (small-scale) forecasts of natural hazards worsened by climate change; factors to consider for making decisions on whether such forecasts necessitate changes in local emergency response, land use, health, floodplain and other programs, procedures and policies; best management practices to consider in climate change adaptation planning (including case studies of successful local government adaptation planning in Maryland and elsewhere); an overview of the existing data, tools and guidance available from the state to support adaptation

planning; and the identification of incentives (e.g., training programs, financial resources) and other voluntary approaches for encouraging local adaptation planning. The audience for the regional meetings will include elected officials, government staff, businesses, and the public.

Implementing Adaptation through Partner Networks and Research

3. Engaging the Business and Engineering Communities

The ARWG acknowledges the importance of engaging with and seeking feedback of the business and engineering communities to achieve adaptation measures for both public and private sectors. The ARWG will continue to seek input from these partners to inform and implement adaptation strategies related to growth and infrastructure, natural resources and resource-based industries, financial and economic well being and human health.

4. Clarifying a Research Agenda

The academic and research communities in Maryland have much to offer the MCCC, the ARWG and other work groups in terms of applied science, modeling, monitoring and social science. The ARWG recommends that the MCCC and its work groups identify immediate and longer-term research needs to communicate with academic partners what priorities might be most actionable to inform decision making around climate preparedness.

5. Non-Coastal Impacts

The ARWG recognizes that climate change affects both coastal and non-coastal communities, and that vulnerable populations exist across the State. The ARWG recognizes that an increasing amount of adaptation work is beginning to develop approaches to non-coastal populations and that this may involve different adaptation strategies focused on different threats. The work group proposes that the MCCC, ARWG and other partners understand, identify and communicate specific non-coastal strategies (e.g., evaluating, and if needed, updating design standards that accommodate forecasts of more frequent or intense heavy rain events).

6. Fostering Natural Resource and Resource-Based Industry Adaptation

One of the ARWG's climate challenges relates to Natural Resources and Resource-Based Industries that addresses both our natural environment as well as those industries – such as agriculture – that are resource-based. In 2016–2017, progress was made establishing a Healthy Soils Consortium to address the role of agriculture in carbon sequestration. Recommendations related to this issue are jointly-referenced in the MWG and ARWG appendices and are as follows:

- An analysis should be undertaken to identify those practices appropriate to Maryland that increase soil health, as well as the co-benefits, including carbon sequestration, greenhouse gas mitigation, water quality improvement, ecological resilience, nutrient content, health impact, crop or animal yield, and economic profitability, of both current and additional practices.
- The ARWG, in concert with the MWG, supports incentivizing a menu of Best Management Practices that improve soil health. In addition, co-benefits should be considered when developing strategies and allocating new resources for existing and planned programs.
- A determination should be made of the tools and metrics available for use in quantifying the potential for carbon sequestration and greenhouse gas reduction that can be achieved through the adoption of healthy soil practices.

- A cross-agency inventory should be conducted of Maryland programs that could prioritize and incentivize healthy soil practices for all scales of farming, including the home gardener.
- Within their respective roles and charges, the MCCC and its four working groups should support the efforts of the Healthy Soils Consortium to inform Maryland farmers not only of the benefits of soil health, but also the programs and incentives that can be accessed to further the adoption of such practices
- The ARWG and MWG support the development of pilot and/or demonstration projects to test innovative soil health practices, monitor results over time, and provide educational site locations.
- Alternative funding sources, such as RGGI, social/environmental impact bonds, or public/private partnerships, should be explored, and new funding, when available, should advance programs and practices that prioritize improved soil health.

Addressing Equity in Adaptation

7. Equity and Environmental Justice

The ARWG will continue to incorporate equity and environmental justice considerations into its implementation work addressing adaptation actions, including Phase I and II strategies[1] for reducing vulnerability to climate change. The work group proposes that this may be accomplished by connecting with the Commission on Environmental Justice and Sustainable Communities (CESJC), and other health equity or environmental justice experts in the academic, research and community realms.

8. Defining Vulnerable Populations for Coastal Resiliency Projects

In 2018, the work group encourages the Department of Natural Resources and its inter-agency review team to understand and further clarify the types of vulnerable populations that would most benefit from coastal resiliency projects addressing climate impacts like sea level rise, flooding and erosion. Specifying climate impacts and affected populations would help to refine the geographic areas that would benefit from natural and nature-based shoreline stabilization and flood reduction projects. Such clarification about vulnerable and under-served populations would assist with project selection that will occur competitively based on (1) the vulnerability of the habitat and community; (2) targeted resiliency areas; (3) level of community engagement; (4) project readiness and status; and (5) broader ecosystem services.

Education, Communication and Outreach Working Group

In 2017, the Education Communication and Outreach (ECO) Working Group made concrete progress in many of the 2017/2018 Work Plan goals. ECO members worked to increase stakeholder awareness and participation in climate-related events in Maryland by continually enhancing the Maryland Department of Health's (MDH) "Environment, Public Health and Climate Change in Maryland" calendar with relevant events and directing traffic to the calendar. The working group developed and began enacting an Outreach Plan, (1) collaborating with partners to both expand and enhance outreach and education by increasing the climate literacy of existing environmental outreach, through development and implementation of the Climate Ambassador pilot; (2) building the Toolkit of climate education resources; and (3) building the list of Climate Communicators. ECO proposed and developed a statement from the Commission regarding President Trump's decision to withdraw from the Paris Climate Agreement. ECO members also worked to produce five one-pagers on the topics of: The Commission, The Greenhouse Gas Reduction Act, Resiliency to Climate Change, Sea-Level Rise and Flooding, and the Health Impacts of Climate Change.

These recommendations continue to expand upon ECO's Work Plan and 2016 recommendations:

Note: The identifying 'Action' numbers refer to the statute which guides the Working Group actions (Md. Environment Code Ann. §2-1303(d)).

Developing broad public and private partnerships (Action 2)

- All Commission stakeholders should contribute to the "Environment, Public Health and Climate Change in Maryland" calendar, maintained by the Maryland Department of Health (MDH), and similar platforms.
- ECO and the Commission should continue to formalize partnerships with the Commission's diverse sectors to support a broader network of information and engagement regarding communities vulnerable to climate change.
- ECO should broaden the group's expertise and reach by increasing membership that maintains a balanced perspective.
- ECO should work to identify and support existing efforts to implement climate change education and environmental literacy.

Developing products for use in education, communication, and outreach on climate change (Action 3)

- ECO should collaborate with the Commission's other working groups: Adaptation and Response, Scientific and Technical, and Greenhouse Gas Mitigation, to provide expertise on communication and education around their work products.
- ECO should support dissemination and utilization of Commission fact sheets developed by the Hatcher group, through existing partnerships, community engagement, Commission activities and other identified pathways. ECO should continue to work with stakeholders to identify, build, and collate resources for outreach relevant to a variety of communities and outreach activities (e.g., Toolkit, Communicators List).

- ECO should support the re-design of the Commission website by the Hatcher group and MDE, and recommends that this process include seeking the input of ECO expertise and feedback where applicable.

Education, communication, and outreach related to the Commission's Annual Report (Action 3)

- ECO should support an effort to raise general awareness of the Annual Report and of the work of the Commission, coordinated around the release of the 2017 Report in the November time frame.
- ECO will advise the Commission on best practices for education and outreach surrounding the 2018 Annual Report/40 by 30 GGRA Draft Plan to increase stakeholder engagement.

Developing strategy and process for education, communication, and outreach on climate change (Action 3)

- The Commission's outreach and education should be informed by the ECO Working Group; ECO will work to support this effort by keeping the Commission and other working groups up-to-date on such best practices and emerging methods.
- ECO will continue to advise the Climate Commission regarding the design and implementation of (1) a Climate Ambassadors program which enables a broader discussion on climate change by taking advantage of networks and events in which a message on climate change may be easily worked into the existing framework; and (2) a Climate Champions program that recognizes companies or groups engaged in efforts to reduce their greenhouse gas emissions or otherwise contribute to the State's climate goals.

Addressing any disproportionate impacts of climate change on low-income and vulnerable communities (Action 5)

- ECO should support the education, communication and outreach goals of the Commission by continuing to provide advisement and additional capacity as applicable, to identify communities especially vulnerable to the impacts of climate change. Vulnerability can be defined by exposure to increased flooding and sea level rise and other climate factors, and/or by ability to respond to these events based on socioeconomic status.
- ECO should continue work to identify and collaborate with existing trusted messengers in communities vulnerable to climate change, and the efforts that they are already undertaking.
- ECO strongly supports the MWG's effort to incorporate considerations for environmental justice and underserved communities in its recommendations for the State's 40 by 30 Plan.

Mitigation Working Group

The 40 Percent by 2030 Plan:

- The Mitigation Working Group (MWG) acknowledges the importance of early collaboration on the 40 by 30 Plan, the draft of which is due at the end of 2018, and is continuing to seek input on any recommendations for additional programs or considerations, to be presented to the State in sufficient time for incorporation into the drafting process.

Enhanced Greenhouse Gas (GHG) Emissions Inventory:

- The State should continue to pursue the most locally relevant and complete methods for calculating its GHG Emissions Inventory, including but not limited to consideration of (1) including the life-cycle emissions generated by out-of-state extraction, processing, and transportation of fossil fuels based on in-state consumption (both direct consumption of fuel as well as fuel used to generate electricity which is then consumed in-state); (2) utilizing NASA-sourced LiDAR to provide a more accurate estimate of site-specific carbon sequestration through planting forests, managing forests, and increasing urban tree canopy; and (3) applying advanced methods to generate a more accurate accounting of sequestration benefits from agricultural soil management practices.

Environmental Justice and Underserved Communities:

- The MWG plans to continue to incorporate considerations for environmental justice in its recommendations for developing the 40 by 30 Plan, especially as it relates to underserved communities (both urban and rural) and populations considered especially vulnerable to the impacts of climate change (e.g., children and the elderly). The MWG encourages the State to also use this lens, particularly when examining the results of the health impacts study to be performed.
- To further inform this perspective, the MWG encourages MDE to work with the Department of Natural Resources (DNR) and the Commission's Adaptation and Response Working Group (ARWG) in developing a personal query within the Coastal Resiliency Tool that would allow for spatially explicit demographic analysis of those that may be most heavily impacted by sea-level rise.

Clean Energy Businesses and Manufacturing Jobs, and Fossil Fuel Dependent Workers:

- The MWG supports the promotion of green-energy manufacturing in-state that will directly provide sustainable, high quality jobs and generate additional jobs along the supply chain. This has the potential to not only put Maryland at the forefront of an emerging market but also reduce life-cycle emissions for renewable energy projects, both in state and in the surrounding area, by decreasing miles traveled and ensuring best practices during manufacturing.
- The manufacturing study required in 2020 under the 2016 Greenhouse Gas Emissions Reduction Act (GGRA) should explore the costs and benefits (both economic and environmental), as well as the general feasibility of: (1) potential modifications or enhancements to the current "buy local" provisions in the GGRA Plan, such as agreements in contracting for "Buy Maryland/Buy USA" and "Hire Maryland"; and (2) the development of an in-state supply chain to create lasting manufacturing and other jobs related to renewable infrastructure.

- In May 2017 the Maryland Public Service Commission (PSC) approved two offshore wind projects as eligible to issue offshore renewable energy credits. The MWG understands that in its approval the PSC considered the extent to which the projects provided for the use of skilled labor. This was in accordance with criteria for project evaluation set forth in the Public Utility article. The PSC approval order included contingencies related to the protection of Maryland workers and benefits to the State's economy. The MWG understands the relevance of appropriate contingencies and provisions relating to local labor and procurement language and will have discussions specific to these topics (including prevailing wages, labor agreements, and buy MD/USA procurement policies) and related costs and benefits, in 2018, to consider a position as it relates to future RPS/PSC agreements.
- The State should consider incorporating climate goals within its general procurement policies, requiring minimum qualifications for bidders related to attributes which will help meet the 40% by 2030 emissions reduction goals, while creating or maintaining quality jobs in the process.
- To the extent possible, the jobs analysis for the Draft 40 by 30 Plan should include the quality of jobs (e.g., wages, benefits) and the quantity of jobs created by new initiatives, as well as where the additional jobs are likely to be located, and in what field of employment.
- Additional economics and jobs analyses should, if feasible, address the following topics: (1) workforce and economic considerations surrounding various emerging technologies in electricity generation/storage and advanced management strategies that decrease the total GHG burden of the electric grid; (2) numbers for actual expected displacement of workers, and geographic location; (3) how the future climate may impact worker productivity and construction seasons; (4) the quality of jobs that may replace fossil fuel industry work; and (5) the potential impacts of combined heat and power (CHP) on industrial operational costs and job retention.
- Additional analysis should be conducted, if feasible, regarding clean energy generation located in Maryland, including economic impacts, environmental impacts, workforce, etc., and opportunities to value reliable, efficient and clean energy resources for their environmental, health and economic qualities.

Healthy Soils and Carbon Sequestration:

- An analysis of both current and additional practices should be undertaken to identify those practices appropriate to Maryland that increase soil health, as well as the co-benefits, including carbon sequestration, greenhouse gas mitigation, water quality improvement, ecological resilience, nutrient content, health impact, crop or animal yield, and economic profitability.
- The MWG, in concert with the ARWG, supports incentivizing a menu of Best Management Practices that improve soil health. In addition, co-benefits should be considered when developing strategies and allocating new resources for existing and planned programs.
- Within their respective roles and charges, the Maryland Commission on Climate Change (MCCC) and its four working groups should support the efforts of the Healthy Soil Consortium to inform Maryland farmers of not only the benefits of soil health, but also the programs and incentives that can be accessed to further the adoption of such practices.
- A determination should be made of the tools and metrics available for use in quantifying the potential for carbon sequestration and GHG reduction that can be achieved through the adoption of healthy soil practices.
- A cross-agency inventory should be conducted of Maryland programs that could prioritize and incentivize healthy soil practices for all scales of farming, including the home gardener.

- The MWG and ARWG support the development of pilot and/or demonstration projects to test innovative soil health practices, monitor results over time, and provide educational site locations.
- Alternative funding sources, such as RGGI, social/environmental impact bonds, or public/private partnerships, should be explored; and new funding, when available, should advance programs and practices that prioritize improved soil health.

Innovative Financing:

- The MWG sub-group lead by the Maryland Energy Administration (MEA) should continue discussion on actionable recommendations for changes to legislation that would help make Commercial PACE loans more attractive to borrowers, lenders, and banks, and increase usage in Maryland.
- The MWG sub-group lead by MEA should continue to work with the Maryland Association of Counties (MACo) and other appropriate parties to move forward with a decision regarding whether the counties wish to make use of the available Qualified Energy Conservation Bonds (QECBs), or if they will waive their allocations to be aggregated and distributed at the state level (in a manner to be discussed by the sub-group), to increase utilization of these funds.

Transportation:

- The MWG recommends that the process for estimating mitigation strategies for the transportation sector be enriched to include synergies of different strategy bundles as well as the co-benefits of various strategies (e.g., social equity, public health, and other environmental benefits).
- Regarding emission modeling processes, MWG recommends that considerations be made for cross-sectoral consistency in assumptions for modeling future baseline and mitigation scenarios, particularly regarding land use and development; and that there be a continued evaluation of best available state-wide inputs, including geographic areas not presently covered by Metropolitan Planning Organization (MPO) travel models.
- The MWG recommends that the Maryland Department of Transportation (MDOT), MDE, MEA and the Department of General Services (DGS) review state fleet procurement procedures and practices and provide direction on electric vehicle (EV) procurement and EV charging station installation guidance and targets by October 2018.
- The MWG recommends researching the costs and benefits of supporting the rapid deployment of ZEV school and transit buses in Maryland. The analysis should include: (1) capital, maintenance and operating cost comparisons; (2) research into the viability of zero emission vehicles (ZEVs) as well as hybrid and alternative fuel technologies; and (3) emissions reduction benefit summaries.
- The MWG recommends that MDOT research the costs and benefits (economic and emissions) of applicable and effective strategies and strategy bundles geared towards decreasing vehicle miles traveled, including increasing public transportation ridership, providing transit access through first and last mile linkages, facilitating the integration of autonomous vehicles, increasing ride-sharing, and integrated land-use planning.

Scientific and Technical Working Group

Looking Back on 2016

The 2016 Annual Report of the Climate Change Commission included a general global update of climate change science and policy.[1] Notably, the Commission summarized the growing and high level of certainty and near unanimity among scientific experts that Earth's climate is being altered by human activities, predominantly by the emissions of heat-trapping greenhouse gases into the atmosphere.

The last Annual Report, like this one, was written before the year ended and in looking back on the full year, 2106 has to be considered a landmark in climate change awareness and policy development. When 2016 concluded, annual temperatures had set new records for the warmest mean temperature measured, both for the globe and in the United States.[2] For 2016 the global average temperature across land and ocean surfaces was 0.94 degrees Celsius above the 20th century average, surpassing the previous record warmth of 2015. All 16 years of the 21st century rank among the 17 warmest years on record and the five warmest years have all occurred since 2010.

In September 2016 the United States formalized its Nationally Determined Contribution (NDC) toward implementing the United Nations Paris Climate Agreement, intended to keep global temperature rise below 2 degrees Celsius. The NDC of a 26-28% reduction in net greenhouse gas (GHG) emissions below 2005 levels by 2025 is the first step in a longer-term pathway. The Paris Agreement came into force on November 4, 2016 after at least 55 parties representing at least 55 percent of global GHG emissions had ratified the agreement. To date, 166 of the 197 parties to the convention have ratified it.[3] Consistent with the Paris Agreement pathway and the U.S. NDC, the Maryland General Assembly passed and Governor Hogan signed into law the reauthorized and enhanced Greenhouse Gas Reduction Act of 2016, committing the state to reduce its emissions by 40 percent by 2030.

Recognizing that climate is changing and will continue to change and produce harmful consequences even if the Paris Agreement goal of limiting global warming to 2 degrees Celsius is achieved, the Federal Government and the State of Maryland also put policies and programs in place during 2016 to promote adaptation in order to reduce risks and enhance resilience to the changing climate. Climate change adaptation plans have been developed and, in many cases, implemented across the Federal agencies under an Executive Order, Preparing the United States for the Impacts of Climate Change.[4] Notably, these efforts included strengthening the Federal Emergency Management Agency's (FEMA) Federal Flood Risk Management Standard by requiring climate-based approach to defining actions that arise in a floodplain.

---

[1] Maryland Commission on Climate Change. 2016. *2016 Annual Report*. http://www.mde.state.md.us/programs/Air/ClimateChange/MCCC/Documents/MCCC_2016_final.pdf

[2] Blunden, J., and D. S. Arndt, Eds. 2017. State of the Climate in 2016. *Bulletin of the American Meteorological Society* 98 (8), S1–S277, doi:10.1175/2017BAMSStateoftheClimate.1.

[3] United Nations Framework Convention on Climate Change. *Paris Agreement – Status of Ratification*. http://unfccc.int/paris_agreement/items/9444.php

[4] President's Executive Order No. 13690. *Preparing the United States for the Impacts of Climate Change*. https://obamawhitehouse.archives.gov/the-press-office/2013/11/01/executive-order-preparing-united-states-impacts-climate-change

Federal Climate Policy Developments in 2017

With the transition to the new Federal Administration in Washington in January 2017, however, the evolution of U.S. science-based policies to limit global climate change and adapt to its consequences has taken a different and uncertain course. New Cabinet officers have repeatedly acknowledged that the climate is changing, but have opined that the extent to which human greenhouse gas emissions are responsible is in dispute, as is the degree of impact of the changes.[5] In fact, there is strong scientific evidence and overwhelming consensus of experts that human activities—predominantly greenhouse gas emissions—have been responsible for virtually all of the observed global warming rather than natural factors .[6]

On March 28, 2017 a new Executive Order rescinded the previous Executive Order on Preparing the United States for the Impacts of Climate Change and several other energy and climate-related policies and directed the EPA to review the Clean Power Plan.[7] On June 1, 2017 the President announced that he would withdraw the United States from the Paris Climate Accord.[8] However, under the terms of the Paris Agreement it takes nearly four years to complete the withdrawal process. Another Executive Order intended to accelerate environmental reviews of infrastructure projects revoked the requirement to consider climate changes in FEMA's Federal Flood Risk Standard.[9] It was signed on August 15, 2017, just two weeks before the disastrous flooding in Houston from Hurricane Harvey.

While none of these Federal actions prevent Maryland from moving forward with its own efforts to limit climate change by reducing its greenhouse gas emissions or adapting and responding to climate change, they make these state-based efforts more difficult. While Maryland is in a good position to comply with the Clean Power Plan with regard to power plants within its borders, it counts in its greenhouse gas emissions that from power plants outside of the state that provide approximately 42 percent of the electricity consumed in Maryland. Regulations proposed under the CPP would reduce carbon dioxide emissions from those plants and thereby help Maryland reach its reduction goals under the GGRA. Maryland and its counties and cities are also taking steps to reduce flood risks exacerbated by sea-level rise and greater downpours, but FEMA's Federal standards play a critical role in permitting, mapping and flood insurance coverage.

With nearly as many miles of tidal coastline as California, Maryland is one of the states potentially most vulnerable to sea level rise associated with climate change. Maryland is fully committed to continuing its efforts to exceed the goals of the Paris Climate Accord. The Maryland Commission on Climate Change fully supports this position. **The Commission is concerned that the President has decided to withdraw from the Paris Climate Accord. The Commission fully recognizes the need for national leadership on the global challenge of climate change and encourages the Federal government to consider the proactive and economically balanced approach taken by Maryland to address climate change.**

---

[5] See for example, interview of U.S. EPA Administrator Scott Pruitt on CNBC, March 9, 2017. https://www.cnbc.com/video/2017/03/09/epa-chief-scott-pruitt-says-carbon-dioxide-is-not-a-primary-contributor-to-global-warming.html

[6] Intergovernmental Panel on Climate Change. 2014. *Climate Change 2014 Synthesis Report: Summary for Policymakers*.

[7] *Presidential Executive Order on Promoting Energy Independence and Economic Growth*. March 28, 2017, https://www.whitehouse.gov/the-press-office/2017/03/28/presidential-executive-order-promoting-energy-independence-and-economi-1

[8] Statement by President Trump on the Paris Climate Accord. https://www.whitehouse.gov/the-press-office/2017/06/01/statement-president-trump-paris-climate-accord

[9] *Presidential Executive Order Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure Projects*. August 15, 2017. https://www.whitehouse.gov/the-press-office/2017/08/15/presidential-executive-order-establishing-discipline-and-accountability

References to "climate change" on the websites of Federal agencies, including EPA and the Departments of Energy, the Interior, and Health and Human Services were eliminated or adjusted, and some websites and online reports are no longer available. This complicates the use of Federal resources in Maryland's education, communication and outreach related to climate changes. The National Advisory Committee for the Sustained National Climate Assessment (NCA), chaired by University of Maryland's Richard Moss, was disbanded and the NCA *Climate Science Special Report*,[10] which has already been reviewed by the National Academies of Science, Engineering and Medicine (NASEM), has not been released by the White House. The Department of the Interior also ordered the NASEM to halt a study of health risks for residents near coal surface mining sites that had been specifically requested by West Virginia health officials.

Of particular consequence for Maryland are the large cuts in funding targeted for climate change science and for research and development of energy technologies in the President's proposed FY 2018 Budget.[11] These targets include research on global change, food-energy-water systems and risk and resilience in the National Science Foundation (NSF); climate research and mid-range weather forecasting in the National Oceanic and Atmospheric Administration (NOAA); earth science research and satellite missions and education in the National Aeronautics and Space Administration (NASA); wind and solar energy research in the Department of Energy (DOE); and research on climate and energy in the EPA. While these proposed reductions have been temporarily postponed by a 90-day Continuing Resolution for FY 2018, should they come to pass they would have a disparate impact on Maryland as many of these NOAA and NASA activities are based in this state and Maryland's universities and research laboratories perform significant portions of this Federal R&D. Furthermore, these Federal science and technology investments yield results that are critical to informing Maryland's efforts to reduce its greenhouse gas emissions and effectively adapt to the changing climate. For, example one of the R&D programs proposed for elimination is the Department of Energy's Advanced Research Projects Agency – Energy (ARPA-E) from which the University of Maryland Energy Research Center receives more competitive grants than any other university for important research in such areas as energy efficiency and storage.

The Scientific and Technical Working Group urges the Maryland Congressional delegation to place a high priority on ensuring that climate change science and research and development of energy technologies are adequately funded and implemented by the Federal government.

Urgency in Rapid Reductions of Greenhouse Gas Emissions

The goal of the Paris Agreement is to hold the increase in global average temperature to well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius. Evidence now indicates that human-caused global warming started before the late 19th century as had been thought. The definition of the pre-industrial baseline affects the probability that these warming targets will be exceeded. One new assessment found that, under even the most aggressive emissions reduction pathway simulated by the Intergovernmental Panel on Climate Change (IPCC scenario RCP2.6), the probability of crossing the 1.5 degree threshold varies from 61 to 88 percent depending on how the baseline is defined.[12] To stabilize warming at 2 degrees Celsius, allowable carbon emissions would decrease by as much as 40 percent when

---

[10] U.S. Global Change Research Program. 2017. *Climate Science Special Report* https://www.nytimes.com/interactive/2017/08/07/climate/document-Draft-of-the-Climate-Science-Special-Report.html?mcubz=0

[11] Office of Management and Budget. 2017. *Appendix, Budget of the U.S. Government Fiscal Year 2018.* https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/appendix.pdf

[12] Schurer, A.P., M.E. Mann, E. Hawkins, S.F.B Tett and G.C. Herger. 2017. Importance of the pre-industrial baseline for likelihood of exceeding Paris goals. *Nature Climate Change* doi:10.1038/NClimate3353

climates existing prior to the nineteenth century are considered as baselines. Other statistical approaches, using projections of population, economic growth and carbon use, paint an even more pessimistic picture of the likelihood of limiting global warming to the 2 degree Celsius Paris threshold, with only about a 5% chance.[13] On the other hand, a group of European scientists published a more optimistic analysis that suggests that limiting warming to 1.5 degrees Celsius is not yet a geophysical impossibility, but will require emissions reductions that are deeper and more rapid than the most aggressive IPCC scenarios.[14] Their paper has been criticized by other scientists because its authors assumed less post-industrial warming (0.93 degrees Celsius) than already observed in many data sets and slightly less warming as carbon dioxide concentrations increase. However, these authors still conclude that, to meet the Paris Agreement goal of less than 2 degrees Celsius warming, emission reductions would need to begin immediately and likely reach zero in 40 years' time.

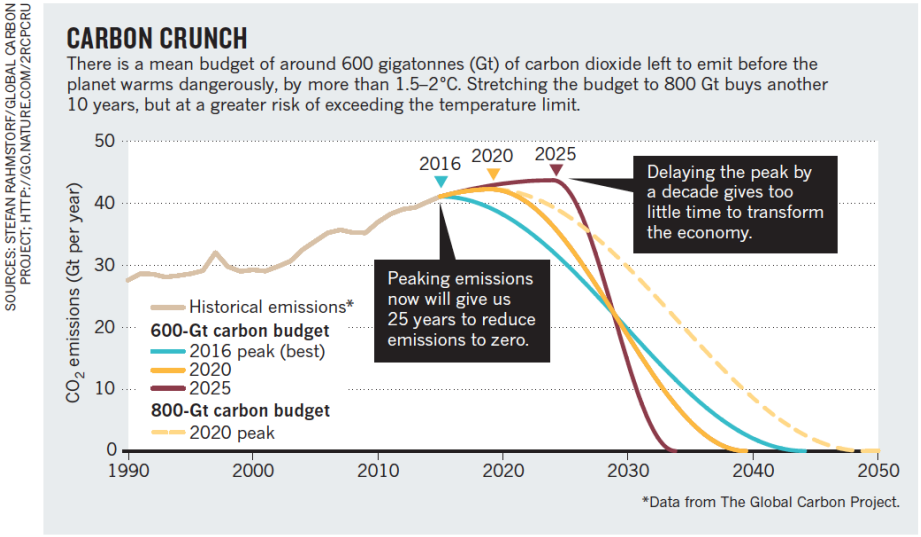


Figure 2. Recent analysis demonstrating that net global emissions of carbon dioxide must peak soon and decline to near zero before the middle of the century in order to avoid dangerous levels of warming by exceeding the thresholds accepted in the Paris Climate Agreement. Figure from Figueres et al. (2017).[27]

The upshot of this emerging scientific research is that if we are to meet the goal of the Paris Agreement we have no time to waste and will likely have to make deeper reductions more quickly than was simulated in the last assessment of the IPCC. Christiana Figueres, who was the Executive Secretary of the U.N. Framework Convention on Climate Change that led to the Paris Agreement, and five prominent climate scientists published a commentary this summer that argued that we have only three years to safeguard our climate and set out a

[13] Rafferty, A.E., A. Zimmer, D.M.W. Frierson, R. Startz and P. Liu. 2017. Less than 2°C warming by 2100 unlikely. *Nature Climate Change* doi:10.1038/NClimate3352

[14] Miller, R.J., J.S. Fuglestvedt, P. Friedlingstein, J. Rogelj, M.J. Grubb, H.D. Matthews, R.B. Skeie, P.M. Forster, D.J. Frame and M.R. Allen. 2017 Emission budgets and pathways consistent with limiting warming to 1.5°C. *Nature Geosciences* doi:10:1038/NGEO3031

plan for turning the tide of the world's carbon dioxide by 2020.[15] Even if we stretched the budget and accepted more risks of exceeding the temperature limit, the world has only until 2050 to become carbon neutral according to their analysis (Figure 2), or maybe only a decade longer based on the recent analysis by the European team of scientists. The longer we wait to turn the tide the more dramatic and economically disruptive reductions will have to be. The implications of these emerging scientific perspectives for Maryland's policies for reducing greenhouse gas emissions are substantial. Maryland was successful in reversing the upward trend in its emissions around the 2010 timeframe and the 40 percent reduction by 2030 goal would bring us close to the required trajectory. However, to be consistent with the global emission reduction requirements, the state should begin to plan to achieve net zero emissions within only 10 to 20 years after passing the 2030 milestone. In short, the 40 percent by 2030 GGRA mandate is not an endpoint but a waypoint along a quick and steep descent. One can debate whether the destination must be reached in 10 years after that waypoint or in 30 years if one takes the optimistic view, but the destination is clear and the time is short. Unlike conventional air pollutants that we regulate the carbon dioxide that will emit will remain in the atmosphere for centuries. More costly reductions will be required for every year of delay.

In developing the Final Plan that reduces statewide greenhouse gas emissions by 40 percent from 2006 levels by 2030 as required by the GGRA of 2016, the Department of the Environment should include not only actions to close the gap to achieve the 40 percent reduction, but should base the Plan on longer-term strategies needed to achieve carbon neutrality over the subsequent two to three decades.

Maryland's Greenhouse Gas Emissions Inventories

During 2017 the Commission's Scientific and Technical Working Group (STWG) examined the procedures used by the Department of the Environment (MDE) in developing periodic greenhouse gas inventories needed to track progress in achieving GGRA reduction goals and in projecting future trends. The STWG found the following:

1. MDE's inventories are adequate for the purpose of three-year snapshots of Maryland's greenhouse gas emissions. Emissions from electricity (36 percent) and fuel use (17 percent) are based on direct measurements. Those from transportation (36 percent are indirectly estimated from conventional models, but are realistic. Together, these account for 89 percent of emissions. Remaining emissions are also indirectly estimated and, while improvements could be attained, they would amount to a small percentage of emissions.
2. Estimation of the net sinks is another matter. It is based on generalized rates of forest carbon flux and organic biomass storage and does not include fluxes from wetlands and waterways and agricultural soils management, which may constitute sources of greenhouse gases as well as sinks. This is non-trivial because the emissions inventory assumes that Maryland's gross emissions of 92.7 $MMTCO_2e$ are offset by 11.8 $MMTCO_2e$ of sequestration (almost 13%).[16] Better estimation is important as the state pursues strategies to increase offsetting sequestration, such as through the healthy soils initiative. It is also critical to quantify the "permanence" of this sequestration in the face of continued warming, land use changes, and sea-level rise. The Commission's STWG will work with the Departments of the Environment, Agriculture and Natural Resources to identify critical uncertainties in and methods to improve the estimation of greenhouse emissions and long-term sinks from forests, agriculture, wetlands and waterways.

[15] Figueres, C., H.J. Schellnhuber, G, Whiteman, J. Rocoström, A. Hobley and S. Rahmstorf. 2017. Three years to safeguard our climate. *Nature* 546:593-595.
[16] Maryland Department of the Environment. *Maryland Greenhouse Gas Emissions Inventory*.

3. Growth simulation modeling suggests that Maryland will confront significant land-use and land-cover changes (LULCC) by 2030 and beyond. LULCC has quantitatively significant implications for net greenhouse gas emissions (including sequestration) from forests, agricultural lands, and wetlands,[17] as well as for vehicle miles travelled (VMT) and, consequently, on-road vehicle emissions. **In developing the Final Plan, the Department of the Environment should take into full account the changes in greenhouse gas emissions associated with population growth and expanded land development in projecting growth in emissions that must be offset to achieve the GGRA mandated reductions**
4. On-Road Mobile Source Inventory methods apply generally accepted methodologies. Projections show declining emissions despite the continued growth of VMT, such that a 30% reduction from the baseline is projected by 2030. However, these projections are heavily dependent on the execution of national standards for passenger vehicles and trucks that the Federal Administration has indicated it plans to rescind or delay. Furthermore, not only does the projected reduction fall short of 40% required over all sources, but it is also clear that other significant changes in transportation systems and efficiencies will be required to achieve additional emissions reductions that will be required after 2030.
5. The Plan for Regional Sustainability Tomorrow (PRESTO) modeling conducted by the National Center for Smart Growth Research and Education at the University of Maryland demonstrates the value of using scenarios that represent greater changes in the economy, societal choices, or public policies than presently included in the state's greenhouse gas emissions forecasts. [18] **The Scientific and Technical Working Group encourages and supports collaboration among State agencies and researchers in forecasting future emissions through approaches that provide a more dynamic basis for evaluating public policy options that achieve the needed greenhouse gas emission reductions together with other social and economic objectives, including, but not limited to, the State's economy and employment.**

Science Priorities for the Commission

Going forward into 2018 the Commission's Scientific and Technical Working Group plans take on the following tasks:

1. Assemble an expert group to identify critical uncertainties in and methods to improve the estimation of greenhouse emissions from forests, agriculture, wetlands and waterways.
2. Assemble an expert group to provide an assessment of emissions from and climate change impacts on Maryland agriculture as called for in the Maryland Commission on Climate Change Act [Maryland Environment Code Ann. §2-1303(d)].
3. Begin to explore energy alternatives to achieve emissions reductions beyond 2030 that carbon neutrality.
4. Work with the Mitigation Working Group and the Departments of the Environment, Agriculture and Natural Resources to improve the projection, tracking and reporting of greenhouse gas emissions and sinks, including sequestration alternatives.

---

[17] Mahowald, N.M., D.S. Ward, S.C. Doney, P.G. Hess and J.T. Randerson. 2017. Are the impacts of land use on warming underestimated in climate policy? Environmental Research Letters doi:10.1088/1748-9326/aa83d.
[18] National Center for Smart Growth Research & Education. Interactive PRESTO Report. http://smartgrowth.umd.edu/PRESTO2/

Maryland Commission on Climate Change

Commission Leadership	
Secretary Ben Grumbles	Commission Chair
Anne Lindner	Commission Co-Chair
Stuart Clarke	Commission Co-Chair

Governor Appointed and Standing Members	
Secretary Ben Grumbles (chair)	Department of the Environment
Nancy K. Kopp	Maryland State Treasurer
Karen Salmon	Superintendent of Maryland Schools
Secretary Joseph Bartenfelder	Department of Agriculture
Secretary Mark Belton	Department of Natural Resources
Secretary Ellington Churchill	Department of General Services
Secretary Pete Rahn	Department of Transportation
Acting Secretary Robert McCord	Department of Planning
Mary Beth Tung	Maryland Energy Administration
Donald Boesch	Professor at UMCES
Chucky Fry	Agriculture Community Representative
Dr. Russell Dickerson	Climate Change Expert
Dr. Jane Kirschling	Public Health Expert
Charles Deegan	Chair of Critical Area Commission
Senate President Appointed Members	
Senator Paul G. Pinsky	Member of the Senate
Stuart Clarke	Philanthropic Organization Representative
Lori Arguelles	Environmental NPO Representative
Jim Strong	Organized Labor Representative
Michael Powell	Business Community Representative
House Speaker Appointed Members	
Delegate Dana Stein	Member of the House of Delegates
Mike Tidwell	Environmental NPO Representative
Anne Linder	Business Community Representative
C. Richard D'Amato	Philanthropic Organization Representative
Larry Kasecamp	Organized Labor Representative
Local Government Appointees	
Councilwoman Deni Taveras	Maryland Association of Counties
Commissioner Michael Bibb	Maryland Municipal League

Maryland Commission on Climate Change

Steering Committee	
Secretary Ben Grumbles (Commission Chair)	Department of the Environment
Anne Lindner (Commission Co-Chair)	Business Community Representative
Stuart Clarke (Commission Co-Chair)	Philanthropic Organization Representative
Secretary Mark Belton	Department of Natural Resources
Secretary Joseph Bartenfelder	Department of Agriculture
Secretary Pete Rahn	Department of Transportation
Mary Beth Tung	Maryland Energy Administration
Nancy K. Kopp	Maryland State Treasurer
C. Richard D'Amato	Philanthropic Organization Representative
Michael Powell	Business Community Representative
Don Boesch	Professor at UMCES
Mike Tidwell	Environmental NPO Representative
Lori Arguelles	Environmental NPO Representative

Adaptation and Response Working Group

Leadership	
Secretary Mark Belton	Chair
Catherine McCall	Coordinator
C. Richard D'Amato	Commission Liaison

Environmental Advocates	
Fredrika Moser	Maryland Sea Grant
Brian Ambrett	Eastern Shore Land Conservancy
Eric Myers	Conservation Fund
Maryland General Assembly Members	
James C. Rosapepe	State Senator
State Government Representatives	
Gary Setzer	Department of the Environment
Don Van Hassent	Department of Natural Resources
Mark James	Maryland Emergency Management Agency
Bruce Michael	Department of Natural Resources
Clifford Mitchell	Department of Health
Jason Dubow	Department of Planning
Sandy Hertz	Department of Transportation
Susan Payne	Department of Agriculture
Catherine McCall	Department of Natural Resources

Technical Advisors	
Katherine Charbonneau	Critical Area Commission
Scott Zacharko	Department of the Environment
Chris Becraft	Department of Natural Resources
Lisa Lowe	Department of Information Technology
Nell Ziehl	Department of Planning
Sasha Land	Department of Natural Resources
Kevin Wagner	Department of the Environment
Shawn Kiernan	Maryland Port Administration
Fiona Burns	Department of Budget and Management
vacant	Local Government Representative
Megan Granato	Department of Natural Resources
Elizabeth Habic	State Highway Administration
Joy Hatchette	Maryland Insurance Administration
Matthew Flemming	Department of Natural Resources
Mostafa Izadi	Department of General Services

Education, Communication and Outreach Working Group

Leadership	
Allison Rich	Co-Chair
John Kumm	Co-Chair
Lori Arguelles	Commission Liaison

Environmental Advocates	
Allison Rich (co-chair)	Maryland Environmental Health Network
Lori Arguelles (liaison)	Alice Ferguson Foundation
Dannielle Lipinski	Maryland League of Conservation Voters
Denise Robbins	Chesapeake Climate Action Network
Joelle Novey	Interfaith Power and Light
Business Community Representatives	
John Kumm (co-chair)	EA Engineering, Science and Technology
Kris Hoellen	National Aquarium
Noah Smock	Baltimore Toolbank
Michele Mitch-Peterson	Honeywell
Richard Reinhardt	Maryland Chamber of Commerce
Isaac Hametz	Mahan Rykiel Associates
Representatives of Academic Institutions	
Ashley Pennington	Johns Hopkins Office of Sustainability
Grant Samms	Washington College Center for Environment and Society
Pat Harcourt	UMCES/MADE-CLEAR
State Government Representatives	
Allison Gost	Department of Health
Colleen Turner	Department of Transportation
Donna Balado	Maryland State Department of Education
Julie Oberg	Department of Agriculture
Kaymie Owen	Maryland Energy Administration
Mark Shaffer	Department of the Environment
Sara Luell	Department of Housing and Community Development
Stephen Schatz	Department of Natural Resources

Technical Advisors	
George (Tad) Aburn	Department of the Environment
David Costello	IEER
John Coleman	Department of Planning

Mitigation Working Group

Leadership	
Mike Tidwell	Co-Chair
Michael Powell	Co-Chair
Tad Aburn	Work Group Lead

Representatives of Environmental Organizations	
Mike Tidwell (co-chair)	Chesapeake Climate Action Network
Joe Uehlein	Labor Network for Sustainability
Anya Schoolman	Community Power Network
Jana Davis	Chesapeake Bay Trust
Arjun Makhijani	Institute for Energy and Environmental Research
Tamara Toles O'Laughlin	Maryland Environmental Health Network
Representatives of Academic Institutions	
Gerrit Knaap	University of Maryland, National Center for Smart Growth
Ben Hobbs	Johns Hopkins University
Representatives of Renewable and Traditional Energy Providers	
Anne Lindner	Exelon
R. Daniel Wallace	Bithenergy
Tom Weissinger	Talen Energy
Tom Dennison	Southern Maryland Electric Cooperative
John Quinn	Baltimore Gas and Electric Company
Representatives of Business Interests and Labor Organizations	
Michael Powell (co-chair)	Gordon Feinblatt LLC
Tom Ballentine	NAIOP - Real Estate Development
Mike Remsberg	Trinity Consultants
Drew Cobbs	American Petroleum Institute
Colby Ferguson	Maryland Farm Bureau
Jim Strong	United Steelworkers
Larry Kasecamp	SMART Transportation Division
Representatives of State and Local Government Agencies	
George "Tad" Aburn (working group lead)	Department of the Environment
Colleen Turner	Department of Transportation
Chris Rice	Energy Administration
Christine Conn	Department of Natural Resources
Susan Payne	Department of Agriculture
Tom Walz	Department of Housing and Community Development
Les Knapp	Maryland Association of Counties
Lisa McNeilly	Baltimore Office of Sustainability

Mitigation Working Group

Steering Committee	
George "Tad" Aburn (working group lead)	Department of the Environment
Michael Powell (co-chair)	Business Community Representative
Mike Tidwell (co-chair)	Chesapeake Climate Action Network
Colleen Turner	Department of Transportation
John Fiastro	Maryland Energy Administration
Christine Conn	Department of Natural Resources
Susan Payne	Department of Agriculture

Scientific and Technical Working Group

Leadership	
Donald Boesch	Chair

Representatives of Academic Institutions	
Donald Boesch (chair)	University of Maryland Center for Environmental Science
Adel Shirmohammadi	College of Agriculture and Natural Resources, University of Maryland College Park
Amir Sapkota	School of Public Health, University of Maryland College Park
Belay Demoz	Joint Center for Earth Systems Technologies, University of Maryland Baltimore County
David A. Vanko	Fisher School of Science, Towson University
Eric A. Davidson	Appalachian Laboratory, University of Maryland Center for Environmental Science
Eric D. Wachsman	University of Maryland Energy Research Center, University of Maryland College Park
Fernando Miralles-Wilhelm	Earth Science Interdisciplinary Center, University of Maryland College Park
Gerrit J. Knaap	National Center for Smart Growth Research and Education, University of Maryland College Park
Ghassem Asrar	Joint Global Change Research Institute
Jane M. Kirschling	School of Nursing, University of Maryland Baltimore
Russell R. Dickerson	Department of Atmospheric and Oceanic Sciences, University of Maryland College Park

LAWRENCE J. HOGAN, JR., Governor

Chapter 429

(House Bill 514)

AN ACT concerning

Maryland Commission on Climate Change

FOR the purpose of establishing the Commission on Climate Change in the Department of the Environment to advise the Governor and General Assembly on ways to mitigate the causes of, prepare for, and adapt to the consequences of climate change; establishing the membership of the Commission; ~~requiring certain members to serve as chair and vice chair of the Commission~~; providing for the terms of ~~a~~ *an appointed* member of the Commission; authorizing the Governor to remove a member of the Commission under certain circumstances; prohibiting a member of the Commission from receiving certain compensation, but authorizing a member to be reimbursed for certain expenses; requiring the Commission to establish certain working groups; requiring the Chair of the Commission to appoint working group members who represent certain public and private interests; requiring the Commission to prioritize certain working group actions; requiring the Commission, on or before a certain date each year, to report to the Governor and General Assembly; requiring each State agency to complete a certain review in accordance with certain requirements; requiring each State agency to identify and recommend certain changes to certain programs under certain circumstances; requiring certain State agencies to report annually to the Governor and General Assembly on the status of certain programs; requiring the University of Maryland Center for Environmental Science to establish and update certain sea level rise projections; requiring the sea level rise projections to include certain maps and to be made publicly available on the Internet; providing for the construction of this Act; establishing the intent of the General Assembly; requiring the Commission members and working group members to be appointed and the Commission to be convened ~~and the working group members to be appointed~~ on or before a certain date; providing that nothing in this Act shall preclude the appointment of a certain member to the Commission; requiring each working group to meet and establish a work plan on or before a certain date; and generally relating to the Maryland Commission on Climate Change.

BY adding to

Article – Environment

Section 2–1301 through 2–1306 to be under the new subtitle "Subtitle 13. Maryland Commission on Climate Change"

Annotated Code of Maryland

(2013 Replacement Volume and 2014 Supplement)

Preamble

WHEREAS, As reported by the United Nations Intergovernmental Panel on Climate Change (IPCC) in March 2014, the effects of climate change are already occurring on all

continents and across the oceans, and numerous opportunities exist to respond to and mitigate associated risks; and

WHEREAS, Maryland has already experienced some effects of climate change, including sea level rise of more than 1 foot in the last century, increasing water temperatures in the Chesapeake Bay, more rain and flooding in the winter and spring, and less in the summer; and

WHEREAS, Maryland has demonstrated its strong commitment to addressing the drivers and consequences of climate change by passing several laws, including the Healthy Air Act, the Maryland Clean Cars Act of 2007, the Greenhouse Gas Emissions Reduction Act of 2009, the Maryland Offshore Wind Energy Act of 2013, and the Coast Smart Council; and

WHEREAS, Although the Maryland Commission on Climate Change was created by Executive Order 01.01.2007.07 in 2007, and then strengthened by Executive Order 01.01.2014.14 in 2014, there is not a statutory body in the State whose sole purpose is to address climate change impacts and make recommendations to the Governor and General Assembly; now, therefore,

SECTION 1. BE IT ENACTED BY THE GENERAL ASSEMBLY OF MARYLAND, That the Laws of Maryland read as follows:

Article – Environment

SUBTITLE 13. MARYLAND COMMISSION ON CLIMATE CHANGE.

2–1301.

(A) THERE IS A COMMISSION ON CLIMATE CHANGE IN THE DEPARTMENT TO ADVISE THE GOVERNOR AND GENERAL ASSEMBLY ON WAYS TO MITIGATE THE CAUSES OF, PREPARE FOR, AND ADAPT TO THE CONSEQUENCES OF CLIMATE CHANGE.

(B) THE DEPARTMENT AND THE DEPARTMENT OF NATURAL RESOURCES SHALL JOINTLY STAFF THE COMMISSION.

2–1302.

(A) THE COMMISSION'S MEMBERSHIP SHALL CONSIST OF THE FOLLOWING ~~25~~ MEMBERS:

(1) ONE MEMBER OF THE HOUSE OF DELEGATES, APPOINTED BY THE SPEAKER OF THE HOUSE;

(2) ONE MEMBER OF THE SENATE, APPOINTED BY THE PRESIDENT OF THE SENATE;

(3) THE STATE TREASURER, OR THE STATE TREASURER'S DESIGNEE;

(4) THE SECRETARY OF THE ENVIRONMENT, OR THE SECRETARY'S DESIGNEE;

(5) THE SECRETARY OF AGRICULTURE, OR THE SECRETARY'S DESIGNEE;

(6) THE SECRETARY OF NATURAL RESOURCES, OR THE SECRETARY'S DESIGNEE;

(7) THE SECRETARY OF PLANNING, OR THE SECRETARY'S DESIGNEE;

(8) THE STATE SUPERINTENDENT OF SCHOOLS, OR THE STATE SUPERINTENDENT'S DESIGNEE;

(9) THE SECRETARY OF TRANSPORTATION, OR THE SECRETARY'S DESIGNEE;

(10) THE SECRETARY OF GENERAL SERVICES, OR THE SECRETARY'S DESIGNEE;

(11) THE DIRECTOR OF THE MARYLAND ENERGY ADMINISTRATION, OR THE DIRECTOR'S DESIGNEE;

(12) THE PRESIDENT OF THE UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE, OR THE PRESIDENT'S DESIGNEE;

(13) THE CHAIR OF THE CRITICAL AREA COMMISSION FOR THE CHESAPEAKE AND ATLANTIC COASTAL BAYS, OR THE CHAIR'S DESIGNEE;

(14) ONE MEMBER APPOINTED BY THE FARM BUREAU REPRESENTING THE AGRICULTURE COMMUNITY;

~~(13)~~ **(15) ONE MEMBER APPOINTED BY THE ~~PRESIDENT OF THE SENATE~~ MARYLAND ASSOCIATION OF COUNTIES AND ONE MEMBER APPOINTED BY THE ~~SPEAKER OF THE HOUSE OF DELEGATES~~ MARYLAND MUNICIPAL LEAGUE TO REPRESENT LOCAL GOVERNMENTS;**

~~(14)~~ (16) ONE MEMBER APPOINTED BY THE PRESIDENT OF THE SENATE AND ONE MEMBER APPOINTED BY THE SPEAKER OF THE HOUSE OF DELEGATES TO REPRESENT THE BUSINESS COMMUNITY;

~~(15)~~ (17) ONE MEMBER APPOINTED BY THE PRESIDENT OF THE SENATE AND ONE MEMBER APPOINTED BY THE SPEAKER OF THE HOUSE OF DELEGATES TO REPRESENT ENVIRONMENTAL NONPROFIT ORGANIZATIONS;

~~(16) THREE REPRESENTATIVES OF PRIVATE PHILANTHROPIC ORGANIZATIONS, ONE EACH APPOINTED BY THE GOVERNOR, PRESIDENT OF THE SENATE, AND SPEAKER OF THE HOUSE OF DELEGATES;~~

(18) ONE MEMBER APPOINTED BY THE PRESIDENT OF THE SENATE AND ONE MEMBER APPOINTED BY THE SPEAKER OF THE HOUSE TO REPRESENT ORGANIZED LABOR ~~IN~~, *ONE OF WHOM SHALL REPRESENT* THE BUILDING OR CONSTRUCTION TRADES *AND ONE OF WHOM SHALL REPRESENT THE MANUFACTURING INDUSTRY*;

(19) ONE MEMBER APPOINTED BY THE PRESIDENT OF THE SENATE AND ONE MEMBER APPOINTED BY THE SPEAKER OF THE HOUSE TO REPRESENT PHILANTHROPIC ORGANIZATIONS;

~~(17)~~ (20) ONE CLIMATE CHANGE EXPERT APPOINTED BY THE GOVERNOR REPRESENTING A UNIVERSITY LOCATED IN MARYLAND; AND

~~(18)~~ (21) ONE PUBLIC HEALTH EXPERT APPOINTED BY THE GOVERNOR REPRESENTING A UNIVERSITY LOCATED IN MARYLAND~~;~~ .

~~(19) ONE REPRESENTATIVE OF ORGANIZED LABOR APPOINTED BY THE GOVERNOR; AND~~

~~(20) ONE REPRESENTATIVE OF THE AGRICULTURAL COMMUNITY APPOINTED BY THE GOVERNOR.~~

(B) ~~(1)~~ THE SECRETARY OF THE ENVIRONMENT OR THE SECRETARY'S DESIGNEE SHALL CHAIR THE COMMISSION.

~~(2) THE GOVERNOR SHALL APPOINT ONE BUSINESS REPRESENTATIVE AND ONE NONPROFIT REPRESENTATIVE FROM AMONG THE COMMISSION MEMBERS TO SERVE AS VICE CHAIRS OF THE COMMISSION.~~

(C) (1) SUBJECT TO PARAGRAPH (2) OF THIS SUBSECTION, THE TERM OF ~~A~~ *AN APPOINTED* MEMBER ~~APPOINTED BY THE GOVERNOR, PRESIDENT OF THE SENATE, OR SPEAKER OF THE HOUSE OF DELEGATES~~ IS 2 YEARS.

(2) THE GOVERNOR, PRESIDENT OF THE SENATE, AND SPEAKER OF THE HOUSE OF DELEGATES SHALL STAGGER THE TERMS OF THE INITIAL APPOINTED MEMBERS.

(3) AT THE END OF A TERM, A MEMBER CONTINUES TO SERVE UNTIL A SUCCESSOR IS APPOINTED AND QUALIFIES.

(4) A MEMBER WHO IS APPOINTED AFTER A TERM HAS BEGUN SERVES ONLY FOR THE REMAINDER OF THAT TERM AND UNTIL A SUCCESSOR IS APPOINTED AND QUALIFIES.

(5) THE GOVERNOR MAY REMOVE AN APPOINTED MEMBER FOR INCOMPETENCE, MISCONDUCT, OR FAILURE TO PERFORM THE DUTIES OF THE POSITION.

(D) A MEMBER OF THE COMMISSION MAY NOT RECEIVE COMPENSATION, BUT IS ENTITLED TO REIMBURSEMENT FOR EXPENSES UNDER THE STANDARD STATE TRAVEL REGULATIONS, AS PROVIDED IN THE STATE BUDGET.

2–1303.

(A) THE COMMISSION SHALL ESTABLISH:

(1) A SCIENTIFIC AND TECHNICAL WORKING GROUP;

(2) A GREENHOUSE GAS MITIGATION WORKING GROUP;

(3) AN ADAPTATION AND RESPONSE WORKING GROUP; AND

(4) AN EDUCATION, COMMUNICATION, AND OUTREACH WORKING GROUP.

(B) THE COMMISSION MAY ESTABLISH OTHER WORKING GROUPS AS NEEDED.

(C) THE CHAIR OF THE COMMISSION SHALL APPOINT WORKING GROUP MEMBERS WHO REPRESENT BOTH PUBLIC AND PRIVATE INTERESTS IN CLIMATE CHANGE, INCLUDING REPRESENTATIVES OF:

(1) ACADEMIC INSTITUTIONS;

(2) RENEWABLE AND TRADITIONAL ENERGY PROVIDERS;

(3) ENVIRONMENTAL ORGANIZATIONS;

(4) GOVERNMENT AGENCIES;

(5) LABOR ORGANIZATIONS; AND

(6) BUSINESS INTERESTS, INCLUDING THE INSURANCE ~~INDUSTRY~~ AND REAL ESTATE INDUSTRIES.

(D) THE COMMISSION SHALL PRIORITIZE WORKING GROUP ACTIONS, INCLUDING:

(1) STRENGTHENING AND MAINTAINING EXISTING STATE CLIMATE ACTION PLANS;

(2) DEVELOPING BROAD PUBLIC AND PRIVATE PARTNERSHIPS WITH LOCAL, STATE, AND FEDERAL AGENCIES;

(3) COMMUNICATING WITH AND EDUCATING CITIZENS ABOUT THE URGENCY OF ACTING TO REDUCE THE IMPACTS OF CLIMATE CHANGE;

(4) MAINTAINING AN INVENTORY OF MARYLAND'S GREENHOUSE GAS EMISSIONS SOURCES AND CARBON SINKS;

(5) ADDRESSING ANY DISPROPORTIONATE IMPACTS OF CLIMATE CHANGE ON LOW–INCOME AND VULNERABLE COMMUNITIES;

(6) ASSESSING THE IMPACTS THAT CLIMATE CHANGE MAY HAVE ON THE STATE'S ECONOMY, REVENUES, AND INVESTMENT DECISIONS;

(7) ASSESSING THE NEEDS FOR UTILITIES AND OTHER PUBLIC AND PRIVATE SERVICE PROVIDERS THROUGHOUT THE STATE TO ADJUST THEIR OPERATING PRACTICES AND INVESTMENT STRATEGIES TO MITIGATE THE IMPACTS OF CLIMATE CHANGE ON THEIR CUSTOMERS AND THE PUBLIC;

~~(7)~~ (8) ASSESSING THE IMPACTS THAT CLIMATE CHANGE MAY HAVE ON AGRICULTURE IN THE STATE;

~~(8)~~ (9) RECOMMENDING SHORT– AND LONG–TERM STRATEGIES AND INITIATIVES TO BETTER MITIGATE, PREPARE FOR, AND ADAPT TO THE CONSEQUENCES OF CLIMATE CHANGE;

~~(9)~~ (10) ASSISTING LOCAL GOVERNMENTS IN SUPPORTING COMMUNITY–SCALE CLIMATE VULNERABILITY ASSESSMENTS AND THE DEVELOPMENT AND INTEGRATION OF SPECIFIC STRATEGIES INTO LOCAL PLANS AND ORDINANCES;

~~(10)~~ (11) ESTABLISHING COMPREHENSIVE AND ACCOUNTABLE ANNUAL WORKING GROUP WORK PLANS THAT SET ANNUAL GOALS AND PERFORMANCE BENCHMARKS AND PRIORITIZE NEW AND EXISTING CLIMATE CHANGE MITIGATION AND PREPAREDNESS ACTIONS AND INITIATIVES;

~~(11)~~ (12) MAINTAINING A COMPREHENSIVE ACTION PLAN, WITH 5–YEAR BENCHMARKS, TO ACHIEVE SCIENCE–BASED REDUCTIONS IN MARYLAND'S GREENHOUSE GAS EMISSIONS ~~OF 80% OF 2006 LEVELS BY 2050~~;

~~(12)~~ (13) CONVENING REGULAR WORKING GROUP AND FULL COMMISSION MEETINGS TO ENSURE THAT SUFFICIENT PROGRESS IS BEING MADE ACROSS ALL SECTORS AND COMMUNITIES IN MARYLAND; AND

~~(13)~~ (14) CONSIDERING OTHER RELATED MATTERS AS THE COMMISSION DETERMINES TO BE NECESSARY.

2–1304.

ON OR BEFORE NOVEMBER 15 OF EACH YEAR, THE COMMISSION SHALL REPORT TO THE GOVERNOR AND GENERAL ASSEMBLY, IN ACCORDANCE WITH § 2–1246 OF THE STATE GOVERNMENT ARTICLE, ON THE STATUS OF THE STATE'S EFFORTS TO MITIGATE THE CAUSES OF, PREPARE FOR, AND ADAPT TO THE CONSEQUENCES OF CLIMATE CHANGE, INCLUDING FUTURE PLANS AND RECOMMENDATIONS FOR LEGISLATION, IF ANY, TO BE CONSIDERED BY THE GENERAL ASSEMBLY.

2–1305.

(A) (1) EACH STATE AGENCY SHALL REVIEW ITS PLANNING, REGULATORY, AND FISCAL PROGRAMS TO IDENTIFY AND RECOMMEND ACTIONS TO MORE FULLY INTEGRATE THE CONSIDERATION OF MARYLAND'S GREENHOUSE GAS REDUCTION GOAL AND THE IMPACTS OF CLIMATE CHANGE.

(2) THE REVIEW SHALL INCLUDE THE CONSIDERATION OF:

(I) SEA LEVEL RISE;

(II) STORM SURGES AND FLOODING;

(III) INCREASED PRECIPITATION AND TEMPERATURE; AND

(IV) EXTREME WEATHER EVENTS.

(B) EACH STATE AGENCY SHALL IDENTIFY AND RECOMMEND SPECIFIC POLICY, PLANNING, REGULATORY, AND FISCAL CHANGES TO EXISTING PROGRAMS THAT DO NOT CURRENTLY SUPPORT THE STATE'S GREENHOUSE GAS REDUCTION EFFORTS OR ADDRESS CLIMATE CHANGE.

(C) (1) THE FOLLOWING STATE AGENCIES SHALL REPORT ANNUALLY ON THE STATUS OF PROGRAMS THAT SUPPORT THE STATE'S GREENHOUSE GAS REDUCTION EFFORTS OR ADDRESS CLIMATE CHANGE, IN ACCORDANCE WITH § 2–1246 OF THE STATE GOVERNMENT ARTICLE, TO THE COMMISSION AND THE GOVERNOR:

(I) THE DEPARTMENT;

(II) THE DEPARTMENT OF AGRICULTURE;

(III) THE DEPARTMENT OF GENERAL SERVICES;

(IV) THE DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT;

(V) THE DEPARTMENT OF NATURAL RESOURCES;

(VI) THE DEPARTMENT OF PLANNING;

(VII) THE DEPARTMENT OF TRANSPORTATION;

(VIII) THE MARYLAND ENERGY ADMINISTRATION;

(IX) THE MARYLAND INSURANCE ADMINISTRATION;

(X) THE PUBLIC SERVICE COMMISSION; AND

(XI) THE UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE.

(2) THE REPORT REQUIRED IN PARAGRAPH (1) OF THIS SUBSECTION SHALL INCLUDE:

(I) PROGRAM DESCRIPTIONS AND OBJECTIVES;

(II) IMPLEMENTATION MILESTONES, WHETHER OR NOT THEY HAVE BEEN MET;

(III) ENHANCEMENT OPPORTUNITIES;

(IV) FUNDING;

(V) CHALLENGES;

(VI) ESTIMATED GREENHOUSE GAS EMISSIONS REDUCTIONS, BY PROGRAM, FOR THE PRIOR CALENDAR YEAR; AND

(VII) ANY OTHER INFORMATION THAT THE AGENCY CONSIDERS RELEVANT.

2–1306.

(A) THE UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE SHALL ESTABLISH SCIENCE–BASED SEA LEVEL RISE PROJECTIONS FOR MARYLAND'S COASTAL AREAS AND UPDATE THEM AT LEAST EVERY 5 YEARS.

(B) THE SCIENCE–BASED SEA LEVEL RISE PROJECTIONS SHALL INCLUDE MAPS THAT INDICATE THE AREAS OF THE STATE THAT MAY BE MOST AFFECTED BY STORM SURGES, FLOODING, AND EXTREME WEATHER EVENTS.

(C) THE SCIENCE–BASED SEA LEVEL RISE PROJECTIONS REQUIRED UNDER THIS SECTION SHALL BE MADE PUBLICLY AVAILABLE ON THE INTERNET.

SECTION 2. AND BE IT FURTHER ENACTED, That, before June 1, 2016, nothing in this Act shall be construed to affect the current membership and duties of the Maryland Commission on Climate Change, established by Executive Order 01.01.2014.14. It is the intent of the General Assembly that the Maryland Commission on Climate Change, established by Executive Order 01.01.2014.14, shall continue to meet and complete its tasks for 1 year following the enactment of this Act and until members are appointed to the Maryland Commission on Climate Change, established by this Act, in accordance with Section 3 of this Act.

SECTION 3. AND BE IT FURTHER ENACTED, That, on or before July 1, 2016, the members and working group members of the Maryland Commission on Climate Change, established in accordance with Section 1 of this Act, shall be appointed and a meeting shall be convened. Nothing in this Act shall preclude the appointment of a member to the Maryland Commission on Climate Change, established in accordance with this Act, who served as a member of the Maryland Commission on Climate Change, established by Executive Order 01.01.2014.14.

SECTION 4. AND BE IT FURTHER ENACTED, That, on or before October 1, 2016, each working group established by Section 1 of this Act shall meet and establish a work plan.

~~SECTION 2. AND BE IT FURTHER ENACTED, That on or before September 1, 2015, the Commission shall be convened and working group members shall be appointed. On or before October 1, 2015, each working group shall meet and establish a work plan.~~

SECTION ~~3.~~ 5. AND BE IT FURTHER ENACTED, That this Act shall take effect June 1, 2015.

Approved by the Governor, May 12, 2015.

Acronyms

ARPA-E	Advanced Research Projects Agency – Energy
ARWG	Adaptation and Response Working Group
BECCS	Bio-Energy with Carbon Capture and Storage
CALEV	California Low Emission Vehicle Standards
CCS	Carbon Capture and Storage
CEJSC	Commission of Environmental Justice and Sustainable Communities
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
COMAR	Code of Maryland Regulations
CPP	Clean Power Plan
CREP	Conservation Reserve Enhancement Program
DGS	Department of General Services
DHCD	(Maryland) Department of Housing and Community Development
DNR	(Maryland) Department of Natural Resources
DOE	(U.S.) Department of Energy
ECO	Education, Communication and Outreach (Working Group)
EPA	(U.S.) Environmental Protection Agency
EV	Electric Vehicle
EVIC	Electric Vehicle Infrastructure Council
GGRA	Greenhouse Gas Emissions Reduction Act
GHG	Greenhouse Gas
GMSL	Global Mean Sea Level
HUC02	Hydrologic Unit Code 02
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
MALPF	Maryland Agricultural Land Preservation Foundation
MCCC	Maryland Commission on Climate Change
MCEC	Maryland Clean Energy Center
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MDH	Maryland Department of Health
MDOT	Maryland Department of Transportation
MDP	Maryland Department of Planning
MEA	Maryland Energy Administration

$MMtCO_2e$	Million Megatons Carbon Dioxide Equivalent
MRCSP	Midwest Regional Carbon Sequestration Partnership
MTA	Maryland Transit Authority
MW	Megawatt
MWG	Mitigation Working Group
NERR	National Estuarine Research Reserves
NOAA	National Oceanic and Atmospheric Administration
NO_x	Nitrous Oxides (NO and NO_2)
NSF	National Science Foundation
OBD	On-Board Diagnostics
OREC	Offshore Wind Renewable Energy Credit
PACE	Property Assessed Clean Energy
PSC	(Maryland) Public Service Commission
RGGI	Regional Greenhouse Gas Initiative
RPS	Renewable Energy Portfolio Standard
SEIF	Strategic Energy Investment Fund
SHA	State Highway Administration
SMM	Sustainable Materials Management
(Solar) PV	(Solar) Photovoltaics
STWG	Scientific and Technical Working Group
QECB	Qualified Energy Conservation Bonds
TMDL	Total Maximum Daily Load
UMCES	University of Maryland Center for Environmental Science
UMERC	University of Maryland Energy Research Center
USDA	U.S. Department of Agriculture
VOCs	Volatile Organic Compounds
ZEV	Zero Emission Vehicle

Photo Credits and Licensing

Photo 1

Photo by Lt. Zachary West, 100th MPAD, some rights reserved.
License available at: https://creativecommons.org/licenses/by-nd/4.0/legalcode
Image available at: https://www.flickr.com/photos/texasmilitaryforces/36015108834/in/album-72157685652287213/

Photo 2

Photo by Will Parson/Chesapeake Bay Program, some rights reserved.
License available at: https://creativecommons.org/licenses/by-nc/4.0/legalcode
Image available at: https://www.flickr.com/photos/29388462@N06/31120587244/in/album-72157667630860295/

Photo 3

Photo by Steve Droter/Chesapeake Bay Program, some rights reserved.
License available at: https://creativecommons.org/licenses/by-nc/4.0/legalcode
Image available at: https://www.flickr.com/photos/29388462@N06/23665816892/in/album-72157625845711857/

Photo 4

"Elliotts Island Road". Guy W. Willey Sr.
Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/)

Photo 5

Photo by Tim Windsor, some rights reserved.
License available at: https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode
Image available at: https://www.flickr.com/photos/timwindsor/2893639754/in/album-72157607539286640/

Photo 6

Photo by William Whaley
Used with permission from Maryland Department of Natural Resources, all rights reserved.

Photo 7

Photo by World Resources Institute, some rights reserved.
License available at: https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode
Image available at: https://www.flickr.com/photos/worldresourcesinstitute/37737522581/in/album-72157686248456982/

Photo 9

Photo by CHRISsadowski, IStockPhoto.com.
License and image available at: https://www.istockphoto.com/photo/downed-power-lines-gm188119523-29939316

Photo 10

Photo by BeyondDC, some rights reserved.
License available at: https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode
Image available at: https://www.flickr.com/photos/beyonddc/36686760242/in/album-72157641328450233/

Photo 11

"Healthy Forest". Jane Hawkey.
Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/)