Maryland Commission on Climate Change

Prepared for: Larry Hogan, Governor, State of Maryland and the Maryland General Assembly

December 2015

Chapter 1 - Introduction

In 2007, the Maryland Commission on Climate Change (MCCC) was established by Executive Order (01.01.2007.07) and charged with evaluating and recommending state goals to reduce Maryland's greenhouse gas (GHG) emissions to 1990 levels by 2020 and to reduce those emissions to 80 percent of their 2006 levels by 2050. The MCCC was also tasked with developing a plan of action that addressed the causes and impacts of climate change and included firm benchmarks and timetables for policy implementation. As a result of the work of more than 100 stakeholders and subject matter experts, the MCCC produced a climate action plan. That plan was the impetus of the Greenhouse Gas Emissions Reduction Act (GGRA) of 2009.

In 2014, the MCCC was re-established by another Executive Order (01.01.2014.14) and its scope and membership were expanded to include non-state government participants. The MCCC now has representatives from the administration, the legislature, business, non-profit organizations and local governments.

The Maryland General Assembly codified the MCCC during the 2015 legislative session and Governor Larry Hogan signed the bill into law. This legislation requires the MCCC to report to the Governor and General Assembly each year on the status of the state's efforts to "mitigate the causes, prepare for and adapt to the consequences of climate change, including future plans and recommendations, if any, to be considered by the General Assembly."

We are pleased to share the first report of the reconstituted MCCC. This report provides background and recommendations on key challenges and opportunities related to the state of Maryland's response to climate change. The report is also intended to promote a structured, predictable and adaptive process for monitoring and managing the state's climate actions and policy decisions. With a clear, timely understanding of the strengths, weaknesses, successes and shortcomings of our climate strategies and programs, we can accelerate Maryland's progress.

This first report closely follows publication of the *Greenhouse Gas Emissions Reduction Act (GGRA) 2015 Plan Update*, prepared by the Maryland Department of the Environment (MDE) and mandated by the 2009 GGRA. While the MCCC worked with MDE on this report and has been deeply informed by the research and analysis undertaken by and included in MDE's report, this MCCC report is distinct from MDE's report. The requirements and parameters of MDE's report are delineated in the 2009 legislation and focus on the provisions of the 2009 GGRA and the elements of the *2012 GGRA Plan*. The MCCC's report, by contrast, is expected to reflect the broad range of perspectives and insights brought to bear on the work of government by its members, in the form of an independent voice.

In accordance with the fact that the MCCC is deeply indebted to MDE's work and is also intended to be independent of it, this first report both engages with MDE's work and

identifies areas where additional effort could lead to continued progress on climate change in a manner that supports a strong economy in Maryland.

Report Overview

This MCCC report is guided by the best available science as supported by the MCCC's Science and Technical Working Group (STWG). In a 2015 science update (Appendix 1) the STWG concludes that science has demonstrated with a high degree of certainty that Earth's climate is being changed by human activities, particularly the emission of greenhouse gases. Science has also provided a reliable description of how increased emissions will warm the Earth and how that warming will affect society and the natural systems on which it depends. Finally, science has estimated the amount and timing of global and state emissions reductions needed to avoid the most harmful consequences of climate change.

Climate change consequences ranging from increased temperatures, higher sea levels and more extreme weather events are likely to have a profound effect on Maryland's environment, economy and overall well-being. By strengthening its climate change mitigation and adaptation actions, the state of Maryland can better protect the state's economy, the local environment and public health, while simultaneously doing its part to limit the negative consequences of global warming. This report highlights the many costs associated with climate change, including its disproportionate impacts on Maryland's most vulnerable communities and the costs and benefits of taking action to limit climate change and its impacts.

The report also provides a summary of MDE's *2015 GGRA Plan Update* as well as recommendations to the Governor and General Assembly for future state climate action, including the maintenance of the 25 percent greenhouse gas emissions reduction required under the GGRA by 2020 and its extension to 40 percent by 2030. Finally, as mandated by law, the MCCC report provides guidance to its working groups as they develop work plans for 2016.

Climate change is real, harmful and predominantly human-caused and it is placing the health and well-being of many Marylanders at risk. The MCCC understands this and is committed to doing all that we can to protect and sustain Maryland's collective health and prosperity and help Maryland avoid the worst-case scenarios of climate disruption. The MCCC embraces its expansive and inclusive mission and looks forward to continuing its work to strengthen Maryland's climate efforts moving forward.

Chapter 2 - Maryland Commission on Climate Change: History, Structure, and Responsibilities

History

Maryland has historically been at the forefront of states taking action to address the causes and growing consequences of climate change. Starting with the development of *A Sea Level Rise Response Strategy for Maryland* in 2000[1]; the passage of the Healthy Air and Clean Cars Acts of 2006 and 2007, respectively, and the establishment of the MCCC, Maryland has consistently and progressively worked to deal with climate change.

The 2007 Executive Order establishing the MCCC stated that it is "imperative that Maryland state Government, as well as local governments, continue to lead by example in the scope and variety of services and activities that government provides and undertakes; and [that] more must be done to reduce GHG emissions and prepare the state of Maryland for the likely physical, environmental and socio-economic consequences of climate change."[2]

The MCCC was tasked with developing a plan of action that addressed the drivers and causes of climate change, to prepare for the likely consequences and impacts of climate change to Maryland and to establish firm benchmarks and timetables for implementing the plan of action. The members and staff of three working groups undertook the bulk of the MCCC's work: climate change impact assessment and scientific and technical issues (Scientific and Technical Working Group or STWG), greenhouse gas and carbon footprint reduction strategy (Mitigation Working Group or MWG) and strategy for reducing Maryland's climate change vulnerability (Adaptation and Response Working Group or ARWG).

As the agency leading development of the plan of action, MDE produced an Interim Report on the Plan in January 2008, with support from the Maryland Department of Natural Resources (DNR) and the University of Maryland Center for Environmental Science (UMCES). The Interim Report provided an update on the most current information emerging from each working group. Following the release of its interim report, the MCCC and its working groups continued to assess the likely impacts of climate change in Maryland, compile the most up-to-date science relating to climate change and fine-tune possible policy options for dealing with the causes and impacts of climate change.

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[1] A Sea Level Rise Response Strategy for Maryland (2000), Available at: http://www.ecy.wa.gov/climatechange/PAWGdocs/ci/071007CIsealevelstrategy.pdf

[2] Maryland Executive Order 01.01.2007.07 (2007). Available at: http://www.mde.state.md.us/assets/document/Air/ClimateChange/AppendixA_Executive_Order.pdf

In August 2008, the MCCC completed its plan of action. At its core, the MCCC's Climate Action Plan (CAP) recommended a suite of 61 policy options: 42 to mitigate GHG emissions and 19 to prepare for and adapt to the consequences of climate change. Among the 61 mitigation and adaptation actions were mechanisms for moving to cleaner, renewable energy and making the state more energy-efficient as well as ideas on how to better prepare for extreme weather and make the state more resilient to sea level rise.

Additionally, the MCCC's 2008 CAP suggested a goal of reducing GHG emissions at least 25 percent by 2020 from a 2006 baseline, a longer-term goal of 90 percent reduction by 2050 and interim reductions of 10 percent by 2012 and 15 percent by 2015. The intent of the goals was to spur early and sustained action.

The CAP also included two climate change adaptation strategies that have been utilized to guide state-level adaptation planning efforts. The first strategy (Phase I), released in 2008, seeks to address the impacts associated with sea level rise and coastal storms. The second strategy (Phase II), released in 2011 as an amendment to the 2008 CAP, seeks to deal with the changes in precipitation patterns and increased temperature and the likely impacts to human health, agriculture, forest and terrestrial ecosystems, bay and aquatic environments, water resources and population growth and infrastructure.

Together, the state's adaptation strategies are the product of the work of more than 100 stakeholders and subject matter experts from the governmental, non-profit and private sectors who held a series of meetings for the purpose of interpreting the most recent climate change literature, evaluating adaptation options and recommending strategies to reduce Maryland's overall climate change vulnerability. The strategies provide the basis for guiding and prioritizing state-level activities with respect to both climate science and adaptation policy over the near and longer terms.

In 2009 the GGRA was signed into law. The GGRA required the state to achieve a minimum 25 percent reduction in statewide GHG emissions from 2006 levels by 2020. To achieve this goal, the GGRA required MDE to develop a statewide GHG reduction plan, which used the 2008 CAP as a roadmap. The state was also required to demonstrate that the reduction goal could be achieved in a way that had a positive impact on Maryland's economy, protected existing manufacturing jobs and created new jobs.

To achieve a 25 percent reduction in Maryland's GHG emissions from 2006 levels by 2020, the state developed the *2012 GGRA Plan*. The plan – the result of an in-depth process involving more than a dozen state agencies and numerous non-governmental organizations – provides a blueprint for action which, if fully implemented, could achieve the GGRA required 25 percent GHG reduction by 2020, with positive job and other economic benefits. The plan's implementation is also likely to advance efforts to restore the Chesapeake Bay, improve the state's air quality and preserve Maryland's agricultural and forestlands.

The *2012 GGRA Plan* outlined more than 150 programs and initiatives designed to reduce statewide GHG emissions. It included an evaluation of the economic and jobs impacts of mitigation strategies on Maryland's manufacturing sector, as well as an analysis of the impacts on electricity reliability in the state. A comprehensive suite of mitigation strategies were developed by state agencies including quantifications for GHG reductions and co-benefits related to the reduction of air pollutants to public health and to the Chesapeake Bay. Extensive jobs and economic benefits for each of the policies were also included.

2014 and Beyond

Following the release of its 2008 CAP, the work of the MCCC was essentially complete. However, in 2014, taking notice of new reports on the consequences of climate change in Maryland, a second Executive Order was issued to strengthen the MCCC. The new order expanded the membership of the commission to include nongovernmental members, consisting of representatives from local governments, the business community and non-profit organizations, as well as at-large members. It tasked the Commission with appointing working groups and prioritizing actions to strengthen and maintain existing state action plans for further mitigating the causes and drivers and addressing the impacts of climate change.[3]

During its 2015 Session, the Maryland General Assembly codified the Commission in the Maryland Climate Change Commission Act of 2015, which was signed into law on May 12, 2015. The tasks and responsibilities assigned to the MCCC under the Act are generally similar to those under the 2014 Executive Order, including the requirement for an annual report. The membership and appointment authorities differ within the Executive Order and the law, but the Act authorizes the members appointed under the Executive Order to function as the Commission until June 1, 2016. Thereafter, the membership will be as specified under the Act. This report responds to the charge to the MCCC under both the Executive Order and the Act and was prepared by the members specified in and appointed under the Executive Order.

The MCCC is chaired by MDE Secretary Ben Grumbles and consists of 26 members representing state and local governments, the business community, labor and the non-profit community.[4] Four working groups now support the work of the Commission: the MWG, the ARWG and the STWG continue to provide support and a new working group, the Education, Communication and Outreach Working Group (ECO).

The MWG focuses on regulatory, market-based and voluntary programs to reduce GHG emissions while supporting economic development and job creation. The ARWG is charged with developing a comprehensive strategy for reducing Maryland's climate

[3] 2014 Maryland Executive Orders. Available on page 26 at:
http://mgaleg.maryland.gov/Pubs/LegisLegal/2014-executive-orders.pdf
[4] Full Maryland Commission on Climate Change and Working Group memberships in Appendix 2

change vulnerability through both short- and long-term measures that state and local governments may use to plan for and adapt to more extreme weather and a rise in sea levels due to climate change. The STWG is responsible for updating and informing the MCCC on the science of climate change, and the ECO working group assists with the MCCC's public outreach and public meetings on climate change as well as educating Marylanders on what the state is doing to address the causes and impacts of climate change.

The 2015 law requires the MCCC to:

- Oversee the development of working group work plans and the prioritization of working group actions;
- Strengthen state climate action plans (mitigation and adaptation);
- Develop broader non-profit/for-profit community and state, federal and local government partnerships;
- Communicate with and educate Maryland residents about the urgency of acting to reduce the impacts of climate change (ECO working group);
- Address any disproportionate impacts of climate change on low-income and vulnerable communities;
- Better assess the impacts that climate change will likely have on the state's economy (including agriculture, utilities and other industries) revenues and investment decisions;
- Maintain an inventory of Maryland's GHG emission sources and carbon sinks; and
- Consider other related matters as the MCCC determines to be necessary**.**

The MCCC is required to meet at least four times per year to ensure that sufficient effort to reduce GHG emissions and prepare for the likely impacts of climate change is being made across all sectors and communities in Maryland. Meetings are open to the public, and time for public comment is provided. The MCCC held its first meeting on December 8, 2014 and has held an additional six meetings in January, March, May, June, September and October 2015.

The four working groups held numerous meetings in 2015, principally on the status of the state's efforts and MDE's and the MCCC's 2015 reports to the Governor and General Assembly. The GGRA required MDE to submit an updated report to the Governor and General Assembly by October 1, 2015. This report (the *2015 GGRA Plan Update*) updates the information contained within the *2012 GGRA Plan* and summarizes the state's progress toward achieving the 2020 emissions reduction goal established by the GGRA. The MCCC working groups assisted MDE in developing the *2015 GGRA Plan Update* and continue to work through the MCCC on both the implementation of the *2012 GGRA Plan* through 2020 and efforts to address climate change beyond 2020. The MWG met frequently throughout 2015 and held various subgroup meetings focusing on the energy and transportation sectors and the economic impacts of climate change programs in Maryland.

The ARWG met in April and July of 2015 to discuss ongoing adaptation actions related to various sectors including the coastal zone, water resources, bay and aquatic ecosystems, human health, agriculture, forest and terrestrial ecosystems and growth and infrastructure.

The ECO Working Group held five public meetings across Maryland between July and August of 2015 and another four in November and December 2015. The purpose of these meetings was to inform the public of the mission and actions of the MCCC, the purpose of the GGRA and the content of the *2015 GGRA Plan Update, this MCCC report* and to take public comment on relevant issues of concern regarding climate change in Maryland.

Details of the meetings and activities of the MCCC and its working groups, as well as copies of climate change-related reports can be found at:
http://mde.maryland.gov/programs/Marylander/Pages/mccc.aspx

Chapter 3 - Strengthening the Framework for Assessing Maryland's GHG Reduction Planning and Programs

Legislative, governmental and scientific bodies around the globe have voiced concerns about the growing risks and costs associated with the severe consequences of climate change. Those concerns have been clearly supported by the Intergovernmental Panel on Climate Change (IPCC)'s *Climate Change 2014 Synthesis Report*[5], the 2014 National Climate Assessment *Climate Change Impacts in the United States*[6] and the 2015 Environmental Protection Agency report *Climate Change in the United States Benefits of Global Action*[7]. The IPCC was set up in 1988 by the World Meteorological Organization and the United Nations Environment Programme and is the world body for assessing the science related to climate change. Relevant findings from these assessments are summarized in the STWG 2015 update (Appendix 1). This and earlier STWG reports lay out the consequences of climate change – from rising property damage costs and falling agricultural output to declines in public health, including increases in Lyme disease and respiratory ailments.

The key finding derived from scientific and technical analyses is that all jurisdictions, particularly developed areas, need to strengthen their climate change mitigation and adaptation efforts to protect and sustain critical infrastructure, economic prosperity and public health.

Understanding the myriad costs and risks associated with unmitigated climate change, as well as the costs and benefits of climate action, will be essential elements of the MCCC's work in the years ahead. Maryland's continued prosperity as a state will be tied to the extent to which we collectively continue to make progress in implementing climate plans, policies and programs.

Climate Science Update

As part of its 2015 work, the MCCC's STWG provided an updated report that included an appraisal of the scientific basis for setting greenhouse gas emissions (GHG) reduction targets beyond 2020 (Appendix 1). The Working Group's appraisal is based on a review of relevant and available scientific analyses including the IPCC's Fifth Assessment,[8] which was completed in 2014.

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[5] IPCC Fifth Assessment (2014) Climate *Change 2014 Synthesis Report*,), available at: http://www.ipcc.ch/report/ar5/syr/

[6] National Climate Assessment Report (2014) *Climate Change Impacts in the United States*, available at http://nca2014.globalchange.gov/downloads IPCC Fifth Assessment. 2014. https://www.ipcc.ch/report/ar5/wg3/

[7] Environmental Protection Agency report *Climate Change in the United States Benefits of Global Action* (2015), available at: http://www2.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf

[8] IPCC Fifth Assessment. 2014. https://www.ipcc.ch/report/ar5/wg3/https://www.ipcc.ch/report/ar5/wg3/

In order to determine future GHG reduction goals, the IPCC studied the relationship of the accumulation of carbon dioxide in the atmosphere since 1870 to the change in temperature. Using this research, it then determined reductions in greenhouse gases required over the next few decades to keep the temperature change under 2 degrees Celsius.[9]

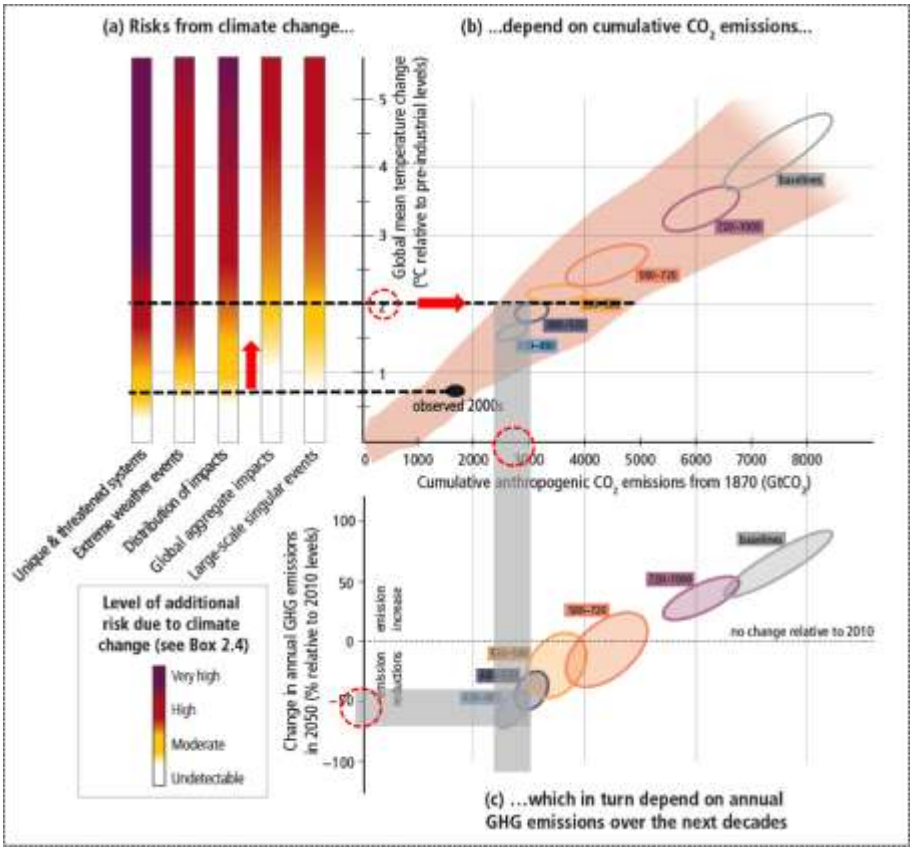

Figure 4. The relationships among risks from climate change, cumulative CO_2 emissions and changes in annual greenhouse gas emissions by 2050.

The IPCC determined that this level of warming would cause additional climate disruption with potentially devastating side effects for communities and ecosystems worldwide.[10] Avoiding an increase of greater than 2 degrees Celsius has become an internationally accepted goal. [11]

According to these calculations, greenhouse gases worldwide would need to be reduced by 41 to 72 percent (compared to 2010) by 2050. In fact, scientists acknowledge that not warming more than 2 degrees Celsius would only be possible if global GHG emissions were reduced by at least 42 percent by 2050.[12]

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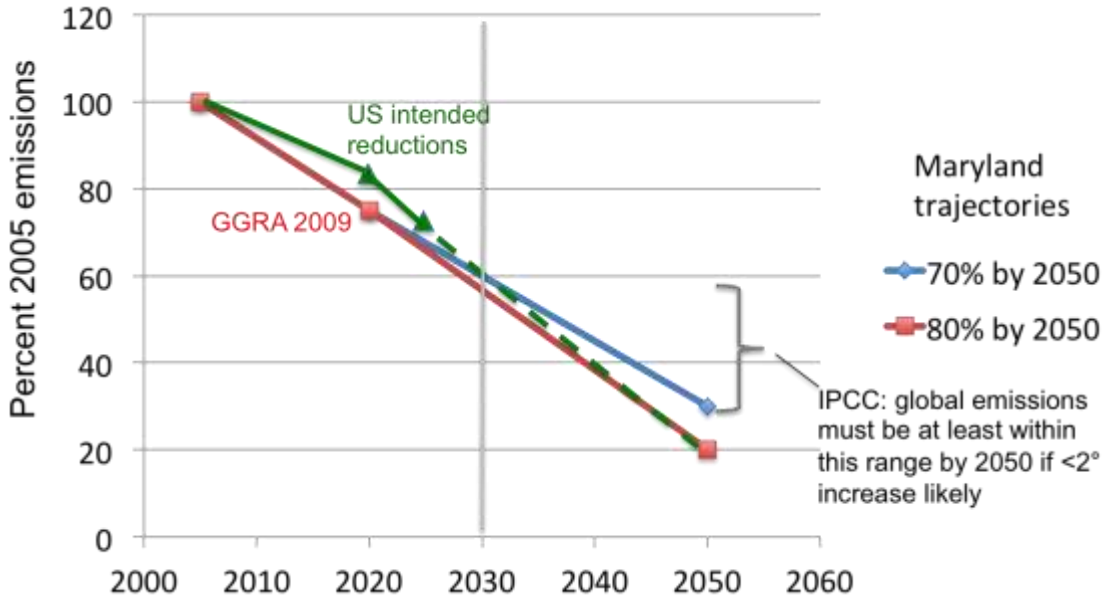
[9] IPCC Fifth Assessment. 2014. https://www.ipcc.ch/report/ar5/wg3/
[10] Scientific and Technical Working Group. "What the IPCC Tells Us About Targets for Reducing Emissions of Greenhouse Gases." June 2015.
[11] Scientific and Technical Working Group. "What the IPCC Tells Us About Targets for Reducing Emissions of Greenhouse Gases." June 2015.
[12] Scientific and Technical Working Group. "What the IPCC Tells Us About Targets for Reducing Emissions of Greenhouse Gases." June 2015.

These evaluations are for global mean temperatures and global GHG emissions. The STWG assumed that, due to much higher emissions per capita than all but a few nations in the world, U.S. emissions must be reduced at least to the upper end of the IPCC's 2050 range to achieve warming of no greater than 2 degrees Celsius worldwide.[13]



Appendix 1: STWG Post-2020 Reduction Goals

In Maryland's Greenhouse Gas Reduction Act of 2009, the Maryland General Assembly found "the state has the ingenuity to reduce the threat of global warming and make greenhouse gas reductions a part of the state's future by achieving a 25 percent reduction in greenhouse gas emissions from 2006 levels by 2020 and by preparing a plan to meet a longer-term goal of reducing greenhouse gas emissions by up to 90 percent from 2006 levels by 2050 in a manner that promotes new 'green' jobs and protects existing jobs and the state's economic well-being."[14]

According to the STWG, to be on a steady trajectory to reach at least a 70 percent reduction by 2050, a 40 percent reduction from 2005[15] levels must be achieved in Maryland by 2030 and to achieve reductions of at least 80 percent, a reduction greater than 43 percent would need to be achieved.

In the years ahead, the MCCC will continue to work with its working groups, state agencies and stakeholders to analyze Maryland's GHG mitigation policies, plans and

[13] Scientific and Technical Working Group. "What the IPCC Tells Us About Targets for Reducing Emissions of Greenhouse Gases." June 2015.
[14] Maryland Greenhouse Gas Emissions Reduction Act of 2009, Section 21201-(4), available at: http://mgaleg.maryland.gov/2009rs/bills/sb/sb0278e.pdf
[15] Maryland's current goal is from 2006 baseline.

programs to ensure that they are protecting Maryland's economy, preparing communities to be resilient in the face of intensifying weather events and achieving science-based emissions reduction targets.

Jobs and the Economy – Likely Costs of Inaction

Climate change consequences ranging from increased temperatures to higher sea levels to more extreme weather events are likely to have a profound effect on all sectors of Maryland's economy through the end of this century, regardless of Maryland's – and the rest of the world's – work to reduce GHG emissions. Scientific analysis allows us to estimate the likely impacts in Maryland should we not undertake GHG mitigation efforts, as well as the likely impacts if we achieve various levels of reduction in global GHG emissions.

Understanding how the effects of climate change can be reduced or avoided through mitigation and adaptation efforts will help inform the near- and long-term policies necessary to address the risks Marylanders face.[16] The choice is not between mitigation and adaptation. Even with aggressive reductions in global greenhouse gas emissions, there will be significant changes to Maryland's climate to which we will have to adapt. However, if emissions continue to grow at recent rates, changes in climate will be so great that we cannot merely adapt to them without the kinds of severe disruption to our economy, our health and wellbeing, and our way of life that were projected in the STWG's 2008 *Comprehensive Assessment of Climate Change Impacts in Maryland*[17] and its 2013 *Updating Projections of Sea-Level Rise in Maryland*[18].

Infrastructure

The STWG's assessment of climate change impacts and increased projections of sea-level rise likely during the remainder of this century indicate that climate change will put at risk one of the state's greatest economic resources – its infrastructure such as roads, bridges and highways. In 2014, trade, transportation and utilities accounted for $47.6 billion (14 percent) of Maryland's gross domestic product (GDP), with manufacturing contributing an additional $18.8 billion to the state GDP.[19] Recent severe weather events, such as Superstorm Sandy in 2012, demonstrate that state infrastructure can be significantly affected by climate change because of sea level rise, storm surges, higher

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[16] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015
[17] STWG Comprehensive Assessment of Climate Change Impacts in Maryland (2008), available at: http://www.mde.state.md.us/programs/Air/ClimateChange/Documents/FINAL-Chapt%202%20Impacts_web.pdf
[18] STWG Updating Projections of Sea-Level Rise in Maryland (2013), available at: http://www.umces.edu/sites/default/files/pdfs/SeaLevelRiseProjections.pdf
[19] U.S. Department of Commerce: Bureau of Economic Analysis (BEA), Gross Domestic Product by State – Maryland, 2014, available at: http://www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=1#reqid=70&step=10&isuri=1&7003=200&7035=-1&7004=naics&7005=-1&7006=24000&7036=-1&7001=1200&7002=1&7090=70&7007=2014&7093=levels.

temperatures and inland flooding due to the increased likelihood of extreme precipitation.[20]

Estimates provided by the MCCC's STWG indicate that Maryland is projected to experience between 2.1 and 5.7 feet of sea level rise over the next century. In fact, sea level could be as much as 2.1 feet higher in 2050 along Maryland's shorelines than it was in 2000. The MCCC's STWG recommends that it would be prudent to plan for such an occurrence. Sea level rise could inundate some facilities of the Port of Baltimore, placing one of the most important ports along the East Coast at risk.[21] In 2014, the Port of Baltimore generated more than $3 billion in business revenue and wages while moving more than $52.5 billion of cargo.[22] Sea level rise can prevent valuable cargo from being delivered. Furthermore, the Federal Emergency Management Agency estimates an additional 36 to 58 percent increase in annual storm damage costs for every one-foot rise in sea level and a 102 to 200 percent increase in damage costs for a three-foot increase.[23]

If GHG emissions are not greatly reduced soon, increased flooding, higher temperatures and elevated freeze-thaw cycles could significantly increase the costs of maintaining, replacing and repairing roads.[24] By 2100, these costs in the Northeast alone are estimated to be more than $1 billion, assuming growth in global emissions, according to the EPA.[25] Substantial GHG reductions by the middle of the century would reduce the estimated cost to between $100 and $250 million in 2100.[26]

The costs to Maryland of adapting to climate change are likely to increase with or without additional mitigation efforts. Urban drainage infrastructure will likely need to be adapted to accommodate increased inland flooding.[27] Baltimore was one of 50 cities modeled by the Massachusetts Institute of Technology's Integrated Global System Model to determine projected costs in 2050 and 2100 for one major storm event every 10, 25 and 50 years. Costs are projected to range between $200,000 and $500,000 per storm by 2050, depending on the storm's intensity.[28] These costs increase to between

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[20] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015
[21] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015
[22] Maryland State Archives, Maryland at a Glance: Waterways, July 22, 2015, available at: http://msa.maryland.gov/msa/mdmanual/01glance/html/port.html.
[23] State of Maryland Department of Environment (MDE), Maryland's Plan to Reduce Greenhouse Gas Emissions, December 31, 2011, available at: http://www.mde.state.md.us/programs/Air/ClimateChange/Documents/2011%20Draft%20Plan/2011GGRADRAFTPlan.pdf.
[24] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015
[25] U.S. Environmental Protection Agency (US EPA), Climate Change in the United States: Benefits of Global Action, June 2015, available at: http://www2.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf.
[26] U.S. Environmental Protection Agency (US EPA), Climate Change in the United States: Benefits of Global Action, June 2015, available at: http://www2.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf.
[27] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015
[28] U.S. Environmental Protection Agency (US EPA), Climate Change in the United States: Benefits of Global Action, June 2015, available at: http://www2.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf.

$300,000 and $600,000 per storm by 2100.[29] Should Baltimore install urban drainage systems, cost savings are projected to be as high as 55 percent, with the largest amount of savings coming from the 50-year highest-intensity storm in 2100.[30]

Tourism

The state's $15.4 billion tourism sector is also likely to feel the impact of climate change.[31] In 2013, tourism resulted in $2.1 billion in tax revenue, which directly supported more than 138,500 jobs with a payroll of $4.6 billion.[32] This was a 3.2 percent increase over 2012.[33] Rising sea levels, increased flooding and elevated storm surges from severe weather are likely to put an additional strain on Maryland's already vulnerable 3,100 miles of low-lying urban and coastal lands. These problems could make it more difficult for tourists to travel to the region and elevate the costs to coastal communities and the state of maintaining bridges, roads and boardwalks. In addition, the Maryland Department of the Environment's 2012 plan for reducing greenhouse gas emissions 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 million and $200 million."[34]

Much of Maryland's tourism growth in 2013 stemmed from an increase in local and regional tourists taking daylong excursions.[35] There could be an impact on regional tourism if steps aren't taken to curtail the impact of climate change, given projections that by 2050 the number of 95-plus degree days could reach five times the current 30-year average of six days.[36] By 2100, that number could increase tenfold.[37] Rising temperatures could result in a 5 percent loss in tourism revenues.[38]

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[29] U.S. Environmental Protection Agency (US EPA), Climate Change in the United States: Benefits of Global Action, June 2015, available at: http://www2.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf.
[30] U.S. Environmental Protection Agency (US EPA), Climate Change in the United States: Benefits of Global Action, June 2015, available at: http://www2.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf.
[31] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015
[32] Maryland Office of Tourism Development, Fiscal Year 2014 tourism Development Annual Report, 2015, available at: http://industry.visitmaryland.org/research/annual-reports/.
[33] Maryland Office of Tourism Development, Fiscal Year 2014 tourism Development Annual Report, 2015, available at: http://industry.visitmaryland.org/research/annual-reports/
[34] Maryland Department of the Environment 2011 GGRA Plan, Page 90, available at: http://www.mde.state.md.us/programs/Air/ClimateChange/Documents/2011%20Draft%20Plan/2011GGRADRAFTPlan.pdf
[35] Maryland Office of Tourism Development, Fiscal Year 2014 tourism Development Annual Report, 2015, available at: http://industry.visitmaryland.org/research/annual-reports/http://industry.visitmaryland.org/research/annual-reports/.
[36] Trevor Houser, Robert Kopp, Solomon Hsiang, Michael Delgado, Amir Jina, Kate Larsen, Michael Mastrandrea, Shashank Mohan, Robert Muir-Wood, DJ Rasmussen, James Rising, and Paul Wilson, American Climate Prospectus: Economic Risks in the United States – Maryland Science Data Table, 2014, available at: http://rhg.com/reports/climate-prospectus.
[37] Trevor Houser, Robert Kopp, Solomon Hsiang, Michael Delgado, Amir Jina, Kate Larsen, Michael Mastrandrea, Shashank Mohan, Robert Muir-Wood, DJ Rasmussen, James Rising, and Paul Wilson, American Climate Prospectus: Economic Risks in the United States – Maryland Science Data Table, 2014, available at: http://rhg.com/reports/climate-prospectus.
[38] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015

Agriculture

According to a recent report from the Center for Energy Solutions on the possible costs of inaction due to climate disruption, the agriculture sector is almost certain to feel the impact of elevated heat levels, extended droughts, increased flooding and unpredictable and severe weather patterns.[39] In 2014, the market value of agricultural products sold by farms in Maryland was $2.7 billion.[40] Of this total, $800 million was in the form of crop sales and $1.9 billion was in dairy and livestock.[41]

By 2050, if no additional action is taken and summer temperatures rise above thresholds where corn, soy and wheat can be grown, median annual losses for these crops could approach $150 million.[42] While the added warmer days could extend the growing season, there could be an increase in invasive species and new animal and plant disease. The health of livestock could also be at risk as the number of 95-plus degree days rises and would need access to cooler areas.[43]

Flooding of fields from sea rise or severe rain events can lead to increased salt-water intrusion of soil, decreased crop production, excessive soil erosion and nutrient runoff as well as declining water quality.[44] Increasingly frequent tidal inundation of fields in low-lying areas due to sea-level rise would impair soil drainage and cause soils to become saline, ultimately resulting in abandonment of valuable farmland from cultivation. Sea-level rise may also cause salt water to infiltrate into some aquifers used for irrigation. More extreme rainfall events, a trend that is already being observed, could also result in greater soil erosion and the runoff of fertilizer nutrients, exacerbating water quality impairment of streams and the tidal waters of the Chesapeake Bay.

Forestry and Terrestrial Ecosystems

Forested systems help to regulate climate and sequester carbon and they also play a major role in adaptation efforts by reducing the impacts of urban heat, enhancing migration corridors, moderating flooding, protecting drinking water supplies and reducing nutrient and sediment runoff. Forests contribute an estimated $2.2 billion to Maryland's economy and $24 billion in ecological services.[45] The condition of these ecosystems and the services they provide will be affected by climate change. Climate

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[39] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015
[40] Maryland State Archives, Maryland at a Glance: Agriculture, July 14, 2015, available at: http://msa.maryland.gov/msa/mdmanual/01glance/html/agri.html.
[41] Maryland State Archives, Maryland at a Glance: Agriculture, July 14, 2015, available at: http://msa.maryland.gov/msa/mdmanual/01glance/html/agri.html.
[42] Rhodium Group, American Climate Prospectus: Economic Risks in the United States, June 24, 2014, Maryland Table available at: http://rhg.com/reports/climate-prospectus.
[43] Maryland State Archives, Maryland at a Glance: Agriculture, July 14, 2015, available at: http://msa.maryland.gov/msa/mdmanual/01glance/html/agri.html.
[44] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015
[45] MDE 2015 GGRA Update, Page 29.

change will alter distributions of species and habitats and exacerbate existing stressors at a rate and degree that cannot be fully predicted. Native species populations are likely to decline or migrate from the State while new species are likely to migrate in due to habitat shifts. Services provided by forests such as temperature regulation, water filtration, aesthetic value and habitat can be altered and existing stressors can be exacerbated by climate change.

Bay and Aquatic Ecosystems

The Chesapeake Bay is the largest estuary in the United States, fed by a watershed that stretches from mountains to sea across 64,000 square miles (166,000 square kilometers), spanning six states - Maryland, Delaware, Virginia, West Virginia, Pennsylvania, and New York - and the District of Columbia. Currently, revenues provided by the Bay and its watershed are estimated to be approximately $1 trillion annually.[46] However, human development and pollution have degraded the natural resilience of the ecosystems of the Bay and its watershed, leaving them more vulnerable to extreme events. Climate change will likely exacerbate this problem, creating a greater threat to these ecosystems. The Bay has already warmed by 3 degrees Fahrenheit and additional temperature increases could change the composition of commercial fisheries and increase anoxia, the absence of oxygen needed for aquatic life to survive, in the Bay.

Public Health – Likely Costs of Inaction

Adaptation and mitigation efforts combined could contribute to cleaner, more resilient communities, resulting in health benefits to individuals, costs savings to the health care sector and lower costs for insurers. Moreover, the cost savings associated with avoided health effects in Maryland are likely to be of substantial economic benefit to the state and should be a priority focus of analysis.

Air pollution

Unmitigated GHG emissions will likely increase the harmful health consequences of air pollution. According to the EPA, ozone – a leading air pollutant – is formed as the result of emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors and chemical solvents.[47] Breathing ozone can trigger a variety of health problems, particularly for children, the elderly and people of all ages who have lung diseases such as asthma.[48]

Concentrations of ozone and particulate matter (solid or liquid particles found in the air) are projected to increase in densely populated regions, including the state of Maryland,

[46] MDE 2015 GGRA Update, Page 30.
[47] http://www3.epa.gov/ozonepollution/
[48] http://www3.epa.gov/ozonepollution/

if GHG concentrations grow and temperatures increase. Ground level or "bad" ozone is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. NOx and VOCs are produced primarily as a result of the combustion of fossil fuels. GHG mitigation thus carries the significant health co-benefit of also limiting increased risks from ozone and other air pollutants.[49] The promotion of renewable energy generation can reduce the harmful and costly health impacts of localized air pollution at the same time that it reduces GHG emissions.

Due to the efforts of government, businesses, environmental advocates, scientists, health professionals and many others, Maryland and surrounding states have seen dramatic improvements in air quality. Maryland has also made significant progress in reducing ozone and particulate matter air pollution. Maryland has been meeting the federal standard for fine particulate pollution since 2008 and is meeting a more rigorous standard that was finalized in 2012.

This year, for the first time in more than three decades, the EPA found that the metropolitan Baltimore area is meeting the health-based federal standard for ground-level ozone. Yet if emissions continue to grow, by 2100, the U.S. average eight-hour maximum ozone concentration during the summer months is projected to increase by 4.7 parts per billion, which would exceed the 2012 standard of 70 parts per billion.[50] To meet the EPA's new ozone standard, specifically designed to protect health, Maryland will have to continue to reduce its criteria pollutants. Reducing GHG emissions will be an important part of this process.

Heat

The average number of days for which Maryland is likely to exceed temperatures of 90 degrees or higher is expected to rise considerably, markedly exacerbating heat-related illnesses and mortality, particularly among the elderly. Pollution, excessively warm temperatures and other environmental factors such as extreme precipitation have been shown to increase the risk of a number of infectious diseases.[51]

In a 2013 Morbidity and Mortality review, the U.S. Centers for Disease Control and Prevention assessed the 12 heat-related deaths in Maryland resulting from the heat wave of June 30 to July 13, 2012.[52] Heat-related deaths were reported most frequently among males and those living alone. In 2012, to forecast heat-related mortality over the 21st century, an independent review of the scientific literature found that the likely death toll in 40 cities over the coming century.[53] That forecast for Baltimore, the only

[49] http://www.stateoftheair.org/2015/assets/ALA_State_of_the_Air_2015.pdf
[50] http://www3.epa.gov/ozonepollution/
[51] Jang C, Shaw KS, Upperman CR, Blythe D, Mitchell C, Murtugudde R, Sapkota AR, Sapkota A. Climate change, extreme events and increased risk of salmonellosis in Maryland, USA: Evidence for coastal vulnerability. Environ Int. 2015 Oct;83:58-62. doi: 10.1016/j.envint.2015.06.006. Epub 2015 Jun 18.
[52] http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6222a1.htm
[53] http://www.nrdc.org/globalwarming/killer-heat/files/killer-summer-heat-report.pdf

Maryland city included, was for an increase of eight excessive heat days on average per summer to 45 such days by mid-century, resulting in 27 additional deaths per summer.[54]

Additionally, heat waves cause greater burdens for vulnerable groups such as the elderly and the low income, even when life is not threatened. An independent 2014 report cited a ruling by the federal court ruling that New York City had violated the Americans with Disabilities Act by not making provisions for disabled and elderly people stranded in high rises during the power outage of Superstorm Sandy. [55] The long-term health consequences of such weather disasters have been documented in a series of papers examining health status in New Orleans, post-Hurricane Katrina, including increased costs to Medicaid and increases in chronic disease and disability.[56] The projected increase in extreme heat poses an immediate and urgent health threat.

By continuing and strengthening its climate change mitigation and adaptation actions, the state of Maryland will be able to better protect public health and avoid many of the health-related costs attributable to global warming.

Environmental and Energy Equity

The negative effects of climate change on infrastructure, tourism, agriculture and public health are a common focus of most studies on this subject. Discussed less often is the disproportionate impact of climate change on low-income households.

The 2015 law codifying the MCCC states that one of the priorities of the Commission's working groups should be "addressing any disproportionate impacts of climate change on low-income and vulnerable communities."[57] In fact, a growing body of literature shows that low-income communities are more likely to be severely affected by the flooding and extreme weather brought about by climate change.

One such paper entitled *Climate change and poverty: vulnerability, impacts, and alleviation strategies* states, "Poorer individuals are expected to have a greater propensity to be harmed by climate change for a variety of reasons[58]: they have fewer assets to help them recover from climate shocks and stresses such as droughts, hurricanes and floods; their livelihoods are more likely to depend on climate sensitive sectors (e.g., agriculture, forestry, fishing, pastoralism) or on low-income, informal or

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[54] http://www.nrdc.org/globalwarming/killer-heat/files/killer-summer-heat-report.pdf
[55] Abell Foundation, **Clean Energy for Resilient Communities:** Expanding Solar Generation In Baltimore's Low---Income Neighborhoods, February 2014, is available at: http://www.abell.org/reports/clean-energy-resilient-communities
[56] Elisaveta Petkova, Kristie Ebi, Derrin Culp, Irwin Redlener. **Climate Change and Health on the U.S. Gulf Coast: Public Health Adaptation is Needed to Address Future Risks**. *International Journal of Environmental Research and Public Health*, August 2015, available at: http://www.sciencedaily.com/releases/2015/08/150814145704.htm
[57] Maryland General Assembly 2015 HB 514, available at: http://mgaleg.maryland.gov/webmga/frmMain.aspx?pid=billpage&tab=subject3&id=hb0514&stab=01&ys=2015RS
[58] *WIREs Clim Change* 2014, 5:539–556. doi: 10.1002/wcc.287

hourly jobs with little protection against climate-related employment disruptions; they are more likely to live in areas with higher exposure to climate extremes and less likely to be insured against such events; they have less access to knowledge and information about adaptation; and, they have fewer alternative livelihood options."[59] [60]

According to a number of recent studies, low-income families may also be disproportionately affected by air pollution.[61] Despite strong regulations on power plants and other sectors, low-income communities are often affected by multiple sectors polluting their areas of residence.[62] What's more, many of these communities lack adequate health services.[63]

A recent study found that increased action to reduce air pollution would have near immediate, positive effects on this population.[64] The study evaluated how improvements in fine particulate pollution in metropolitan areas correlated with life expectancy and found that reducing this type of pollution resulted in "significant and measurable improvements in life expectancy."[65] As mentioned earlier, GHG mitigation carries the significant health co-benefit of also mitigating ozone and other air pollutants and therefore part of the priority state actions under the MCCC.[66]

Energy

Low-income households also spend a higher percentage of their income on energy than do moderate- and high-income households and are thus more sensitive to increases in the cost of energy."[67] A 2011 national survey found that more than one-third of energy-insecure households across the country had to forgo medical and dental care and purchasing medicines to cover the cost of heating or cooling their homes.[68] Almost one in five became ill because their homes were too cold. Moreover, 6 percent of energy assistance recipients were evicted from rental units and 4 percent faced foreclosure, exacerbating homelessness and increasing costs to society.[69]

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[59] *WIREs Clim Change* 2014, 5:539–556. doi: 10.1002/wcc.287
[60] Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Cambridge: Cambridge University Press; 2007, 976.
[61] Maryland Environmental Health Network. Energy & Health in Maryland: A Briefing for Health Advocates. 2015. https://mdehndotorg.files.wordpress.com/2014/12/mdehn_energyhealth_md.pdf
[62] Maryland Environmental Health Network. Energy & Health in Maryland: A Briefing for Health Advocates. 2015. https://mdehndotorg.files.wordpress.com/2014/12/mdehn_energyhealth_md.pdf
[63] Maryland Environmental Health Network. Energy & Health in Maryland: A Briefing for Health Advocates. 2015. https://mdehndotorg.files.wordpress.com/2014/12/mdehn_energyhealth_md.pdf
[64] Pope, C. A., M. Ezzati, and D. W. Dockery. "Fine-Particulate Air Pollution and Life Expectancy in the United States." New England Journal of Medicine 360.4 (2009): 376-86
[65] Pope, C. A., M. Ezzati, and D. W. Dockery. "Fine-Particulate Air Pollution and Life Expectancy in the United States." New England Journal of Medicine 360.4 (2009): 376-86
[66] Institute for Energy and Environmental Research, Energy Justice in Maryland's Residential and Renewable Energy Sectors, September 2015.
[67] Institute for Energy and Environmental Research, Energy Justice in Maryland's Residential and Renewable Energy Sectors, September 2015.
[68] 2011 national survey at http://neada.org/wp-content/ uploads/2013/05/NEA_ Survey_Nov11.pdf
[69] 2011 national survey at http://neada.org/wp-content/ uploads/2013/05/NEA_ Survey_Nov11.pdf

An average-income Maryland family spends 3 to 4 percent of its income on electricity and heating.[70] This is defined as its "energy burden." For low-income households, that energy burden can be anywhere from 10 to 20 percent or more, which means that many low-income households in Maryland are unable to cover basic needs and regularly face choices between paying for energy, health, food and housing.[71] These elevated energy burdens are due in part to the energy inefficiency of low-income housing, including older appliances, poor insulation and over-reliance on space heaters. As a result, low-income households, on average, use 50 percent more energy per square foot than the average household.[72] The elderly and those more susceptible to illness may also need to keep their homes warmer in the winter in order to not fall ill.

High-energy burdens have thus far been abated in Maryland through assistance with paying electricity and heating bills, although some state and federal funds are also devoted to improving efficiency in low- and moderate-income households. About one-third of eligible Maryland households get aid, which materially reduces their energy burdens. Even so, energy burdens often remain unaffordable at as little as 7 percent of income. Assistance funds are limited, household income has stagnated and needs have increased. Following the current path is not sufficient to ensure energy equity.[73]

As the MCCC and the state of Maryland consider strengthened climate change mitigation and adaptation actions in the coming years, it will be important to consider environmental and energy inequity – for the sake of the state's economic future as well as for the health and well-being of its lower income residents. Strategically targeted climate mitigation and adaptation actions could reap deeper and broader benefits for low-income communities and thus for the state as a whole.

2016 and Beyond

With more than 3,000 miles of coastline and a healthy economy, Maryland has a lot to lose from unmitigated climate change. Furthermore, climate mitigation and adaptation efforts in Maryland result in local economic, environmental and public health co-benefits.

With what we have at stake as a state, what we have to offer in the way of solutions and what we have to gain in the form of mitigation- and adaptation-related jobs and economic development, we cannot afford to wait to take responsibility for our future.

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[70] Institute for Energy and Environmental Research, Energy Justice in Maryland's Residential and Renewable Energy Sectors, September 2015.
[71] Institute for Energy and Environmental Research, Energy Justice in Maryland's Residential and Renewable Energy Sectors, September 2015.
[72] Institute for Energy and Environmental Research, Energy Justice in Maryland's Residential and Renewable Energy Sectors, September 2015.
[73] Institute for Energy and Environmental Research, Energy Justice in Maryland's Residential and Renewable Energy Sectors, September 2015.

Maryland needs to continue to work together at all levels of government to avoid the worst-case scenarios of climate disruption. To alleviate these risks and to better protect and sustain Maryland's economic prosperity, the MCCC will continue to work with all societal sectors and stakeholders in the state to address the causes and consequences of climate change. In 2016 and beyond, the MCCC will work to improve Marylanders' understanding of the costs associated with climate change, and the costs and benefits of those mitigation and adaptation actions that are likely to be most effective in ensuring our collective health and prosperity. A more detailed work plan for 2016 is included in Chapter 6.

Chapter 4 – Maryland's Greenhouse Gas Emissions Reduction Act (GGRA) and the 2015 GGRA Plan Update

Overview

The 2009 GGRA law required MDE to submit a report by October 1, 2015 to the Governor and General Assembly on the state's progress toward achieving a 25 percent reduction in Maryland's GHG emissions by 2020. It also required MDE to provide an update on emerging GHG emissions reduction technologies; a review of contemporary climate science; recommendations on the need for science-based adjustments; an update on the status of federal GHG emissions reduction programs; and an analysis of the overall economic, environmental and public health costs and benefits of the GGRA. MDE's *2015 GGRA Plan Update* provides updated information on the state's climate-related programs and initiatives, including its adaptation and resilience efforts and concludes that the GGRA's overall impact is positive and that Maryland is on track to not only meet, but to exceed the state's GHG emissions reduction goal of 25 percent by 2020. This chapter summarizes MDE's *2015 GGRA Plan Update*.

GHG Emissions Reductions

In the *2015 GGRA Plan Update*, MDE reports that the state continues "to implement the GGRA and look for opportunities to enhance emissions reductions and economic and job creation benefits through additional legislative, budgetary or regulatory action."[74] MDE's report summarizes all current and planned GGRA programs and policies and assigns projected 2020 GHG emissions reduction targets to select programs and program sectors.

As anticipated in MDE's *2012 GGRA Plan*, the state's energy sector programs are projected to achieve the largest GHG emissions reductions, estimated at 15.1 MMt CO2e (million metric tons of carbon dioxide equivalent), followed by Maryland's transportation sector at 10.72 MMtCO2e. Of all of the state's programs, EmPOWER Maryland is now projected to contribute the greatest level of emissions reductions by 2020: 7.24 MMtCO2e from Maryland's 2006 baseline. EmPOWER Maryland and eight other programs and strategies – Maryland Renewable Portfolio Standard (RPS), Regional Greenhouse Gas Initiative (RGGI) transportation technologies, public transportation, transportation pricing, forestry, building codes and standards and waste management – are projected to achieve more than 100 percent of the state's GGRA-related reductions by 2020.

MDE noted in its report that the reduction programs outlined in the *2015 GGRA Plan Update* have worked well, but changes in the energy market and travel behavior are also helping Maryland achieve the GGRA's emissions reduction goal. MDE also noted

[74] 2015 GGRA Plan Update, Page 4

that additional efforts will be needed to continue progress "because scientific consensus is that worldwide GHG reductions as high as 72 percent by 2050, or earlier,"[75] will be needed to minimize the impacts of climate change.

Economic Impacts

Updated analysis by the Regional Economic Studies Institute at Towson University (RESI) projects that the *2012 GGRA Plan* will result in estimated economic benefits of between $2.5 billion and $3.5 billion by 2020 and help create and maintain between 26,000 and 33,000 new jobs.

To reach that estimate, RESI reviewed data from state agencies on benefits, cost and economic output. In addition, RESI was able to review and analyze detailed data from state agencies regarding funding of programs, spending and program implementation details. In the *2015 GGRA Plan Update,* RESI lists the jobs, output, total cost and net benefit for each of the programs.

Adaptation and Preparedness

The Chesapeake Bay region's geography and geology make Maryland one of the three most vulnerable areas of the country to changes resulting from sea level rise – only Louisiana and Southern Florida are more susceptible. Historic tide records show sea level has increased approximately one foot in the Chesapeake Bay over the last 100 years. Estimates provided by the STWG indicate that Maryland is projected to experience between 2.1 to 5.7 feet of sea level rise by the end of this century.[76]

Between 2008 and 2015, the state as a whole made substantial progress to implement high-priority elements of Maryland's Phase I and II Adaptation Strategies. Chapter 8 of the *2012 GGRA Plan,* the Adaptation Update, provided detailed information on state agency implementation efforts to date, along with short-, medium- and long-term priorities for future action.[77]

It is also important to note that even as the state moves forward with actions that will reduce GHGs and ultimately result in increased energy efficiency, a more sustainable economy and cleaner air, negative climate change impacts will continue to be felt well into Maryland's future. Therefore, robust adaptation and preparedness efforts together with mitigation will be necessary to adequately address the impacts of climate change. Mitigation and adaptation efforts must go hand in hand to reduce the state's risk to climate impacts.

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[75] 2015 MDE GGRA Update, Page 3
[76] http://www.umces.edu/sites/default/files/pdfs/SeaLevelRiseProjections.pdf
[77] Adaptation update available at: http://www.mde.state.md.us/programs/Air/ClimateChange/Documents/2011%20Draft%20Plan/2011GGRADRAFTPlan.pdf

Climate Science

MDE's *2015 GGRA Plan Update* includes an extensive report from the STWG in Appendix L of its update; it is also updated and included as this report's Appendix 1 and notes that scientific research has validated the reality of climate change and its causes.

In addition, the report describes the impacts that Maryland can expect from the changing climate. Some of those impacts are described below:

- Maryland will be significantly impacted by changes to the global climate. With thousands of miles of shoreline and a vast and vital resource in the Chesapeake Bay, any increases in temperature will have large impacts that reshape our state.
- The extent of warming for Maryland will differ from any global averages; in fact, because of our relatively high latitude (High latitudes are characterized by strong variation in day-length during different seasons of the year), it is very likely to be greater.
- Impacts include changes to temperatures, heat waves, Chesapeake Bay temperatures, precipitation, soils moisture and agriculture, water supply and quality and coastal vulnerability.

A full assessment of the impacts to Maryland from climate change can be found in the 2008 Climate Action Plan developed by Maryland at: http://www.mde.state.md.us/programs/Air/ClimateChange/Pages/Air/climatechange/legislation/index.aspx.

Emerging Technologies

MDE's *2015 GGRA Plan Update* addresses emerging technologies to reduce GHG emissions, both in the text and in Appendix E of the report. Promising emerging technologies discussed in that update include energy storage, smart grid technology, electric vehicles, water-energy nexus, carbon dioxide reduction technology, bio-energy with carbon capture and storage, biochar, green cement, algae systems, fuel cell vehicles and geoengineering.

Status of Federal Efforts

The GGRA required that MDE report on federal programs designed to reduce GHG emissions. MDE has included a number of key EPA-managed programs in the *2015 GGRA Plan Update*. Federal agency programs that contribute to GHG emissions reductions other than the EPA's programs are not included in MDE's *2015 GGRA Plan Update*.

Programs listed in the report include:

- **The Clean Air Act 111 (Clean Power Plan)** – This act addresses both new and existing power plants under separate regulations and provides direction for

setting standards for stationary sources from a specific source sector such as power plants. This act also gives EPA the ability to establish guidelines for states to set standards for existing sources. States then formulate emission limits following the guidance.

- **Final GHG Tailoring Rule** – As part of a 2010 rule that sets thresholds for what permits are needed for which new and existing facilities, this final rule "tailors" the requirements of these Clean Air Act permitting programs to limit covered facilities to the nation's largest GHG emitters: power plants, refineries and cement production facilities.
- **Standards to Cut Greenhouse Gas Emissions and Fuel Use for New Motor Vehicles** – EPA and the National Highway Traffic Safety Administration are working together to enable the production of a new generation of clean vehicles with reduced GHG emissions and improved fuel use. Together, the enacted and proposed standards are expected to save more than six billion barrels of oil through 2025 and reduce more than 3,100 million metric tons of carbon dioxide emissions.
- **Renewable Fuel Standard (RFS) Program** – As part of this program, the EPA develops and implements regulations to ensure that transportation fuel sold in the U.S. contains a minimum volume of renewable fuel. By 2022, the RFS program will reduce GHG emissions by an amount roughly equal to annual emissions of 27 million passenger vehicles, 7 percent of expected annual diesel consumption and decreasing oil imports by $41.5 billion.[78]
- **Heavy-Duty Trucks** – This program creates a standard for medium- and heavy-trucks that will build on technology-advancing standards through model year 2027. The first phase of this program is expected to result in saving 530 million barrels of oil and avoiding the emissions of 270 million metric tons of GHG emission, while also producing $50 billion in fuel savings and $49 billion in societal benefits.
- **GHG Reporting** – This program collects data from large emission sources across a range of industry sectors, as well as from suppliers of products that would emit GHGs if released or combusted. The data is available here: http://www.epa.gov/ghgreporting/ghgdata/reportingdatasets.html

Improved Air Quality and Public Health

By using the EPA's Benefits Mapping and Analysis Program, MDE determined that the successful implementation of Maryland's *2012 GGRA Plan* would likely result in "reduced incidences of respiratory ailment, asthma attack, heart attack, hospital room visits and lost work and school days."[79] MDE also determined that deaths related to poor air quality in Maryland would likely drop. Overall, MDE estimated that improved air quality (through reduced ozone and particulate matter) would lead to a decrease of between 43 and 100 deaths annually, with that figure climbing to as many as 192 per

[78] MDE 2015 GGRA Update, Page 198
[79] MDE 2015 GGRA Update, Page 203

year if the GGRA Plan recommendations are fully implemented.

Moreover, when considering avoided deaths in economic terms, MDE found that Maryland's economy could see benefits ranging between $420 million to $850 million per year under the GGRA Plan's ongoing programs and between $810 million to $1.6 billion per year under the GGRA Plan's strengthened programs in 2020. This economic benefit is due to decreased health care costs, lost income and decreased productivity, which is the result of decreased air pollution.

Manufacturing

MDE also tasked RESI with completing an impact analysis of the policies from the *2012 GGRA Plan* on Maryland's manufacturing industry as mandated by the 2009 law. In addition to analyzing economic impacts, RESI communicated directly with regional manufacturers for feedback. RESI and MDE representatives met with manufacturers in the region to review their approaches to reducing GHG emissions and to assess challenges they face in implementing these measures. RESI also analyzed historical manufacturing trends in Maryland.

RESI found that weekly manufacturing wages increased from 2002 to 2012 by nearly $400. In addition, manufacturers are working in partnership with state-based groups such as the Regional Manufacturing Institute and state agencies such as Maryland Public Service Commission and Maryland Energy Administration on funding opportunities to meet energy efficiency goals.

RESI's analysis found that implementing strategies to fulfill the GGRA will continue to create demand for jobs in higher-skilled sectors, such as computer and electronic product manufacturing and electrical equipment and appliance manufacturing.

The *2015 GGRA Plan Update* concluded: "despite all the change in Maryland's Manufacturing industry, there is no conclusive evidence that any closures or relocations outside Maryland are directly attributable to the GGRA or climate change planning."[80] Based on the analysis provided within its report, RESI discovered no discernible impacts on the manufacturing sector as a result of the GGRA programs.

Finally, MDE's report observed that "implementing the *2015 GGRA Plan Update* will lead to increased investments in energy efficiency, green buildings, renewable energy and low emission vehicles. Investing in Maryland's economy now will encourage smarter investments and support more sustainable economic growth for generations to come."[81]

[80] MDE 2015 GGRA Update, Page 196.
[81] MDE 2015 GGRA Update, Page 4.

Chapter 5 - MCCC Report and Recommendations on Maryland's Climate Action Efforts

The MCCC is pleased that Maryland is on track to meet the GGRA's goal of reducing the state's GHG emissions 25 percent by 2020. In addition, the state and the MCCC's working groups should address several related issues.

Key developments – the increased reliance on natural gas and an overall reduction in driving – have helped the state reduce emissions. The MCCC has tasked the MWG with tracking these trends and identifying strategies to maintain these positive developments. These strategies are included in Chapter 6 under the MCCC's 2016 Work Plan priorities.

The MCCC also notes there is ongoing investigation and controversy about the extent to which methane leakage contributes to GHG emissions. The MCCC has charged the MWG and STWG to begin exploring the emerging science on fugitive methane gas, identifying best management practices for leakage avoidance and mitigation and employing the best available science to determine whether or not and how to incorporate out-of-state methane leakage into Maryland's GHG emissions inventories and projections.

While the programs in the GGRA and market-driven changes in the energy and transportation sectors are helping to power progress towards meeting the 2020 goal, the MCCC believes that there are practical amplifications that can be made to a number of programs in the *2012 GGRA Plan*. The MCCC recommends that the state and the MWG continue to analyze the initiatives listed in Chapter 6 to identify strategies that will further reduce GHG emissions while having a clear positive impact on the state's economy and on job creation.

Several of the enhancements to existing programs that were proposed as part of the *2012 GGRA Plan* (e.g. EmPOWER Maryland, Maryland RPS, Transportation Technologies and Zero Waste) have not yet been fully achieved.

While it appears that the state is on track to meet the 25 percent reduction by 2020 requirement of the GGRA without these enhancements, the MCCC believes that the challenge of reducing the state's GHG emissions will grow more difficult in the years ahead. It is therefore vitally important that we develop clear and complete understandings of the strengths, weaknesses, successes and shortcomings of the strategies and programs that the state is employing. The MCCC believes that an adaptive management approach is the best way to ensure that the state is conceiving, developing and pursuing targets in the most efficient and effective ways possible.

An adaptive management approach also requires regular information and timely feedback. Accordingly, the MCCC recommends that the Commission establish a process

for all relevant state agencies to provide regular reports on their GHG reduction and program implementation progress to the MCCC and to the governor.

The MCCC also recommends that the state explore several critical new initiatives, including targeted reduction of emissions of greenhouse gases, which could have near-term effects on limiting the rate of climate change that need to be explored as the state moves toward a post-2020 goal. The MCCC therefore has tasked the MWG with analyzing the emerging issues identified in Chapter 6 to determine the potential impacts of the new initiatives.

GGRA's Renewal and Beyond

The MCCC endorses MDE's recommendation that the General Assembly continue to implement the GGRA Plan to achieve the goals of the GGRA: a 25 percent reduction in GHG emissions by 2020 that also supports economic development and job creation.

The MCCC acknowledges MDE's recommendation that Maryland continue to move forward and explicitly recommends 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, studies of those exemptions, reassessment provisions and other relevant language contained in the 2009 Act. Except for the 2030 date, the MCCC recommends that the other deadlines for reassessment provisions and reports be adjusted to provide a comparable amount of time after enactment as provided in the 2009 Act.

The MCCC believes that this 40 percent by 2030 goal must continue to have a net positive impact on both the economy and job creation in Maryland and should emphasize technology innovation, economic development, jobs and consumer protection, as well as public health and well-being. The MCCC endorses MDE's recommendation to incorporate beneficial economic impacts into the 2030 climate action objectives, and believes that Maryland's 2030 climate action goals and plans should be broadened to include the following additional items:

- The degree to which climate action strategies, policies and programs produce economic benefits that are equitably distributed across Maryland's population;
- The degree to which climate action strategies, policies and programs produce economic benefits that are sustainable;
- The degree to which climate change strategies, policies and programs effectively address the economic dislocations that they may cause;
- The degree to which climate action strategies, policies and programs produce public health benefits;
- The degree to which climate action strategies, policies and programs reduce energy burdens in low-income households; and
- The degree to which climate action strategies, policies and programs improve resilience in vulnerable communities.

Chapter 6 - 2016 MCCC Priorities & Work Plan

Based on the recommendations and observations in Chapter 4, the MCCC will instruct its working groups to prepare work plans for 2016 that are designed to analyze and address at least the following MCCC priorities:

1) **Reporting**. Ensuring that the state of Maryland is adopting the best and most comprehensive practices for measuring, tracking and reporting regularly on the progress that Maryland is making to address the causes, impacts and economics of climate change.
2) **Methane leakage**. Analyzing and generating recommendations to determine whether and how to incorporate out-of-state methane leakage into the state's GHG emissions inventories and projections, employing the best available science and analysis.
3) **Additional strategies**. Identifying additional climate strategies, goals, policies and programs that would put Maryland on a path of leadership towards GHG emissions reductions by 2050, informed by science and international agreements and that would:
    - Have the potential for significant near-term reductions in GHG emissions ("fast-acting climate changers");
    - Produce economic, environmental and public health benefits that are equitably distributed across Maryland's population (including addressing the economic dislocations that they may generate); and
    - Effectively address the impacts climate change will have on the state's most vulnerable populations and communities.

    In particular, the MCCC's 2016 priorities include an analysis of possible additional climate strategies, goals, policies and/or programs in renewable energy, energy efficiency and conservation and zero-emission vehicles and transportation.

    In addition, the MCCC would like to better understand how the public health co-benefits of climate action translate into economic growth and how that is reflected through net economic benefits, job creation and annual wages paid to workers.

4) **Building Resilience.** To advance Maryland's ability to address known threats and future vulnerabilities to climate change, adaptation and response efforts will work to increase and broaden public and private partnerships; address the challenge that low-income and otherwise vulnerable communities will likely be disproportionally impacted by climate change; assess the impacts that climate change will likely have on the state's economy, revenues and investment decisions; and continue to deliver and refine tools and assistance for local governments.

The MCCC will ask that its working groups develop these work plans by December 31, 2015.

Appendix 1
Reducing Emissions of Greenhouse Gases beyond 2020

Scientific and Technical Working Group
Maryland Commission on Climate Change

September 29, 2015

Introduction

Science has demonstrated with a high degree of certainty that Earth's climate is being changed by human activities, particularly the emission of heat-trapping gases, generally called greenhouse gases, including carbon dioxide, methane, and nitrous oxide. Science has also provided a reliable description of (1) how further emissions will warm the Earth, (2) how this will alter the climate and have consequences for human society and the natural systems on which it depends, and (3) the amount and timing of reductions in emissions needed to limit climate change in order to avoid its most harmful consequences.

Maryland's **Greenhouse Gas Reductions Act of 2009** requires the State to reduce Statewide greenhouse gas emissions by 25% from 2006 levels by 2020. The Act further directs the Maryland Department of the Environment to report on "the greenhouse gas emissions reductions needed by 2050 in order to avoid dangerous anthropogenic changes to the Earth's climate system, based on the predominant view of the scientific community" on or before 2020.

The **Maryland Climate Change Commission**, established by Executive Order in 2007, was responsible for laying the groundwork for the Greenhouse Gas Reduction Act by developing a Climate Action Plan in 2008. In its 2015 Session the, Maryland General Assembly established the Maryland Climate Change Commission in statute. House Bill 514 was signed into law by Governor Hogan and became effective on June 1, 2015. Among the actions the Commission is charged to undertake include "maintaining a comprehensive action plan, with 5-year benchmarks, to achieve science-based reductions in Maryland's greenhouse gas emissions." Toward this end the Commission's Mitigation Working Group requested advice from the **Scientific and Technical Working Group (STWG)** to inform its considerations of the greenhouse gas emissions reductions that should be pursued beyond 2020 in the preparation of the Commission's first annual report, due on November 15, 2015.

Herein the STWG provides its immediate appraisal of the scientific basis for setting targets for emissions reductions beyond 2020. This appraisal is founded largely on the Fifth Assessment of the **Intergovernmental Panel on Climate Change (IPCC)** that was completed in 2014, over five years after the enactment of Maryland's Greenhouse Gas Reductions Act. This reliance is appropriate because the IPCC

assessment was both comprehensive (integrating global and regional climate and emission trends, credible evaluation of likely future impacts, and state-of-the-art projections of climate change as a function of global greenhouse gas emissions) and subjected to extensive internal and external review. The IPCC Fifth Assessment is the most through and recent scientific appraisal available of greenhouse gas emissions reduction pathways and is accepted and relied on by nations around the world as the framework for both national planning and international negotiations.

The IPCC Fifth Assessment includes an evaluation of the amount and timing of reductions in greenhouse gas emissions required globally in order to avoid increases in global average temperature and associated climate disruption that would result in dangerous risks to society and the natural systems on which it depends. It is appropriate that these scientifically determined pathways inform the determination of greenhouse gas reduction targets for Maryland. It is also understood that the Commission's recommendations will also take into account additional economic, social and political factors that go beyond the natural sciences. For example, in June 2015 the leaders of the Group of Seven industrialized nations agreed to take steps to phase out fossil fuel use by the end of this century. The national commitments the United States will make during the 2015 United Nations Climate Change Conference (so-called COP 21) to be held in Paris in November and December will be particularly consequential for Maryland's reduction pathway. These international deliberations have been and will be informed principally by the IPCC scientific assessment.

IPCC Approach

The Intergovernmental Panel on Climate Change (IPCC) is the international body for assessing the science related to climate change. It was initiated in 1988 by the World Meteorological Organization and the United Nations Environment Program to provide policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation[1], IPCC assessments are written by prominent scientists who serve as lead or contributing authors. The assessments undergo multiple rounds of drafting and peer review. The last assessment, completed in 2014, was the IPCC's fifth and had 235 authors from 58 countries and received and considered over 38,000 comments on drafts.

The IPCC Fifth Assessment presents the results of three working groups:

- Working Group I (WGI) addressed *The Physical Science Basis*, including climate observations; ancient climate archives; carbon and other biogeochemical cycles; anthropogenic and natural forces that affect the

[1] As used in climate change discussions, mitigation refers to steps taken to limit the amount of climate change rather than to offset its consequences.

retention of heat from solar radiation; evaluation of climate models; detection and attribution of climate change; and near and long-term projections of climate change and sea level change.

- Working Group II (WGII) addressed *Impacts, Adaptation and Variability*, including observed impacts; vulnerability and adaptation; future risks and opportunities for adaptation; and managing future risks and building resilience.
- Working Group III (WGIII) addressed *Mitigation of Climate Change*, including approaches to climate change mitigation; trends in stocks and flows of greenhouse gases and their drivers; mitigation pathways and measures; and mitigation policies and institutions.

The determination of appropriate pathways for reductions of greenhouse gases requires the integration of the analyses of all three IPCC working groups. This integration is brought together in separate **Climate Change 2014 Synthesis Report**. The results and graphs presented here come from the Synthesis Report.

Rationale for Limiting Global Warming to 2°C

The degree of global warming and climate disruption we will experience in the future depends on the concentration of greenhouse gases in the atmosphere. These greenhouse gases accumulate in the atmosphere over time. Once released into the atmosphere, carbon dioxide, in particular, can persist there for hundreds of years if not taken up by growing vegetation or dissolved in the ocean. Once elevated, the concentrations of these greenhouse gases decline slowly. Complex computer simulations, or models as they are called, estimate the net accumulation of greenhouse gases in the atmosphere and, based on their known heat-trapping properties, project the degree of warming over the planet. The higher the accumulated greenhouse gas concentrations, the warmer the average temperature over the surface of Earth (in the air and oceans) will become. Thus, the emissions pathway that we choose to take depends on the degree of warming we are willing to risk.

IPCC WGII assessed the likely consequences of increased global temperature and associated climate disruption in five Reasons for Concern: unique and threatened systems, extreme weather events, distribution of impacts, global aggregate impacts, and large-scale singular events (Figure 1). For each of these criteria WGII rated the global mean temperature change at which risks from climate disruption would be undetectable, moderate, high or very high. Note that Earth had already (2003-2012 average) experienced an increase in global mean temperature of about 0.8°C (1.4°F) when measured from the benchmark of pre-industrial conditions (1850-1900) and, at least for 2015, is likely to cross the 1°C threshold.

Based on the IPCC analysis, risks become moderate for some criteria and high for others as the global mean temperature increase exceeds 2°C (3.6°F). Based on the analyses in both the IPCC Fourth and Fifth Assessment, avoiding an increase of greater than 2°C has become an internationally accepted goal. Some scientists have argued that limiting the increase in global mean temperature to 1.5°C or less would be a more prudent goal and that serious irreversible impacts would occur if that level of warming were exceeded. On the other hand, an increase in global mean temperature of 3°C or more would impose high to very high risks across all of the Reasons of Concern criteria.

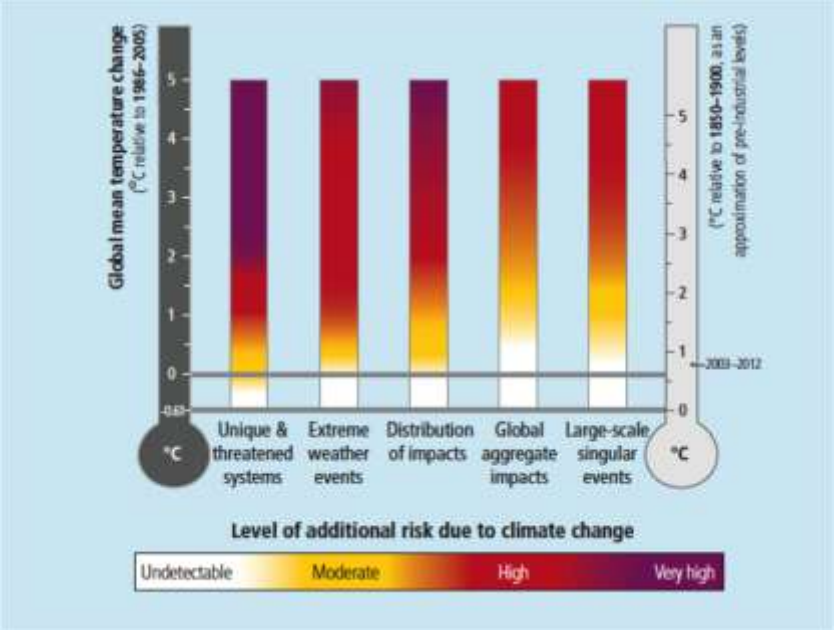

Figure 1. Risks at a global scale for increasing levels of climate change.

Determining the Required Amount and Timing of CO_2 Emission Reductions

IPCC WGI used ensembles of different computer simulations to project global average surface temperature change through the 21st century and beyond using four uniform scenarios of greenhouse gas emission pathways. These scenarios are called Representative Concentration Pathways (RCP) and range from aggressive reductions in emissions beginning around 2020 and leading to no net emissions before the end of the century (RCP2.6), to continued growth in emissions throughout the rest of the century (RCP8.5). The figure below shows the change in global average temperature (relative to 1986-2005) for these two extreme scenarios as the multi-model means (solid colored lines, with number of models on which they depend indicated) and the 5 to 95% statistical range across the distribution of individual models. In other words, there is very high confidence that the global average surface temperature change would fall within the colored bands

around the means. On the right, the means and statistical ranges for the last 20 years of the 21st century are shown for all four RCP scenarios.

It is clear that of the four RCPs only RCP 2.6 would result in a high likelihood of keeping the change in global average temperature to less than 2°C—but this is relative to the 1986-2005 average temperature, not the pre-industrial benchmark discussed earlier. Even under RCP4.5, which entails substantial reductions in emissions beginning around mid-century, the change in global average temperature would likely exceed 2°C.

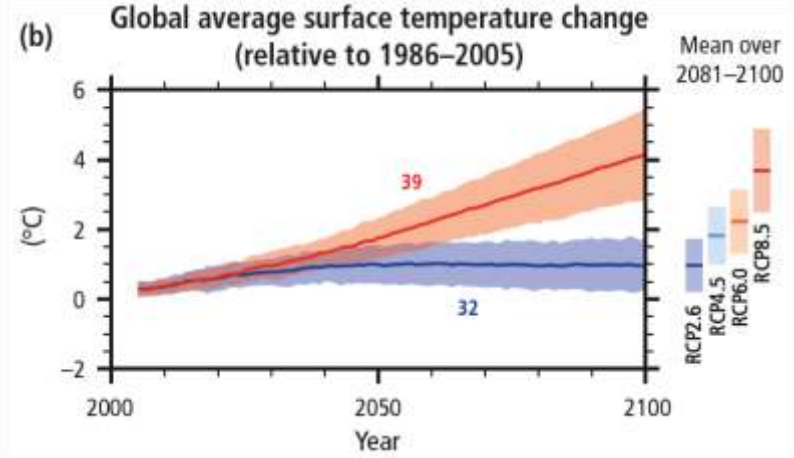

Figure 2. Global average temperature change for RCP scenarios.

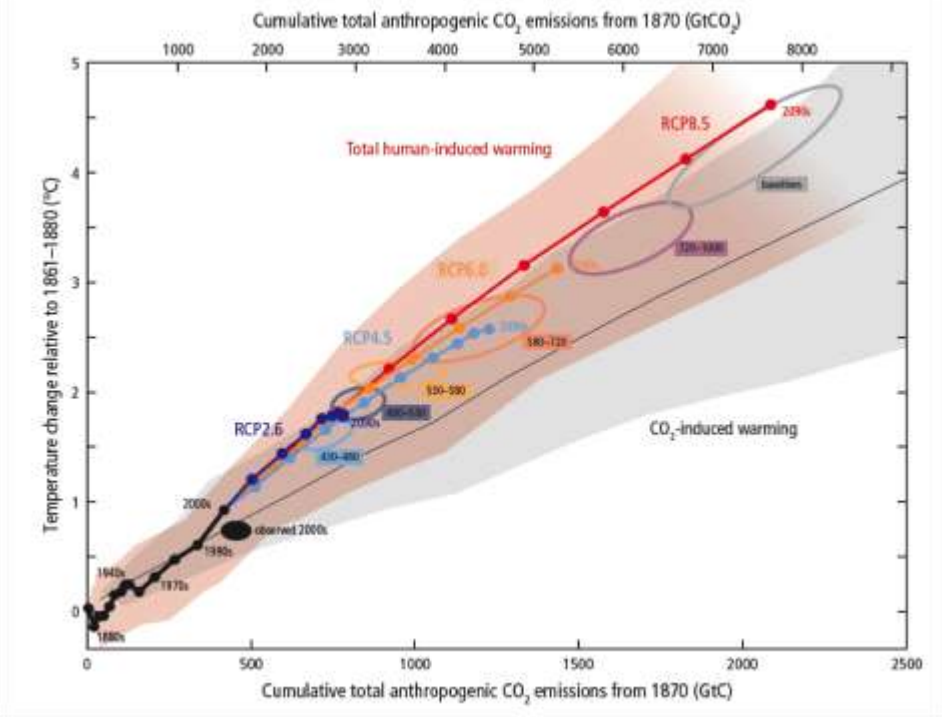

Figure 3. Global mean surface temperature increase as a function of cumulative global carbon dioxide (CO2) emissions in gigatons of CO_2 ($GtCO_2$) or carbon (GtC).

Another way that the IPCC looked at this relationship of emissions pathways to temperature change was to compare the relationship of the cumulative total CO_2

emission from human sources since 1870 to the temperature change. This is appropriate because of the large role of CO_2 in total human induced warming and the long persistence of CO_2 in the atmosphere compared to other greenhouse gases. The relationship of cumulative CO_2 emissions through the century to temperature change is shown below in Figure 3.

This approach allowed to IPCC to consider cumulative emissions in the context of a budget constrained by how much CO_2 can be emitted over time and still keep the temperature change below 2°C. The black dots and lines show the historical pathway up to the 2000s as estimated by hindcast (looking back in time) computer simulations. Future pathways for the four RCPs used by the IPCC are also shown over the rest of this century. The ellipses show the ranges in total anthropogenic warming in 2100 versus cumulative emissions from a simpler climate model, labeled with the associated concentration ranges of greenhouse gases in parts per million (ppm) of CO_2-equivalents.

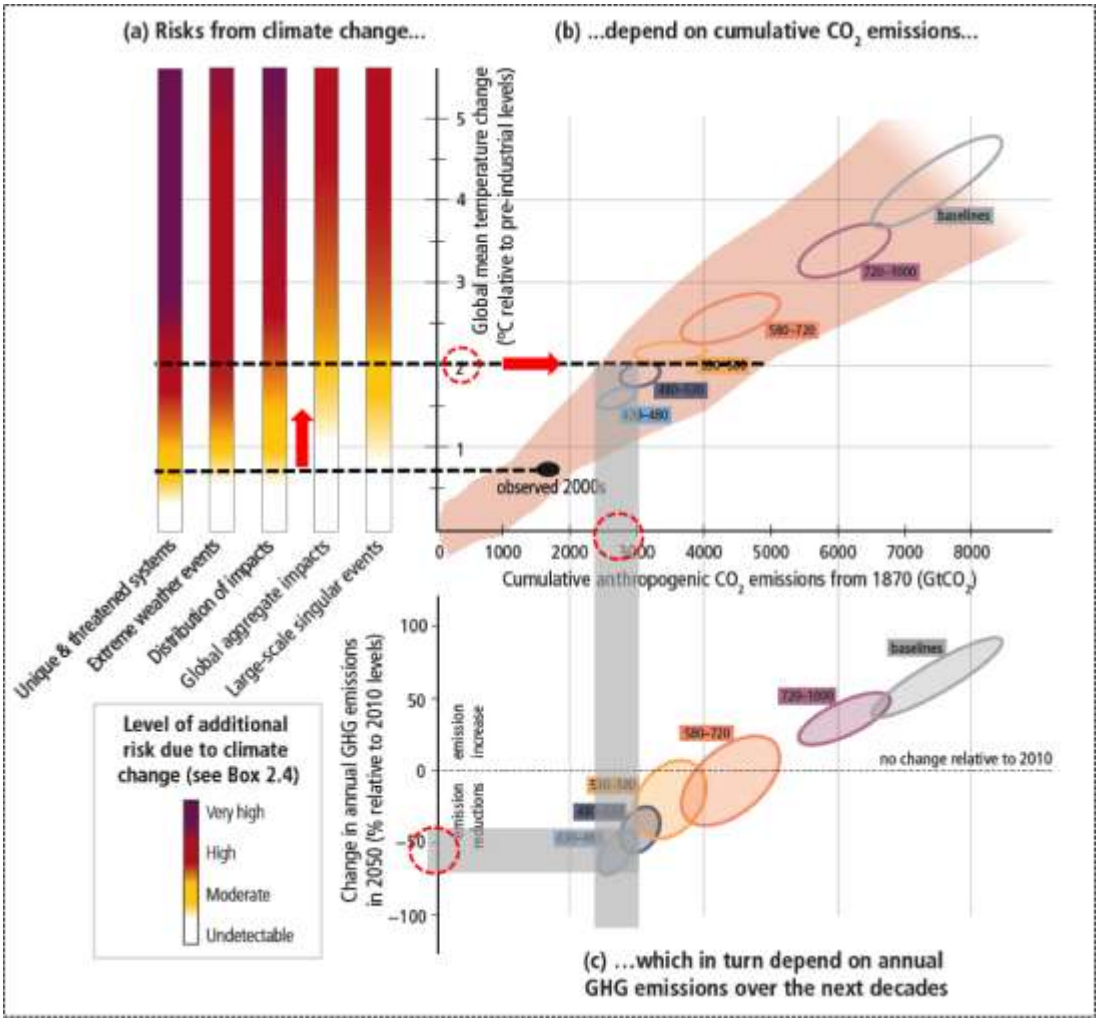

Figure 4. The relationships among risks from climate change, cumulative CO_2 emissions and changes in annual greenhouse gas emissions by 2050.

This cumulative emissions approach allowed the IPCC to determine the reductions in greenhouse gas emissions that would be required over the few next decades in order to achieve a given greenhouse gas concentration range by the end of the century. This synthesis is shown in Figure 4, which relates the risks from climate change [(a) from Figure 1] with cumulative CO_2 emissions though this century [(b) from Figure 3]. From these cumulative emissions the amount of change in greenhouse gas emissions over the next decades that are required in order to achieve these cumulative amounts is then determined (c).

So, for example, if one wanted to ensure that the global mean temperature increase line would not likely cross 2°C, this would require limiting anthropogenic greenhouse gas concentrations to about 450 (430-480) ppm CO_2-eq. Thus, in turn, this would require constraining the total cumulative CO_2 emissions through this century to less than 3000 $GtCO_2$ (a gigaton is one billion tons). This would require the emissions pathway close to that assumed under the RCP2.6 scenario. Achieving that objective would, in turn, require reducing annual greenhouse gas emissions somewhere between 41 to 72% (compared to 2010) by 2050, with the range reflective of the uncertainties included in the analyses of computer simulations.

From the extensive IPCC analyses using this approach the likelihood of staying below a specific increase in global mean temperature over the 21st century as a function of greenhouse gas emissions pathways is summarized in Table 1.

Table 1. Key characteristics of the scenarios assessed by IPCC. For all parameters the 10th and 90th percentile of the scenarios is shown.

CO_2-eq Concentrations in 2100 (ppm CO_2-eq)[1] Category label (conc. range)	Subcategories	Relative position of the RCPs[2]	Change in CO_2-eq emissions compared to 2010 (in %)[3]		Likelihood of staying below a specific temperature level over the 21st century (relative to 1850–1900)[4,5]			
			2050	2100	1.5°C	2°C	3°C	4°C
<430	Only a limited number of individual model studies have explored levels below 430 ppm CO_2-eq[1]							
450 (430 to 480)	Total range[4,5]	RCP2.6	−72 to −41	−118 to −78	More unlikely than likely	Likely	Likely	Likely
500 (480 to 530)	No overshoot of 530 ppm CO_2-eq		−57 to −42	−107 to −73	Unlikely	More likely than not		
	Overshoot of 530 ppm CO_2-eq		−55 to −25	−114 to −90		About as likely as not		
550 (530 to 580)	No overshoot of 580 ppm CO_2-eq		−47 to −19	−81 to −59		More unlikely than likely[7]		
	Overshoot of 580 ppm CO_2-eq		−16 to 7	−183 to −86				
(580 to 650)	Total range	RCP4.5	−38 to 24	−134 to −50				
(650 to 720)	Total range		−11 to 17	−54 to −21		Unlikely	More likely than not	
(720 to 1000)[8]	Total range	RCP6.0	18 to 54	−7 to 72	Unlikely[9]		More unlikely than likely	
>1000[8]	Total range	RCP8.5	52 to 95	74 to 178		Unlikely[9]	Unlikely	More unlikely than likely

Limiting the increase in global mean temperature to 1.5 °C, as some scientists suggest is necessary to avoid serious climate disruption, is unlikely under any emissions pathway that has been studied. Limiting the increase to 2°C would only

be more likely than not if greenhouse gas emissions were reduced by at least 42% by 2050, but greater reductions are required to make this confidently likely. Analyses not shown in this table further suggest that annual global greenhouse gas emissions would have to be reduced by about 25% by 2030 in order to achieve this pathway. This pathway would also require reducing net emissions to near-zero (by 78-118%) by 2100. Emissions reductions of greater than 100% implies that the rate of carbon sequestration (either by organic growth or capture and storage) would have to exceed emissions. Even to limit the increase in global mean temperature to 3°C (5.4°F) would entail reducing greenhouse gas emissions 24-38% by 2050 and near carbon neutrality by the end of the century.

Implications for Setting Maryland's Goals

It is important to understand that the IPCC's analyses are for global mean temperatures and global greenhouse gas emissions. Realized warming for Maryland will differ from the global average; in fact, because of our relatively high latitude, it is very likely to be greater. Furthermore, warming in Maryland will be controlled by global emission and not just Maryland's own emissions. Of course, Maryland contributes only a small part of annual global greenhouse gas emissions, but a disproportionately large share on a per capita basis. Because of the higher per capita emissions rates in the United States it will be reasonably expected in international negotiations that U.S. commitments should be toward the higher end if not beyond the 41 to 72% reductions required by 2050 to avoid exceeding the 2°C warming goal, based on the IPCC analysis. On the other hand, per capita emissions in Maryland (11 metric tons per year) are less than the average for the United States (17 metric tons per year), so it might be argued that emission reductions in more energy intensive states should be more aggressive than that for Maryland. These considerations go beyond what the IPCC scientific analyses tell us.

In advance of the COP 21 Conference, the United States government announced that the U.S. had taken steps to reduce GHG emissions in the range of 17% below the 2005 baseline by 2020 and pledged its intention to achieve an economy-wide target of reducing emissions by 26-28% in 2025, making best efforts to reduce emissions by 28%. The leaders of the Group of Seven nations agreed in June 2015 to limit global warming to 2°C and declared their support for 40 to 70% reductions in greenhouse gas emissions by 2050 (compared to 2010 levels). A month earlier, the states of California, Vermont, Oregon and Washington joined in a nonbinding "Under 2 MOU" with states and regions in Germany, the United Kingdom, Brazil, Germany, Mexico, Spain, Columbia and Canada that commits them to either reduce greenhouse gas emissions by 80-95% by 2050 or achieve a per-capita annual emissions target of less than 2 metric tons per year. Many other U.S. states have indicated emissions reduction goals in the 75-90% range by 2050 by statute, executive order or commission recommendations (although reductions are referenced to an earlier 1990 baseline in a number of these states). Indeed Maryland's Greenhouse Gas Emission Reduction Act of 2009 (GGRA 2009) that sets

the requirement for a 25% reduction by 2020 makes reference to preparing a plan to meet a longer-term goal of reductions up to 90% from 2006 levels.

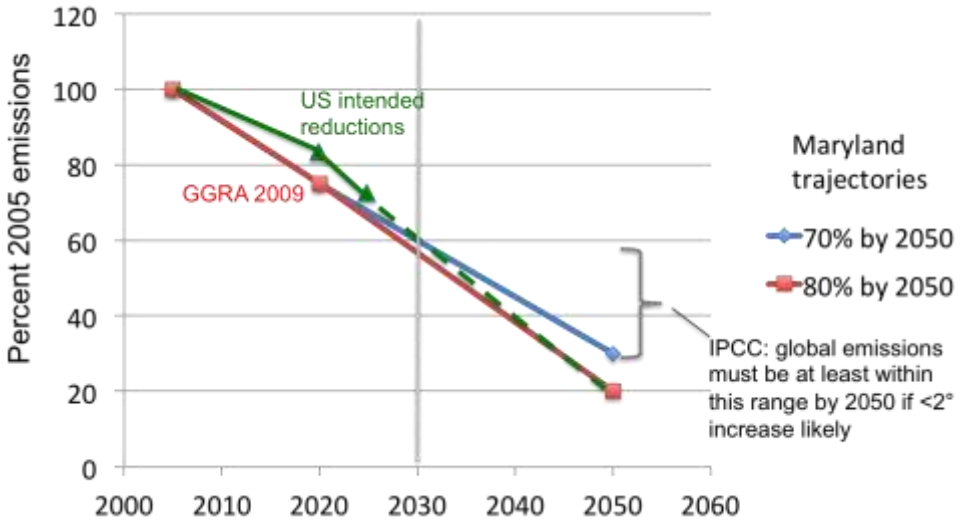

Figure 5. Simplified linear trajectories to reach 2050 emission reduction goals for Maryland and the United States as a whole.

Assuming that emissions are reduced below the 2006 baseline by 25% in 2020 as required under GGRA 2009, what then should be the next interim target for reductions if the state is to achieve a reduction of at least 70% and potentially 80% or more by 2050? To be on a steady (linear) trajectory to 70% reduction, a 40% reduction from the 2006 level would have to be achieved by 2030 (Figure 5). For a trajectory to an 80% reduction by 2050 the line crosses about 43% in 2030. For the U.S. as a whole, assuming that the effort to reduce emissions by 28% is achieved in 2025 goal is successful, would also require at least a 40% reduction by 2030 to achieve 80% by 2050. Of course, one could take the position that the trajectory could be non-linear, with greater reductions coming between 2030 and 2050, but such a postponement would increase the risks of not being able to achieve the 2050 reductions that are necessary.

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Appendix 2
Maryland Commission on Climate Change Membership

Government Appointees	
Ben Grumbles	Chief of Commission and Secretary of Environment
Nancy K. Kopp	Maryland State Treasurer
Jack R. Smith	Interim Maryland Superintendent of Schools
Joseph Bartenfelder	Secretary of Agriculture
Mark Belton	Acting Secretary Natural Resources
David Craig	Secretary of Planning
Pete Rahn	Secretary of Transportation
Adelisia "Leigh" Williams	Director, Maryland Energy Administration
Donald Boesch	University of Maryland Center for Environmental Science (UMCES)
C. Gail Bassette	Secretary of General Services
Senate President Appointed Member	
Senator Paul G. Pinsky	Senator, Maryland General Assembly
House Speaker Appointed Member	
Delegate Dana Stein	Delegate, Maryland General Assembly
Non-Profit Sector Appointees	
Stuart Clarke	Town Creek Foundation
Lori Arguelles	Alice Ferguson Foundation
Mike Tidwell	Chesapeake Climate Action Network
Lynn Heller	Abell Foundation
Chuck Fry	Maryland Farm Bureau
Brad Karbowsky	United Association of Plumbers and Fitters
Local Government Appointees	
Kelley Russell	Frederick City Alderman
Jacob Day	Maryland Municipal League
Leslie Knapp	Maryland Association of Counties
For-Profit Sector Appointees	
Sue Briggum	Vice President, Waste Management, Inc.
C. Richard D'Amato	Retired Attorney
John Quinn	Director of State Affairs, BGE
Peter Zadoretzky	Sustainability Manager, The Bozzuto Group
Michael Powell	Business Community Representative

Mitigation Working Group Membership

Co-Chairs	
George "Tad" Aburn (Working Group Lead)	MDE
Stuart Clarke	Town Creek Foundation
Michael Powell	Representing the Business Sector
For-Profit Representatives	
Anne Linder	Exelon
Mike Remsberg	Trinity Consultants
R. Daniel Wallace	Bith Energy
Melanie Santiago-Mosier	Sun Edison
Drew Cobbs	API
Tom Ballentine	NAIOP – Real Estate Development
Tom Dennison	SMECO
Tom Weissinger	Raven Power
Non-Profit Representatives	
Jana Davis	Chesapeake Bay Trust
Mike Tidwell	Chesapeake Climate Action Network
Gerrit Knaap	National Center for Smart Growth
Arjun Makhijani	Institute for Energy and Environmental Research
Joe Uehlein	Labor Network for Sustainability
Anya Schoolman	Community Power Network
Rebecca Ruggles	Maryland Environmental Health Network
Other Representatives	
Chuck Fry	Maryland Farm Bureau
Ben Hobbs	John Hopkins University - Economist
Brad Karbowsky	United Association of Plumbers and Fitters
Jim Strong	United Steelworkers
Leslie Knapp	Maryland Association of Counties
Alice Kennedy	Maryland Municipal League
Government Members	
Dorothy Morrison	MDOT
Kristen Ahearn	MEA
Matthew Fleming	DNR
Steering Committee	
Michael Powell	Representing the Business Sector
Stuart Clarke	Town Creek Foundation
George "Tad" Aburn	MDE
Dorothy Morrison	MDOT
Kristen Ahearn	MEA

Adaptation and Response Working Group Membership

Chair	
Mark Belton	DNR
Coordinator	
Catherine McCall	DNR
MCCC Liasons	
Amy Owsley	Eastern Shore Land Conservancy
C. Richard D'Amato	Retired Attorney
Non-Profit Representatives	
Fredrika Moser	Maryland Sea Grant
Eric Myers	Conservation Fund
State-Agency Adaptation Sector Leads	
Matt Fleming	DNR (Coastal Hazards)
Clifford Mitchell	DHMH (Health)
Susan Payne	MDA (Agriculture)
Bruce Michael	DNR (Bay & Aquatic)
Don Van Hassent	DNR (Forest & Terrestrial)
Jason Dubow	MDP (Growth & Infrastructure)
Meg Andrews	MDOT (Growth & Infrastructure)
Saeid Kasraei	MDE (Water Resources)

Adaptation and Response Working Group Technical Advisors

Technical Advisors	
Kate Skaggs	DNR
Megan Granato	DNR
Bhaskar Subramanian	DNR
Chris Becraft	DNR
Katherine Charbonneau	Critical Area Commission
Dave Guignet	MDE
Luke Wisniewksi	MDE
Jason Dubow	MDP
Nell Ziehl	MDP-MHT
Lisa Lowe	DoIT
Mark James	MEMA
Fiona Burns	DBM
Shawn Kiernan	MPA
Elizabeth Habic	SHA
Joy Hatchette	MIA
David Buegelmans	MEA
Mostafa Izadi	DGS

Science and Technology Working Group Membership

Chair	
Donald Boesch	UMCES
Members	
Ghassem Asrar	Joint Global Change Research Institute, Pacific Northwest Laboratories
Antonio J. Busalacchi	Earth Science Interdisciplinary Center, University of Maryland, College Park
Eric A. Davidson	Appalachian Laboratory, UMCES
Gerrit J. Knaap	National Center for Smart Growth Research and Education, University of Maryland, College Park
Cindy L. Parker	Bloomberg School of Public, Johns Hopkins University
Karl Steiner	University of Maryland, Baltimore County
David A. Vanko	Fisher School of Science, Towson University
Eric D. Wachsman	University of Maryland Energy Research Center, College Park

Education, Communications and Outreach Working Group Membership

Chair	
Lori Arguelles	Alice Ferguson Foundation
Government Members	
Mark Shaffer	MDE
Dorothy Morrison	MDOT
Devan Willemsen	MEA
Kristen Peterson	DNR
Julie Oberg	MDA
Samantha Lozano	DHCD
For-Profit Sector Representatives	
Steve Arabia	NRG
Deriece Pate Bennett	Maryland Chamber of Commerce
Louis Campion	Maryland Motor Truck Association
Michele Mitch-Peterson	Honeywell
Non-Profit Sector Representatives	
Tiffany Hartung	Maryland Climate Coalition
Mary Kay Page	Fuel Fund of Maryland
Allison Rich	Maryland Environmental Health Network
Pat Harcourt	UMCES (MADE Clear)
Kelly Trout	CCAN
Joelle Novey	Interfaith Power and Light
Noah Smock	Baltimore Toolbank
Ashley Pennington	Johns Hopkins Office of Sustainability
Kate Dowling	Parks and People
Dannielle Lipinski	Maryland League of Conservation Voters
Dan Brellis	Alliance for the Chesapeake Bay
Isaac Hametz	Mahan Rykiel Associates

Education, Communication and Outreach Working Group Technical Advisors

Technical Advisors	
George "Tad" Aburn	MDE
Coreen Weilminster	DNR
Crystal Romeo Upperman	DHMH
Wiley Hall	DHCD
John Coleman	MDP
David Costello	UMCES
Larissa Johnson	UMCES
Alex Fries	UMCES
Samantha Kappalman	The Hatcher Group