

MARYLAND COMMISSION ON CLIMATE CHANGE

A report to Governor
Larry Hogan and the Maryland
General Assembly with
recommendations for reducing
greenhouse gas emissions and
preparing for and adapting to the
impacts of climate change

*2021 Annual Report
and Building Energy
Transition Plan*

Table of Contents

<i>Message from the Chair</i>	2
<i>Commission Members</i>	4
<i>Executive Summary</i>	5
<i>Introduction</i>	6
<i>Recommendations</i>	8
Buildings	8
Transportation	9
Power Sector	9
Short-Lived Climate Pollutants	10
Biomass-to-Energy	10
Technology	11
Carbon Sequestration	11
Adaptation and Resiliency	12
Environmental Justice, Climate Justice, and Public Health	13
Education, Communication, and Outreach	13
<i>A More Equitable and Inclusive Climate Strategy</i>	15
<i>Adaptation and Resiliency Background</i>	17
<i>Update on the Science – Informing the Process</i>	20
Appendix A - Building Energy Transition Plan: A Roadmap for Decarbonizing the Residential and Commercial Building Sectors in Maryland	
Appendix B - Maryland Commission on Climate Change Working Group Recommendations for 2020-2021	



Secretary Ben Grumbles
Maryland Dept of the Environment

Message from the Chair

Just after the Maryland Commission on Climate Change (Commission) convened to overwhelmingly approve this annual report, I traveled to Glasgow to participate in the United Nations' Climate Change Summit known as COP26. There, I met with climate scientists and policymakers to discuss strategies for reducing greenhouse gas emissions to net-zero as quickly as possible while growing the economy and adapting to a rapidly changing climate. Maryland continues to be a leader on climate action – ranked #1 in the nation for reducing greenhouse gas emissions while growing its economy – but the needs for deeper emissions reduction and stronger resilience is abundantly clear and our commitment to bold and balanced action has never been stronger.

Maryland's Greenhouse Gas Emissions Reduction Act (GGRA) laid the groundwork for our state's ambition on tackling impacts of climate change. The state's new *2030 GGRA Plan* charts a detailed path to reducing emissions by 50% by 2030, and introduces longer-range measures to help reach the Commission's recommendation that Maryland achieve net-zero emissions by 2045. Maryland is doing its part, but we need additional policies to go further. With continued support from the Commission, Maryland can help bridge the gap with a combination of new voluntary agreements, legislation, regulation, and executive action. *The 2030 Plan* has been a useful tool in helping Maryland lead on climate.

In 2021, the Commission worked to develop plans and recommend measures for further climate action. Notably, the Commission undertook a major initiative to engage consultants, stakeholders, and citizens in the development of a Building Energy Transition Plan to identify low-cost pathways for decarbonizing the residential and commercial buildings sectors. That plan and more than 50 recommendations for improving mitigation, sequestration, adaptation, resilience, and education are presented in this annual report.

The Commission is stepping up its efforts to help guide the state on responsibly addressing these issues at a rate consistent with the latest science and technical innovation. We are striving to show that bipartisanship, collaboration, and urgency are key to timely and durable solutions.

I am honored and humbled to chair this exceptional group of individuals who devoted their time and expertise for the benefit of all, with robust debate and civility throughout the year, even during a global pandemic. 2021 also was a year with two important milestones: Congratulating Treasurer Nancy Kopp on her tremendous service to Marylanders, including this Commission, as she retires at the end of the year and mourning the passing of longtime Maryland Department of the Environment staff member Brian Hug after a lengthy illness. Brian led many efforts on the Commission in its earlier days. I am forever grateful to these outstanding public servants for their contributions.

A handwritten signature in black ink, appearing to read "B Hug". The signature is fluid and cursive, with the first letter "B" being particularly large and stylized.

Commission Members

LEADERSHIP

Ben Grumbles
Anne Lindner
Kim Coble

Commission Chair
Commission Co-Chair
Commission Co-Chair

LEADERSHIP/CLIMATE JUSTICE

Charmaine Brown

Commission Co-Chair

STANDING MEMBERS

Ben Grumbles
Nancy K. Kopp
Mohammed Choudhury
Joseph Bartenfelder
Jeannie Haddaway-Riccio
Ellington Churchill
Greg Slater
Robert McCord
Dr. Mary Beth Tung
Dr. Peter Goodwin
Wayne Stafford
Charles Deegan
Dr. Russell Dickerson
Dr. Jane Kirschling
David Lapp

Department of the Environment Secretary
State Treasurer
Superintendent of Maryland Schools
Department of Agriculture Secretary
Department of Natural Resources Secretary
Department of General Services Secretary
Department of Transportation Secretary
Department of Planning Secretary
Maryland Energy Administration Director
President of UMD Center for Env. Science
President, Maryland Farm Bureau
Chair, Critical Area Commission
Climate Change Expert
Public Health Expert
Office of People's Counsel

SENATE PRESIDENT APPOINTED MEMBERS

Paul G. Pinsky
Jesse Iliff
Michael Powell
Jim Strong

State Senator
Environmental Nonprofit Org Representative
Business Community Representative
Organized Labor Representative

HOUSE SPEAKER APPOINTED MEMBERS

Dana Stein
Beth Harber
Anne Lindner
David Smedick
Gerald Jackson

Delegate
Philanthropic Organization Representative
Business Community Representative
Environmental Nonprofit Org Representative
Organized Labor Representative

LOCAL GOVERNMENT APPOINTEES

Charles County Administrator Mark Belton
Town of St. Michael's Commissioner Michael Bibb

Maryland Association of Counties
Maryland Municipal League

Executive Summary

The Maryland Commission on Climate Change (Commission) exists to advise the Governor and General Assembly on strategies for reducing greenhouse gas (GHG) emissions and preparing for and adapting to the impacts of climate change. In 2021, the Commission engaged in significant activities in pursuit of the body's specific statutory charges while ensuring that environmental and climate justice considerations are integrated across its work and recommendations.

The Commission's working groups heard from experts on topics, including decarbonizing the buildings sector, the power sector, and the transportation sector; the impact of climate change on coastal construction, labor and manufacturing, and the agricultural community; natural solutions to climate change, including carbon sequestration from forests and healthier soils; new targets for solar development and the offshore wind supply chain; emerging technologies; energy efficiency in homes and at businesses; and long and short-term climate resiliency and coastal hazard mitigation. The working groups developed the recommendations that are included in this Commission Report.

Creating a Building Energy Transition Plan was a special focus this year. The state's 2030 Greenhouse Gas Emissions Reduction Act Plan (GGRA Plan) called on the Commission to produce a Building Energy Transition Plan in 2021 to flesh out the policies that are needed to decarbonize the residential and commercial buildings sectors. That Plan is included as an appendix to this Commission Report.

The Commission's recommendations that are included in this Commission Report and the Building Energy Transition Plan are meant to guide state agency leaders, elected officials, legislators, and other stakeholders to meet the 2030 GGRA Plan goals and the Commission's recommendation that the state should achieve net-zero GHG emissions economywide by 2045. The Commission presents a set of recommendations herein in the following areas:

- Buildings
- Transportation
- Power
- Short-Lived Climate Pollutants
- Biomass
- State Government Operations
- Carbon Sequestration
- Adaptation and Resilience
- Environmental Justice, Climate Justice & Public Health
- Education, Communications, and Outreach

Woven across the recommendations is a focus on creating economic opportunity and jobs as the state simultaneously tackles climate and energy transitions; preparing our residents and infrastructure for the impacts of climate change like rising sea levels, increased flooding, and changing weather conditions; and centering equity and justice to ensure that all people, especially those who have historically been left behind, can benefit from state efforts, policies, and programs.

Introduction

The Commission is an independent, statutory body established under executive order (01.01.2007.07) charged with developing an action plan and firm timetable for mitigating and adapting to the impacts of climate change in Maryland. As a result of the work of more than 100 stakeholders and experts, the Commission produced a climate action plan, which was the catalyst for the Greenhouse Gas Emissions Reduction Act.

In 2014, a second executive order (01.01.2014.14) expanded the scope of the Commission and its membership to include non-state government participants. In 2015, the Commission was codified into law. Tasks and responsibilities in the 2014 executive order were maintained. In statute, the Commission is charged with advising the Governor and General Assembly "on ways to mitigate the causes of, prepare for, and adapt to the consequences of climate change." Serving in an advisory capacity, the Commission is focused on climate mitigation, but in congruence the Commission ensures that environmental and climate justice considerations are reflected in all recommendations. Fulfilling this role, the focus is to:

- Provide independent advice on setting and meeting GHG emission reduction targets
- Review the most up-to-date climate change science and how it informs state efforts on greenhouse gas mitigation, adaptation, resiliency, economics, and policy
- Engage with a wide range of organizations and individuals to share evidence and analysis

The Commission creates an annual report for the Governor and the General Assembly to provide recommendations on the necessary steps to avoid the most dramatic impacts of climate change in Maryland. The Commission is diverse. It is comprised of citizens, stakeholders, and policymakers who serve to advise the Maryland Department of Environment (MDE), which develops the plan to mitigate and adapt to the impacts of climate change. The plan is a requirement of the GGRA. The Commission also recommends goals, strategies, programs, and policies aimed at mitigation, adaptation and resiliency responses to climate change.

This set of recommendations is the key deliverable produced as the result of the annual meetings of the Commission process.

Maryland's Greenhouse Gas Emission Reduction Goals and National Commitments

In recognition of the escalating urgency of climate change and the reduction pathways recommended by the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) report, the Commission applauds our federal partners for setting a U.S. climate target to reduce net GHG emissions at least 50-52% below 2005 levels by 2030.

In the 2020 annual report, the Commission recommended that Maryland should adopt more ambitious GHG reduction goals by amending the relevant provisions of the GGRA of 2016 to include a statewide gross emissions reduction goal of at least a 50% from 2006 levels by 2030, with a requirement to develop a plan (2030 GGRA Plan) in recognition of the finding by the IPCC that developed countries will need to reduce GHG emissions to net-zero as early as 2045.

Maryland's climate targets cover not only carbon dioxide but also other GHGs. The state reduction targets are calculated based on gross GHG emissions, as opposed to net emissions, and relative to a 2006 baseline. On balance, a gross reduction goal of at least 50% by 2030, and net-zero by 2045 would be consistent with developed nations' responsibilities to follow the steeper end of global reduction pathways evaluated by the IPCC.

Maryland has made considerable progress in reducing GHG emissions since 2006 and is recognized as the leading state in the nation for reducing GHG emissions while growing its economy. The state has a comprehensive plan to cut emissions in half by 2030, but the implementation of the 2030 GGRA Plan will be challenging. Achieving the mitigation and adaptation goals detailed in the 2030 GGRA Plan will require unprecedented partnership and collaboration across all levels of government.

In 2020, the state overcame significant adversity in responding to the COVID-19 pandemic. The year was marred by uncertainty and delay in implementing some key climate strategies. Still, despite the pandemic, some progress was made. Sustaining progress will require sustained leadership, underpinned by ambitious goals. The Commission's recommendation that the state adopt a net-zero goal requires that all policy decisions, initiatives, and legislation be consistent with that goal.

This report offers numerous well vetted and ambitious recommendations. The recommendations are urgently needed. Some build on current policies and suggest ways in which those existing policies can be strengthened or enhanced. The Commission is dedicated to ensuring that policy recommendations consider impacts to all people, especially those who have historically been marginalized and overburdened.

Throughout the year, the Commission discussed many topics and determined that certain policy proposals must be delayed. Those policy proposals will be included in each working group's 2022 work plan and will be considered by the Commission in the coming year.

Recommendations

These Commission recommendations are meant to guide Maryland policymakers on decisions related to reducing GHG emissions from all sectors of Maryland’s diverse economy in accordance with the 2030 GGRA Plan, and to achieve net-zero emissions by 2045. The recommendations are further meant to influence decisions related to adaptation, resiliency, and climate and environmental justice.

Buildings

The full text of the following buildings recommendations can be found in the Building Energy Transition Plan (attached to this report).

1. Adopt an All-Electric Construction Code
2. Develop a Clean Heat Retrofit Program
 - A. Retrofit 100 % of low-income households by 2030
 - B. Encourage fuel-switching through EmPOWER beginning in 2024
 - C. Encourage beneficial electrification through EmPOWER beginning in 2024
 - D. Target 50% of residential heating, ventilation, and air conditioning and water heater sales to be heat pumps by 2025, 95% by 2030
 - E. Align energy plans, approvals, and funding with the objectives of this Plan
3. Create a Building Emissions Standard
4. Develop Utility Transition Plans
5. Prioritize an equitable level of benefits for all Marylanders
6. Improve interagency coordination for holistic building retrofits
7. Use federal funds for comprehensive retrofits of low-income housing
8. Sunset financial subsidies for fossil fuel appliances within EmPOWER
9. Offer incentives for net-zero energy all-electric new buildings
10. Lead by example through the electrification and decarbonization of state buildings
11. Allow local jurisdictions to set higher fines for non-compliance on building performance
12. Offer tax credits or other incentives for enhanced energy efficiency in new construction
13. Allow above-code green programs to comply with the state-adopted International Energy Conservation Code
14. Allow a portfolio approach to renewable energy generation
15. Evaluate property tax assessment processes to support decarbonization efforts
16. Identify locations that need grid upgrades to accommodate new all-electric buildings

Transportation

17. The state should continue to provide valuable assistance with the hope of joining a strong and equitable Transportation Climate Initiative Program to reduce pollution and improve transportation options in communities throughout the mid-Atlantic region.
18. State agencies should identify regulatory and policy mechanisms that encourage the development and use of low and zero emission technologies and fuels and provide recommendations for amendments.
19. State agencies should expand financial incentives for purchase of zero emission vehicles (ZEVs) and installation of electric vehicle supply equipment (EVSE). Incentives should be structured to ensure equitable disbursement and deployment of EVSE in underserved communities and rural areas.
20. The Maryland Department of Transportation (MDOT) should continue the expansion of 'Commuter Choice Maryland' Travel Demand Management programs to reduce congestion and emissions associated with commuter travel. State agencies should seek partnerships that recognize employers and organizations for offering transportation benefits and creative program incentives to their employees.
21. State agencies should identify and install charging infrastructure at state sites to support government owned vehicle electrification as well as identify fleet vehicles eligible for conversion that will meet legislative ZEV purchase requirements.
22. The state should enact policies requiring the transition of diesel school buses to ZEV beginning as soon as possible with a full transition no later than 2040.
23. The state should enact policies requiring the transition of all locally operated transit passenger buses to ZEV beginning as soon as possible with a full transition no later than 2040.
24. As a signatory of the Medium and Heavy-Duty Truck ZEV Memorandum of Understanding (MOU), the state should work through the existing multi-state ZEV Task Force facilitated by the Northeast States for Coordinated Air Use Management (NESCAUM) to develop and implement a ZEV action plan for trucks and buses.

Power Sector

25. As part of the third program review of the Regional Greenhouse Gas Initiative, MDE and the Maryland Public Service Commission should champion program improvements, including an emissions cap, which reduces CO2 emissions from regulated sources to zero by 2040 with cost controls, enhanced public health protections, particularly for environmental and climate justice communities; and ensure that the program provides significant job and economic benefits to all Marylanders.
26. The state should expand the development of offshore wind energy resources and the accompanying industry supply chain and workforce work by streamlining permitting and regulatory processes in collaboration with SMART-POWER partner states.

Short-Lived Climate Pollutants

27. MDE should continue evaluating and drafting regulatory options to address methane emissions from the natural gas distribution system.
28. The Scientific and Technical Working Group (STWG) should support the experts at MDE and the University of Maryland (UMD) who are developing air monitoring sites at landfills to determine how field data can improve the accuracy of methane emissions monitoring at point sources.
29. MDE should consider including black carbon data in the state GHG inventory.
30. The STWG's expert subgroup on livestock and animal feed should conclude their assessment of the feasibility of additives to cattle feed to reduce animal emissions of methane.

Biomass-to-Energy

31. The state should use waste from timber slash (i.e., woody material typically left behind after a timber harvest), thinnings for healthy and climate-adapted forest stand densities, urban tree management, the wood products industry, and untreated wood that otherwise would be recycled or landfilled for mid-sized (1-2 Megawatts) combined heat and power systems or thermal-only systems.
32. The Maryland Department of Natural Resources (DNR) should track new and existing woody biomass to energy facilities in the state along with their feedstock and report this as part of DNR's annual GGRA progress report. Through partnerships with regulatory and incentive agencies (i.e., MDE and the Maryland Energy Administration (MEA)), DNR should ensure the sourcing of wood fuels does not exceed the supply through the sources mentioned above.
33. The Mitigation Working Group (MWG) is directed to make recommendations about whether thermal renewable credits should be granted, and under what terms, when the credits would be generated from solely woody biomass to energy facilities where the woody biomass is sourced from timber slash, thinnings for healthy and climate-adapted forest stand densities, urban tree management, the wood products industry, and untreated wood that otherwise would be recycled or landfilled. Currently only facilities that co-fire with a majority of manure can qualify.

State Government Operations

34. The Maryland Department of General Services (DGS) should report annually on GHG emissions for all state government operations and oversee the development of an interagency Climate Action Plan that aims to achieve net-zero emissions by 2035 across all state operations for scope 1 & 2 emissions. * All state-funded operations, including the University System of Maryland should be included in the GHG report and Climate Action Plan.

**Scope 1 emissions are direct GHG emissions that occur from sources that are controlled or owned by an organization (e.g., emissions associated with fuel combustion in boilers, furnaces, vehicles). Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling. Although scope 2 emissions physically occur at the facility where they are generated, they are accounted for in an organization's GHG inventory because they are a result of the organization's energy use.*

Technology

35. The STWG has expanded its membership with experts in innovative technologies. As the impacts of climate change continue to become a threat to ecosystems and human health, a substantial number of innovative concepts are evolving. STWG will continue to compile information (articles and webinars) of potential interest to the Commissioners. Specifically, STWG will focus on feasible energy storage for renewable energy sources and advances in direct capture and storage of carbon technologies.
36. As requested by the Commission and MDE, STWG will provide scientific guidance related to setting priorities on how Maryland can achieve GHG reduction goals set by state or federal legislation. STWG members will coordinate with other working groups and respond to their requests for information. STWG will work with other working groups to identify common science and engineering priorities for planning or implementation of strategies that may arise in 2022. STWG will continue to host webinars on emerging science and technology topics as requested by the Commission, its working groups, and agencies.
37. The state should provide incentives for solar domestic hot water systems, especially in multifamily buildings.

Carbon Sequestration

38. MDE, in collaboration with the Maryland Department of Agriculture (MDA) and DNR, should include agricultural soil carbon and blue carbon within the 2023 GHG inventory based on the best available science to support a full ongoing assessment of Maryland's natural carbon sinks. Achieving this recommendation may require additional engagement with expert scientists, the U.S. Climate Alliance, or other funding partners.
39. MDE, in collaboration with MDA and DNR, should work to provide clarity on Natural and Working Lands (NWL) project eligibility for multiple forms of conservation finance, including low-interest loan financing and voluntary carbon markets, and position the state for leadership on innovative private-public partnerships for environmental restoration.
40. In support of a Maryland net-zero GHG goal, MDE, in collaboration with MDA and DNR, should complete a comprehensive assessment of potential strategic pathways for growing the state's natural carbon sinks. Such an effort should begin by leveraging the science and research on NWL currently included within the 2030 GGRA Plan and GHG Inventory. Implementing this recommendation may require additional engagement with scientists, the U.S. Climate Alliance, or other funding partners.
41. STWG will support MDE, DNR and external partners (such as COMPASS, Restore America's Estuaries) to explore the opportunities associated with blue carbon for carbon sequestration, protecting shorelines and enhancing the tidal ecosystem. Blue Carbon is defined as the carbon accumulating in vegetated, tidally influenced ecosystems such as tidal forests, tidal marshes and intertidal to subtidal seagrass

meadows. Blue carbon exhibits significant potential for both mitigating and adapting to the adverse impacts of climate change. Three events are planned in late 2021 and early 2022 to cover: (a) methodology for quantifying blue carbon sequestration potential, (b) innovative models to finance blue carbon projects, and (c) highlight wetland restoration and other nature-based solutions that have been implemented in Maryland.

42. The state should work with STWG in reviewing and supporting the Ocean Acidification Research and Monitoring Action Plan as part of the state's membership in the International Alliance to Combat Ocean Acidification

Adaptation and Resiliency

43. Maryland Climate Adaptation and Resilience Framework (Framework): Building on its success over the past two years, with the Commission approval of the Framework, the Adaptation and Resiliency Working Group (ARWG) along with state, local and non-governmental partners will develop a 2022 work plan that outlines implementation steps for the Framework. The work plan will include specific strategies and goals for prioritization in 2022 and identify partners who will lead the implementation. ARWG will establish a subgroup to lead the implementation of Cross-Framework priorities. The priority will be to establish an effective tracking system to measure progress on the Framework as it moves into implementation and develop an online platform to house the Framework and the newly created tracking system. This will ensure accountability and transparency in the implementation of the Framework and progress on adaptation goals for the state.
44. Advance Saltwater Intrusion Plan recommendations: The state agency saltwater intrusion team will request that DNR, MDE, MDA, the Maryland Department of Planning (MDP) and the Critical Area Commission identify strategies and solutions that align opportunities to support wetland migration and inform a statewide wetland adaptation plan. The state agency saltwater intrusion team recognizes that landscape scale coastal change is occurring in parts of Maryland, and that rapid coastal change impacts local economies as land use changes with rising seas and intruding saltwater. The team recommends that existing state strategies prioritize the most vulnerable parts of Maryland's coast and support local governments, local planning and conservation tools, and local landowners seeking to protect land while possible, protect the capacity of land to transition, consider alternative transitional land uses, and/or to relocate when conditions become unsustainable. Lands most impacted will be stewarded to adapt to changing coastal conditions, improve resilience for landward properties, and maximize co-benefits like supporting wetland migration, while protecting private property rights and values.
45. Building capacity to compete for Natural Infrastructure Resiliency Funds - ARWG continues to recognize the need to prepare Maryland and its communities to take advantage of upcoming federal funding (i.e., Federal Emergency Management Agency, National Oceanic and Atmospheric Administration (NOAA), the U.S. Army Corps of Engineers) and public private partnership opportunities that promote the use of natural infrastructure to build resilience to climate impacts.

ARWG and its partners will continue to explore and expand the potential use of the Targeted Resiliency Area effort to serve as a prioritization tool for the larger-scale funding opportunities that are emerging. DNR will lead a group of ARWG partners throughout 2022 to discuss landscape-level needs for Natural and Nature-based project identification so that Maryland and its communities are better situated to compete for future funding.

46. When requested by DNR, STWG will review recommendations on resiliency indicators at the [project's website](https://mdcoastaladaptation.net), <https://mdcoastaladaptation.net>.

Environmental Justice, Climate Justice, and Public Health

47. Like other working groups and the Commission, ARWG will work to ensure that an environmental justice lens is used in all its programming and initiatives. ARWG will look to expertise and collaboration with the Maryland Commission on Environmental Justice and Sustainable Communities (CEJSC) as well as the Commission's Climate Justice team to advise and ensure underserved communities are given the assistance needed to prepare for and adapt to the impacts of climate change. ARWG recommends that it, and all necessary partners, explore and identify an intervention to address the intersection of urban heat, climate change, vulnerabilities, and environmental justice.
48. STWG will assign a member to track and contribute to the Commission's focus on climate justice issues. STWG will embed principles of climate justice as needed into reviews and recommendations and engage additional professional experts as needed.
49. One of the most immediate impacts of climate change in Maryland is expected to be heat. Heat waves are expected to increase in frequency, daily elevated temperatures, daily high-lows, and duration. Heat waves disproportionately impact the elderly, those with co-morbidities and disadvantaged communities. STWG will help the environmental justice team and the Education, Communication, and Outreach Working Group (ECO) understand the impacts of heat waves on human health and what mitigation mechanisms are feasible within Maryland. This effort should include MDE, MEA, the Maryland Department of Health (MDH), the Maryland Department of Housing and Community Development (DHCD), and the Department of Emergency Management (MDEM).

Education, Communication, and Outreach

48. The Commission should identify and share key resources and tools to assess, improve, and track progress of specific measures that improve climate justice outcomes in Commission work products (recommendations, work plans, meetings/discussions, membership/participation).
49. The Commission should build a network of regional community leaders in 2022, to seek their guidance about climate change issues impacting vulnerable and underrepresented communities.
50. The Commission should identify opportunities for the chair and co-chairs to engage with diverse audiences to discuss the Commission's work with particular emphasis on conferences and podcasts.

- 51.** The Commission should continue to coordinate with the Maryland State Department of Education (MSDE) and other partners like the Maryland Association for Environmental & Outdoor Education, Chesapeake Bay Program, the National Association of Marine Educators, and the Maryland Climate Leadership Academy (MCLA), to identify opportunities to further collaborate and integrate climate policy and climate action into primary and secondary education curricula in Maryland.
- 52.** The Commission should explore opportunities to initiate a college level campaign to engage with community colleges, historically black colleges and universities, and other institutes of higher learning in the state.
- 53.** The Commission should engage with representatives of Maryland's Black, Indigenous, and People of Color (BIPOC) communities and in the public, private, and nonprofit sectors to develop partnerships that will foster voluntary sustainable initiatives that support environmental, social, and governance (ESG) policies.
- 54.** The Commission should appoint professionals to ECO that would fit into each of those sectors, with an emphasis on adding members with graphics design or digital media skills to complement the existing skills of our membership.

A More Equitable and Inclusive Climate Strategy

Climate change poses a significant threat to vulnerable communities with little adaptive capacity. Furthermore, disadvantaged communities are disproportionately impacted by pollution, often stemming from previous policy and planning decisions. Environmental (EJ) and Climate Justice (CJ) are ethical mandates that seek equal protection from environmental and public health hazards for all people regardless of race, age, income, culture, and social class. The state must ensure that equity and environmental justice are key principles of climate policies moving into 2022. The Commission is committed to incorporating environmental and climate justice considerations into all the recommendations it makes to the state.

In 2020, the Commission chair appointed a third co-chair who is specifically empowered to ensure that Diversity, Equity, Inclusion, and Justice (DEIJ) is considered and included in all Commission and working group deliberations and products. In 2021, the co-chair led a team of Steering Committee members consisting of appointees with environmental justice knowledge and one liaison from each of the Commission's working groups. Environmental and climate justice considerations were discussed and are reflected in this report's recommendations to better incorporate DEIJ into state programs.

Over the course of the last year, the CJ team worked diligently to apply their expertise to some of the most daunting climate issues facing our state. Here are highlights of a few of those accomplishments:

One of the first steps we took was to recognize that the residents in the communities, especially Black, Indigenous, People of Color, marginalized individuals and underrepresented groups such as people with disabilities, and the LGBTQ+ communities, are represented and reflected in the climate justice priorities. We know that a one size fits all approach is, in and of itself, contrary to equity. In reaching out to trusted advisors in these communities, we developed a database of organizations, including faith-based groups that serve the most vulnerable communities that are overburdened by climate change impacts. In our aim to apply an equity lens, we recognized that for some communities, the stakes are much higher and there needed to be a greater sense of urgency. This approach is core to our guiding principles that all actions have equity considerations and extra effort will be consistently applied to ensure we do our best to involve, engage, and include historically marginalized people.

We collaborated with HBCUs and community connectors who could be a source of information for Marylanders. An example of our outreach includes appearing on Howard University's radio station, WHUR to discuss resources available to Marylanders, including financial resources to address affordability in terms of utility expenses and energy efficiency. ECO has met with community leaders this year and will build on those relationships in 2022. ECO also hosted an ESG webinar in partnership with Fannie Mae and the CJ team.

Equally important was our work to create a compelling mission statement that would bring clarity to our role and illuminate our obligation to stay true to our core purpose.

The Climate Justice team supports, encourages, and ensures that the work of the Commission facilitates equitable outcomes for all Marylanders.

Our state, like our nation, is growing more diverse; rich diversity makes us stronger. To increase our awareness and ability to serve our multicultural, multigenerational, multiethnic state, the Climate Justice team, along with representatives from the CEJSC, participated in a Cultural Competency and Climate Justice Education Lab. To become more effective in serving our diverse state, we need to understand the fundamentals of inter-cultural competencies and identify ways to adapt our approach accordingly.

This year the Commission worked to diversify our committees and working groups by elevating opportunities to attract talent from higher education, the private and nonprofit sectors, and state government.

In 2022, the Commission will continue to ensure that an environmental and climate justice lens is used in all our initiatives. We will embed principles of climate justice into reviews and recommendations and engage additional professional experts as needed. We will continue to collaborate with the Maryland Commission on Environmental Justice and Sustainable Communities (CEJSC) to advise and ensure underserved communities are given the assistance needed to prepare for and adapt to the impacts of climate change. The Commission and its partners will explore and identify an intervention to address the intersection of urban heat, climate change, vulnerabilities, and environmental justice.

Adaptation and Resiliency Background

Climate adaptation efforts are a critical component to successfully protecting Marylanders, our natural resources and economy from the impacts of climate change. Fortunately, Maryland has recognized that critical need and supported a robust portfolio of adaptation and resiliency efforts across the state for well over ten years. The ARWG of the Commission serves as the state's lead on adaptation and resiliency. Through ARWG, adaptation practitioners and partners come together throughout the year to learn from each other, support the adaptation efforts, and work collaboratively to move Maryland forward. Maryland saw considerable progress across a range of priorities, and within many ongoing adaptation efforts during 2021. Following is a highlight of the most critical progress and updates for adaptation and resiliency progress in the state; this is not a comprehensive assessment of the activities of ARWG or the state overall.

ARWG completed an 18-month process in the early summer of 2021 to evaluate and update the state's adaptation plan, with the creation of the Draft Maryland Climate Adaptation and Resilience Framework (Framework). The intent of the Framework is to guide and prioritize action over the next ten years, specifically in vulnerable and underserved communities.

When developing the concept for the Framework, ARWG members recognized the importance of addressing sector-specific adaptation needs and opportunities as well as considering overarching issues that impact all sectors. As a result, the Framework was organized into five sectors: Natural Resources & Ecosystems, Working Lands & Natural Resources-Based Economies, Human Health, Water Resources - Quality and Quantity, and Protecting Critical Infrastructure. In addition, there are three focus areas that were integrated into all the sectors: Diversity and Environmental Justice, Climate Jobs and Training, and Local Government Action and State Service Delivery.

The Phase I and II plans laid the foundation for this approach and were developed with a wide variety of experts across the governmental, nonprofit, and private sectors who came together to interpret the most recent climate change literature, evaluate adaptation options, and recommend strategies to reduce Maryland's overall climate change vulnerability. Recognizing the invaluable contributions of our partners in the success of the first two phases (Phase 1 - 2008 and Phase II - 2011), Maryland undertook a similar approach with the Framework. Each sector and focus area had a work group, with representatives from state, federal and local government agencies, universities, nonprofits, and the private sector. Through facilitation by the University of Virginia Institute for Engagement and Negotiation alongside DNR, ARWG and partners came together to evaluate current science, assess progress on Phase I and Phase II strategies, identify gaps in adaptation activities in Maryland, and develop a suite of prioritized goals and strategies for each of the sector and focus groups. Additionally, a project team identified cross-Framework priorities, and recommended goals and strategies that are essential to ensure the successful implementation of the Framework and ensure all climate resiliency benefits are realized. After drafting, the Framework moved into a robust review process. That process, still underway at the end of 2021, will include review periods for agency and partner leadership, the Commission and its working groups, and public comment. Once the review period is complete and comments incorporated, Maryland will have an updated, comprehensive plan to guide, prioritize and track the

adaptation efforts throughout the state, ensuring that Marylanders, our natural resources, and economy are protected now and into the future. ARWG anticipates delivery of the final Framework in 2022.

In 2020, DNR's Chesapeake and Coastal Services (CCS) funded the University of Maryland Center for Environmental Sciences - Integration and Application Network (UMCES-IAN) to develop a Maryland Coastal Adaptation Report Card (Report Card) and suite indicators to track Maryland's adaptation progress. Through a year-long partnership with ARWG, its members, stakeholder workshops, and expertise within their organization, UMCES-IAN reviewed existing adaptation metrics, discussed targets and goals of state climate adaptation work, and developed a series of metrics to track progress towards these goals. The report card provides a high-level overview to decision and policy makers, including a thorough methodology providing the scientific rationale for the indicators, their thresholds and the data used to calculate the scores. The Report Card will be a first of its kind when it is released by the end of this year. The Report Card will be used by the Commission, ARWG, and others across the state and region to monitor progress toward climate adaptation goals in Maryland.

ARWG and its partners have worked throughout the year on the other priority actions and ongoing activities outlined in the *2020 Maryland Commission on Climate Change Annual Report*. The Water Quality and Climate Change Resiliency Portfolio is currently evaluating criteria to identify Targeted Resiliency Areas (TRA) - previously referred to as Resiliency Opportunity Zones - areas with restoration and conservation potential that provide high value resiliency benefits for communities, economies, public lands, and important ecosystems. Once the TRA's are established, DNR will work closely with climate affected communities and public, private, and nonprofit sectors, to establish a portfolio of projects within these areas, solicited through the Grants Gateway that work together to optimize resiliency benefits and leverage important habitat, water quality and GHG mitigation gains. The Grants Gateway is a streamlined grant application portal from DNR CCS that provides a single point of entry for financial and technical assistance opportunities that provide support to government and non-governmental organizations and academic institutions in their efforts to address restoration, resiliency and technical assistance needs.

MDP, who is an active member on ARWG and serves as the lead for the Saltwater Intrusion Plan priority activity, continued to implement the recommendations of the Saltwater Intrusion Plan by convening the State Agency Saltwater Intrusion Plan Workgroup (The Workgroup). The Workgroup saw progress on two recommendations, 1) develop the first phase of a statewide wetland adaptation plan and 2) expand coastal resilience easement efforts led by DNR.

These efforts further the work outlined in the 2019 Maryland Saltwater Intrusion Plan.

MCLA continued to operate in a fully virtual capacity in 2021. This allowed the MCLA to continue to provide continuing education and executive training programs specifically designed for state and local government officials, infrastructure executives and business leaders even as COVID-19 continued to limit live functions. In 2021, the MCLA offered training and capacity building to 80 individuals across all their offerings including four cohorts of the Certified Climate Change Professionals (CC-P) course, and two webinars each from MEA, MDH and MEMA. Recordings of the offerings, and additional information on MCLA trainings can be found on the

website, <https://www.mdclimateacademy.org/>. The MCLA continues to support the work of the Commission, by educating a community of climate smart local government and infrastructure leaders.

The integration of environmental and climate justice principles and approaches saw mixed success in 2021 across ARWG activities and partner efforts. The Framework effort includes a focus area dedicated to Diversity, Equity, Inclusion, and Justice (DEIJ), and includes recommendations, key strategies, and action items to inform more equitable adaptation efforts. ARWG and partners look forward to using the Framework as a guide for best incorporating environmental and climate justice initiatives and DEIJ considerations into efforts in 2022.

Maryland recognizes the need to invest, support and expand adaptation and resiliency efforts to effectively address climate change impacts to their resources and communities. Continued investment in, and support of adaptation and resiliency programs, projects, and partnerships are essential if Maryland is to meet the critical need to combat risks associated with climate impacts now and in the future.

Update on the Science – Informing the Process

The Commission continues to rely on scientific evidence to guide its evaluations and recommendations. The United Nations Intergovernmental Panel on Climate Change (IPCC) released the Physical Science Basis Report¹ (PSB Report) Sixth Assessment in August 2021. This report was conducted by 234 contributing authors synthesizing more than 14,000 scientific references. The primary findings provide stark evidence of the accelerating need for actions to reduce GHG emissions and the importance of the work of the Commission. Improvements in the ability to monitor the environment and the unprecedented collaboration of the global scientific community to better understand the changing climate has resulted in less uncertainty than described in the 5th Assessment Report although some significant drivers of the consequences of climate change such as the behavior of the cryosphere (ice and the polar regions) continue to change at an increasing and yet poorly understood rate.

Selected significant findings of the PSB Report include:

It is unequivocal that human influence has warmed the atmosphere, ocean, and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have occurred. [Finding A.1]

This is a momentous change from the 5th Assessment that concluded that human influence is “extremely likely to have been the dominant cause of the observed warming since the mid-20th century”

The scale of recent changes across the climate system as a whole and the present state of many aspects of the climate system are unprecedented over many centuries to many thousands of years. [Finding A.2]

Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO₂ and other greenhouse gas emissions occur in the coming decades. [Finding B.1]

Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic Sea ice, snow cover and permafrost. [Finding B.2]

Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events. [Finding B.3]

Many changes due to past and future GHG emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level. [Finding B.5]

From a physical science perspective, limiting human-induced global warming to a specific level requires limiting cumulative CO₂ emissions, reaching at least net-zero CO₂ emissions, along with strong reductions in other GHG emissions. Strong, rapid and sustained reductions in CH₄ emissions would also limit the warming effect resulting from declining aerosol pollution and would improve air quality. [Finding D-1]

The PSB report will guide discussions at the Conference of Parties (COP 26) meeting in November 2021 that will also discuss current Nationally Determined Contributions (NDCs) to reduce GHG emissions. Current NDCs are projected to result in a 2.4°C rise in temperature rather than the 1.5°C advised by IPCC.^{2,3,4,5,6} In 2020, under COVID-19, the world saw a 6% reduction in GHG emissions over 2019 levels⁵. Projections for 2021 indicate a 4% increase in GHG emissions and combined with the actual observed emissions (not the declared NDCs) a 2.7°C increase in temperature can be expected.⁶ Further, the PSB and the Global Carbon Project predict the 1.5°C threshold will be surpassed in the 2030s at the 2021 rate of emissions. It is anticipated that many countries will renew and increase NDCs at the 2021 COP.

There are myriad implications of climate change to Maryland that require mitigation and adaptation strategies. The following consequences are selected based on emerging scientific findings and weather events experienced in North America during the past year.

Greenhouse Gas Emissions⁶

The latest analysis of observations from the WMO Global Atmosphere Watch shows that globally averaged surface concentrations calculated from this in-situ network for CO₂, CH₄ and N₂O reached new highs. The growth rates of the CO₂, CH₄ and N₂O concentrations in the atmosphere averaged over the 2015–2017 period for which data have been completed and processed are each about 20% higher than those over 2011–2015. Preliminary analysis shows that in May 2018 the CO₂ annual mean concentration at Mauna Loa Observatory, Hawaii, reached 417ppm [<https://sioweb.ucsd.edu/programs/keelingcurve/>] and the increase from 2017 to 2018 was 1.97 ppm. From January to August 2019 the increase in the concentration (de-seasonalized trend) was 0.85 ppm. 2020 saw a 6% reduction but there was a rebound of 4% by October 2021 negating many of the gains made during the COVID pandemic.

Temperature⁷

The average temperatures for the five-year period 2015 - 2019 were the highest on record with 2020 being the second warmest on record behind 2016. The world's seven warmest years on record have all occurred since 2014. The average global temperature for 2015–2019 was 1.1 °C above pre-industrial (1850–1900) levels and the average temperature is now 0.20°C warmer than the average for 2011–2015.

There is an increasing emphasis by scientists to conduct attribution analyses that connect changing climate conditions to weather extremes being experienced across the globe. For example, these changes in climate result in more frequent, longer lasting, and more dangerous heatwaves. The 2018 National Climate Assessment, a major scientific report issued by 13 federal agencies, notes that the number of hot days is increasing, and the frequency of heatwaves in the United States jumped from an average of two per year in the 1960s to six per year by the 2010s. Also, the season for heatwaves has stretched to be 45 days longer than it was in the 1960s. It is all part of an overall warming trend: the seven warmest years in the history of accurate worldwide record-keeping have been the last seven years, and 19 of the 20 warmest years have occurred since 2000; worldwide, June 2019 was the hottest June month ever recorded and June 2020 tied it.

Ocean

Scientific evidence is mounting of the significant changes occurring in the oceans. This is captured in the recent IPCC report:⁸

It is virtually certain that the global ocean has warmed unabated since 1970 and has taken up more than 90% of the excess heat in the climate system (high confidence). Since 1993, the rate of ocean warming has more than doubled (likely). Marine heatwaves have very likely doubled in frequency since 1982 and are increasing in intensity (very high confidence). By absorbing more CO₂, the ocean has undergone increasing surface acidification (certain). A loss of oxygen has occurred from the surface to 1000 m (medium confidence).

[The Maryland Ocean Acidification Action Plan](#) (2020) is developed in collaboration with the International Alliance to Combat Ocean Acidification.⁹ Over the last several years, Maryland has begun to analyze the acidification processes within Chesapeake Bay and recommendations are being developed including a monitoring program to provide further insights to the trends being observed.

Cryosphere

During 2019-2021, there continued to be an alarming reduction in the amount of ice on Earth's surface, the so-called cryosphere. Around the world, mountain glaciers are continuing to retreat. Arctic surface air temperatures have increased more than twice as fast as the global mean since the mid-1980s¹⁰. This is linked to the continued decline in the extent and thickness of ice cover in the Arctic Ocean, which by mid-October 2020 was the least ever recorded at that time of the year. The decline in ice cover is allowing the sea surface to warm, which has far-reaching consequences for weather across the United States. As a result of the warming of both the air and surrounding seas, the Greenland ice sheet has been losing mass at an unprecedented rate since the 1990s, twice as fast in 2019 than the average over 2003-2016. Some scientists have suggested that Greenland has reached the point of no return such that, even if global warming were to stop today, the ice sheet would continue to shrink¹¹. Although air temperatures over Antarctica are not warming as rapidly as in the Arctic, the surrounding seas are warming. This is destabilizing the ice shelves where massive glaciers meet the ocean,¹² which alone could cause several meters of sea-level rise over the next century or two.

The IPCC Special Report³¹ reviewed the observed physical changes in the cryosphere and projected future changes and their implications for sea-level rise under different pathways of global GHG emissions. Sea-level rise in the future will be determined by the rate of melting of polar ice sheets, which will result from the warming of the atmosphere and surface ocean waters. For the unabated warming path we have been on, the IPCC's median estimate was 71 cm (2.3 feet) of sea-level rise by 2100; however, if GHG emissions were reduced quickly enough to limit the increase of global mean temperature to less than 2°C, as per the Paris Agreement, the median estimate was 39 cm (1.3 feet). That does not tell the full story, as the IPCC estimated that it is possible that sea-level could rise more than 1 m this century and as much as 5 m by 2300 if global emissions continue to grow over the next 60 years. On the other hand, it is unlikely to exceed 1 m even through the next century if emissions can be brought to net-zero by or shortly after 2050. A more recent expert estimate generally agrees with the IPCC but suggests that sea-level rise could be even higher under an unabated warming path.³³ To put it quite simply, the future of Maryland's low-lying coastal areas depends on the amount of ice lost from Antarctic and Greenland ice sheets.

In Maryland, the effects of accelerated sea-level rise are already apparent, including shoreline erosion, deterioration of tidal wetlands, and saline contamination of low-lying farm fields. "Nuisance" tidal flooding (also referred to as high tide flooding) that occurred just a very few days per year in Annapolis in the 1950s now occurs 40 or more days per year. Storm surges from tropical storms or Nor'easters also spread farther and higher, riding on the higher sea level. If emissions increase into the second half of the 21st century, the likely range of sea-level rise experienced in Maryland is 2.0 to 4.2 feet over this century, a rate that is 2-4 times greater than experienced during the 20th century.³²

Extreme Events³⁷

Many of the extreme events associated with climate change such as hurricanes, floods or droughts can bring substantial loss of life or population displacement and inflict major economic impacts.

Heatwaves have been the deadliest meteorological hazard in the 2015–2019 period, with wildfires also featuring especially in the Western United States, the Arctic, including Greenland, Alaska, and Siberia, and in the Amazon Forest. In June 2019 alone, these Arctic fires emitted 50 Mt of CO₂ into the atmosphere. This is more than was released by Arctic fires in the same month for the totality of the period 2010–2018.

The largest economic losses were associated with hurricanes and tropical cyclones. The 2017 Atlantic hurricane season was one of the most devastating on record, with more than \$125 billion in losses associated with Hurricane Harvey alone.

The trends of increasing frequency of extreme events continues. For only the second time, the National Hurricane Center in 2020 reached the end of the 21 alphabetical tropical storm names for the Atlantic Ocean and the subsequent named storms used Greek letters and the naming had reached Zeta before the end of October.³⁴

The frequency of billion-dollar weather-related disasters are tracked by the National Oceanic and Atmospheric Administration (NOAA).¹⁵ During the first nine months of 2021 new records have been set. There have been 18 separate billion-dollar weather and climate disaster events across the United States. The disaster costs for the first nine months of 2021 are \$104.8 billion, already surpassing the disaster costs for all of 2020 (\$100.2 billion, inflation-adjusted to 2021 dollars). The total costs for the last five years (\$691.7 billion) is nearly one-third of the disaster cost total of the last 42-years (1980-2021), which is \$2.085 trillion (inflation-adjusted to 2021 dollars).

Human Health

The most recent [National Climate Assessment](#)¹⁶ concluded that ongoing climate change is negatively impacting public health by exacerbating climate sensitive health outcomes that are tied to rising temperatures and increases in the frequency of extreme weather events. June 2021: A historic heat wave developed for many days across the Pacific Northwest shattering numerous all-time high-temperature records across the region. This prolonged heat dome was maximized over the states of Oregon and Washington and extended well into Canada. These extreme temperatures impacted several major cities and millions of people. For example, Portland reached a high of 116°F while Seattle reached 108°F. The count for heat-related fatalities is still preliminary but is estimated at more than 1300.

The public health impacts of ongoing climate change among Marylanders were first outlined in the [2016 joint report](#) by the University of Maryland School of Public Health and the Maryland Department of Health.¹⁷ Direct threats of increasing extreme events in Maryland are best exemplified by the experience of communities in Ellicott City who have had to deal with three “once in a thousand-year rainfall events” over the last decade alone. Studies have shown that rising frequencies of extreme heat and precipitation events are increasing risk of asthma hospitalizations, myocardial infarctions, and motor vehicle accidents, as well as food and waterborne illness in Maryland¹⁸⁻²². More recent work has demonstrated how climate change can simultaneously impact ecosystem health and human health. For example, wintertime temperature anomalies are changing the timing of spring onset, which is closely linked with the tree pollen season, and thus, increasing the risk of asthma hospitalization in Maryland.²³⁻²⁵

Since the ongoing trends in increasing frequency of extreme events are projected to continue in the near future, protecting public health will require the capacity to anticipate and adapt to these new threats. This should be supported by a clear understanding of underlying community vulnerabilities. For instance, a community may be more vulnerable because they are disproportionately exposed to the new threats, such as inner-city residents with higher prevalence of poverty and air pollution exposure are excessively exposed to heat because of the urban heat island effect, or coastal residents who are increasingly exposed to allergenic mold because of frequent flooding. Likewise, communities may be more vulnerable because they lack the capacity to adapt to the new threats. For example, poor communities are more vulnerable to heat exposure because they do not have access to air conditioning, and individuals undergoing dialysis cannot cope with the heat by drinking more water because of medical restrictions to their liquid intake. Moreover, certain subgroups may be more vulnerable to the new threats because of their underlying conditions, such as certain minority groups, linguistically isolated communities, those suffering from mental health issues or individuals

living with preexisting conditions. The most recent IPCC report highlighted that keeping the ongoing warming to 1.5°C above the preindustrial average as opposed to 2°C will reduce frequent exposure to extreme heat waves among 420 million people. Moving forward, public health early warning systems with seasonal to sub-seasonal lead times incorporating such community specific vulnerabilities, may help communities to better prepare against the threats of climate change.

Wildfire

2020 and 2021 are two of the worst US wildfire seasons on record with several western states experiencing record areas burned and smoke plumes visible in Maryland. Changing precipitation patterns and rising temperatures combine to exacerbate the intensity and duration of dry periods, yielding more intense wildfires that are frequently beyond our ability to control. The Western US provides examples of this year after year, however, in 2016, the Great Smoky Mountain wildfires burned into Gatlinburg, Tennessee, destroying thousands of homes and structures, causing over \$1 billion in damages, and costing 14 lives, indicating that the Eastern US is vulnerable too. Future climate projections for the region anticipate increases in the frequency of both high and low precipitation events with an overall trend of drying soils¹⁶. In the US (1992-2015), approximately 44% of wildfires were ignited by lightning, but they accounted for over 70% of land burned.²⁶ Lightning strikes are likely to increase with climate change, but to an uncertain degree in the US, with projected increases ranging from slight²⁷ to as much as 50%.²⁸

The potential for increasing wildfire in Maryland and implications for carbon emissions and sequestration are uncertain, although Maryland scientists at DNR and academe continue to monitor and research the changing landscape characteristics of Maryland.

Economic and Social Consequences of Climate Change in Maryland ⁵

Since 1981, Maryland has experienced 66 'billion-dollar' weather related events resulting in an estimated \$10-20bn (CPI-adjusted) in damages. The NOAA National Center for Environmental Information tracks drought, flood, freeze, severe storm, tropical cyclone, wildfire, and winter storm events. Maryland has not experienced a wildfire event of this magnitude during the period 1981-2021. 20% of these events were tropical cyclones that inflicted over 40% of the total damages. Droughts and severe storms were the second and third most costly weather events. A significant concern is the increasing frequency of these extreme events and the attribution of these weather events to the changing climate (Table 1). In the period 1980-1989, the average was 0.7 events per year. This has increased by decade and 5 events were recorded in 2020. The rapid escalation of the frequency and severity of these events reinforce the urgent need for climate action for mitigation and adaptation.

Select Time Period Comparisons of Maryland Billion-Dollar Disaster Statistics (CPI-Adjusted)

TIME PERIOD	BILLION-DOLLAR DISASTERS	EVENTS/YEAR	COST	PERCENT OF TOTAL COST
1980s (1980-1989)	7	0.7	\$1.0B-\$2.0B	11.1%
1990s (1990-1999)	13	1.3	\$2.0B-\$5.0B	17.7%
2000s (2000-2009)	10	1.0	\$2.0B-\$5.0B	26.3%
2010s (2010-2019)	26	2.6	\$5.0B-\$10.0B	39.0%
Last 5 Years (2016-2020)	16	3.2	\$1.0B-\$2.0B	12.5%
Last 3 Years (2018-2020)	12	4.0	\$1.0B-\$2.0B	11.0%
Last Year (2020)	5	5.0	\$250M-\$500M	3.3%
All Years (1980-2021)	66	1.6	\$10.0B-\$20.0B	100.0%

**Statistics valid as of October 8, 2021*

Table 1: The Increasing Occurrence of Extreme Events in Maryland

[Source: NOAA National Centers for Environmental Information (NCEI)²⁹]

Ecological Consequences of Climate to Chesapeake Bay

The changing climate and the impacts of more frequent extreme weather events are being continually monitored and studied by scientists through state agencies, the Chesapeake Bay Program, the United States Geological Survey (USGS), NOAA, non-governmental organizations (NGOs), and universities. Climate changes that have been detected include a longer growing season, altered precipitation patterns and a changing temperature dynamic in Chesapeake Bay and its tributaries. One study analyzed changes over the past century³⁰ and found the region receives about 4.5 inches more precipitation, the growing season has been extended by a month with about 30 more warm nights (>68°F) per year and 36 more warm (>77°F) summer days a year. This climate shift contributes to disruptions in the migratory behaviors of fish, birds and other species and changes to the biogeochemical processes of the bay and watershed. These climate changes impact the actions taken to achieve the Chesapeake Bay TMDL for nutrient and sediment loading and are accounted for in the Phase III Watershed Implementation Plan.³¹

These changes in physical conditions reverberate through biological and human systems, which have co-evolved to exist under current conditions. A thorough understanding of the ramifications which accompany unmitigated climate change, as well as the complexity of costs and benefits (economic, environmental, and human) associated with climate action, is essential to the core function of the Commission. The scientific community is constantly improving and refining the models and projections for various emission reduction scenarios, providing policy makers with increasingly detailed information on which to base its decisions and recommendations. It is the ongoing endeavor of the Commission and its working groups to ensure that Maryland is utilizing the best science available to move forward with progress on limiting (or mitigating) climate change and adapting to evolving conditions.

References

1. IPCC, 2021. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)). Cambridge University Press. In press.
2. Ripple, W.J., C. Wolf, T.M Newsome, P. Barnard, W.R. Moomaw and 11,258 Scientist signatories from 153 Countries 2019. *World Scientists' Warning of a Climate Emergency*. *Bioscience*. November 5, 2019.
3. IPCC, 2018: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global GHG emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Portner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. P.an, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)].
4. World Meteorological Organization, 2019. *WMO Statement on the State of Global Climate in 2018*. WMO No 1233. 44pp
5. UN World Meteorological Organization. *Greenhouse Gas Bulletin: no. 17, 25 October 2021*
6. *Climate Transparency Report: Comparing G20 Climate actions Towards net-zero, 2021*. www.climate-transparency.org
7. NOAA. <https://www.noaa.gov/news/2020-was-earth-s-2nd-hottest-year-just-behind-2016>
8. IPCC, 2019: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama, N. Weyer (eds.)].
9. Maryland Department of the Environment and Maryland Department of Natural Resources, 2020. *Maryland Ocean Acidification Action Plan*. 17p.
10. Blunden, J., and D.S. Arndt. 2020. *State of the Climate in 2019*. *Bulletin of the American Meteorological Society* 101(8): Si–S429.
11. King, M.D., I.M. Howat, S.G. Candela, M.J. Noh, S. Jeong, B.P.Y. Noel, M.R. van den Broeke, B. Wouters, and A. Negrete. *Dynamic ice loss from the Greenland Ice Sheet driven by sustained glacier retreat*. *Communications Earth & Environment* 1 (1) doi: 10.1038/s43247-020-0001-2

12. Lhermitte, S., S. Sun, C. Shuman, B. Wouters, F. Pattyn, J. Wuite, E. Berthier and T. Nagler. 2020. *Damage accelerates ice shelf instability and mass loss in Amundsen Sea Embayment. Proceedings of the National Academy of Sciences* 117: 24735–24741.
13. Horton, B.P., N.S. Khan, N. Cahill, J.S.H. Lee, T.A. Shaw, A.J. Garner, A.C. Kemp, S.E. Engelhart, and S. Rahmstorf. 2020. *Estimating global mean sea-level rise and its uncertainties by 2100 and 2300 from an expert survey. npj Climate and Atmospheric Science* 3, 18. doi: 10.1038/s41612-020-0121-
14. NOAA National Hurricane Center
<https://www.noaa.gov/news/with-alpha-2020-atlantic-tropical-storm-names-go-greek>
15. NOAA Billion Dollar Disasters in the US. <https://www.ncdc.noaa.gov/billions/>
16. US Global Change Program, Fourth National Climate Assessment.
<https://www.globalchange.gov/nca4>
17. [Maryland Department of Health and Mental Hygiene and UM School of Public Health, 2016. Maryland Climate and Health Profile Report. 67p.](#)
18. Soneja S, Jiang C, Fisher J, Upperman CR, Mitchell C, Sapkota A. *Exposure to extreme heat and precipitation events associated with increased risk of hospitalization for asthma in Maryland, U.S.A. Environ Health.* 2016; 15:57.
19. Fisher JA, Jiang C, Soneja SI, Mitchell C, Puett RC, Sapkota A. *Summertime extreme heat events and increased risk of acute myocardial infarction hospitalizations. J Expo Sci Environ Epidemiol.* 2017;27(3):276-280.
20. Liu A, Soneja SI, Jiang C, et al. *Frequency of extreme weather events and increased risk of motor vehicle collision in Maryland. Sci Total Environ.* 2017; 580:550-555.
21. Soneja S, Jiang C, Romeo Upperman C, et al. *Extreme precipitation events and increased risk of campylobacteriosis in Maryland, U.S.A. Environ Res.* 2016;149:216-221.
22. Jiang C, Shaw KS, Upperman CR, et al. *Climate change, extreme events, and increased risk of salmonellosis in Maryland, USA: Evidence for coastal vulnerability. Environ Int.* 2015; 83:58-62.
23. Sapkota A, Dong Y, Li L, et al. *Association Between Changes in Timing of Spring Onset and Asthma Hospitalization in Maryland. JAMA Netw Open.* 2020;3(7): e207551.
24. Li X, Zhou Y, Meng L, Asrar G, Sapkota A, Coates F. *Characterizing the relationship between satellite phenology and pollen season: A case study of birch. Remote Sensing of Environment.* 2019; 222:267-274.

25. Li X, Zhou Y, Asrar GR, Mao J, Li X, Li W. Response of vegetation phenology to urbanization in the conterminous United States. *Glob Chang Biol.* 2017;23(7):2818-2830
26. Short, K.C., 2017. *Spatial Wildfire occurrence data for the United States, 1992-2015, 4th Edition.* <https://doi.org/10.2737/RDS-2013-0009.4>)
27. Finney, D.L., et al., 2018. A Projected decrease in lightening under climate change. *Nature Climate Change.* Vol 8, 210-213)
28. Romos, D.C, et al., 2014. Projected increase in lightning strikes in the United States due to global warming. *Science* Vol. 346, Issue 6211, 14 Nov. pp 851-854.
29. NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2021). <https://www.ncdc.noaa.gov/billions/>, DOI: 10.25921/stkw-7w73
30. NOAA, UMCES, National Estuarine Research Reserves of Maryland and Virginia, and Chesapeake Environmental Communications. <http://www.chesapeakeedata.com/changingchesapeake/>
31. Maryland Department of the Environment, August, 2019. *Maryland's Phase III Watershed Implementation Plan (WIP). Chapter VIII: Climate Change* <https://mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/Phase3WIP.aspx>
32. Boesch, D.F., W.C. Boicourt, R.I. Cullather, T. Ezer, G.E. Galloway, Jr., Z.P. Johnson, K.H. Kilbourne, M.L. Kirwan, R.E. Kopp, S. Land, M. Li, W. Nardin, C.K. Sommerfield, W.V. Sweet. 2018. *Sea-level Rise: Projections for Maryland 2018*, 27 pp. University of Maryland Center for Environmental Science, Cambridge, MD.