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ECONOMIC AND ENVIRONMENTAL IMPACTS OF CLIMATE CHANGE IN VIRGINIA

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Virginia's climatic changes have been thoroughly documented over recent decades. The overwhelming weight of scientific evidence predicts that climate change will continue and may accelerate unless strong action is taken to reduce global greenhouse gas emissions. Climate change threatens serious harm to Virginia's economy, its people and its treasured natural resources. Virginia's political leaders should promote vigorous state, national and international policies to halt global warming. Virginia's current leadership, both in government and in the private sector, should take up this mission.

Although Virginia has experienced a relatively moderate rate of climate change compared to many other parts of the country over the past century as a whole, the speed and scale of climatic changes has gained momentum and has been accelerating throughout the last 50 years. Warming has occurred across the state, mostly during the winter months, when average temperatures rose about one degree C.[1] Precipitation patterns also changed: summer rainfall declined on average by 0.50mm/day but in the fall months, precipitation increased by about the same amount.[2] Correspondingly, there were more days of intense precipitation and precipitation became more variable, with greater frequency of both wet and dry periods, including the pronounced drought of 2010.[3]

All regional climate models project rising temperatures over coming decades. Annual average temperatures are expected to rise by three to four degrees centigrade over this century and possibly much more if emission levels continue to grow rapidly, with corresponding increases in both maximum and minimum temperatures. Overall precipitation is expected to increase by about ten percent and some models forecast that most of the increase will occur during the summer. The number of hot and humid days and the corresponding "misery index" will climb substantially. There are likely to be more heat waves like the one that Virginia suffered in the summer of 2011.[4] Virginia's seasons will change: spring will come earlier, summer will last longer into the fall and winters will be milder.

INCREASED STORM SURGES AND SEA LEVEL RISE

The combination of land subsidence, sea level rise, flat and low tidewater topography and intensive coastal real estate and infrastructure development puts southeastern Virginia, namely the Virginia Beach/Norfolk/Hampton Roads region, at extreme risk from storm surges. Past tropical storms, such as Hurricane Isabel, did extensive damage from storm surge. An analysis based on catastrophe models developed by RMS, a risk management firm, identified this region as the 10th most vulnerable in the entire world to flooding from storm surges and in the United States, second only to Miami.[5] Some of those at risk have already taken notice. The US Navy and Air Force, which have spent many millions of dollars to harden their facilities against flooding, are taking climate change into account in plans for the future of their bases in the region.[6] Insurance companies have realized the potential for serious losses. CoreLogic, a real estate data firm, estimates that in the event of a major storm more than one-third of the houses in the Hampton Roads region would suffer flood damages[7].

The lower tidewater area around Virginia Beach and Norfolk, as the result of climate change, will lose 19 percent of undeveloped dry land, 79 percent of beaches, and a third of brackish and freshwater marshes.

Most property and casualty insurers operating in the mid-Atlantic area now refuse to insure businesses and primary residences in the coastal region.[8] Many industry members believe it will soon become too costly to cover many of these potentially high-risk properties, even with higher premiums. Some insurers have begun to refuse coverage for vacation homes. Limited insurance coverage puts property owners at great risk. Less than one-quarter of homes in the Hampton Roads area now have flood insurance, even in the highest flood risk areas. Insurance coverage for losses from storms is less than 25 percent of actual losses.[9] Though that area will bear the brunt, these storm surge risks extend far into Chesapeake Bay and up Virginia's rivers as far as Richmond and Alexandria. The National Weather Service estimates that a Category 3 storm making landfall in the Carolinas could produce a 13-foot surge as far north as Baltimore and 14-16 foot surges further south in the Bay.[10]

Climate change will make the situation much worse. The pace of sea level rise at Norfolk is the highest on the East Coast because the shoreline is subsiding and global warming is increasing the rate of sea level rise, both because of thermal expansion and the melting of land ice.[11] The lower tidewater area around Virginia Beach and Norfolk, as the result of climate change, will lose 19 percent of undeveloped dry land, 79 percent of beaches, and a third of brackish and freshwater marshes. An extensive analysis based on catastrophe modeling and 10,000 simulated storm tracks super-imposed on shoreline characteristics found that the mid-Atlantic region is more at risk than even the Gulf Coast or Atlantic Florida.[12]

The analysis considered only flood damages to above-ground structures, not in-ground infrastructure, but did include losses to building contents and interrupted use. Wind damages were not considered. Tests of the model showed that estimated losses compared closely with actual losses in past storms. The analysis considered three levels of risk: 1) losses at the current sea level height; 2) losses at the predicted higher sea level; and 3) losses at the higher sea level combined with warmer sea surface temperatures, which increase the intensity of tropical storms. Warmer sea surface temperatures significantly increase the number of hurricane-strength storms making landfall along the Atlantic coast.[13]

At the predicted level of sea level rise, expected annual losses exceed those at current sea levels by about 20 percent because storm surges would be higher and would extend further inland and up the estuaries. However, the combination of higher sea level and warmer sea surface temperatures elevated expected annual losses by roughly 55 percent above current levels because of the higher probability of intense storms making landfall. A

particularly intense storm, one with a 50-year return period, would raise expected damages by 25 percent above current levels with only a higher sea level but by about 95 percent with both sea level rise and higher sea surface temperatures, almost four times as high as the current expected losses. The study concludes that the risks to coastal property from global warming are greatest in the mid-Atlantic region.[14]

Although these studies serve as serious warnings, they badly underestimate the actual risks. First, they consider only damages from storm surges, ignoring damages from high winds or from flooding caused by intense rainfall. Second, the analysis considered damages only to property that exists now but did not consider that population and construction in the coastal area will increase even as global warming continues, so future risks and damages will be considerably higher. Third, these studies consider only property damage, not potential injuries or loss of life and not the disruption that such storms bring to businesses and households. In the aftermath of a severe storm, these disruption losses alone are estimated to be equivalent to about a week's worth of total income, which is currently about $1.5 billion just for the Hampton Roads area. In only measuring a fraction of the absolute damage wrought by such storms, these analyses diminish the true scale of devastation that would result from storms that are more common and more powerful.

HURRICANES AND EXTREME STORMS

The effects of climate change on hurricane frequencies and intensities have been the subject of considerable scientific research and discussion. As they generate power from warm, moist air over warm ocean waters, hurricanes are becoming more intense as climate change continues to increase ocean temperatures. The current scientific understanding is that sustained warming will result in the more intense hurricanes becoming more frequent in Virginia's latitudes and the less intense hurricanes growing less frequent.[15] With climate change driven by increasing emissions, the frequency of the most intense Category 4 and 5 storms would be expected to increase by 80 percent by 2080, or by roughly one percent per year. Over the same period the frequency of the less intense Category 1-3 hurricanes will diminish by 38 percent.

These changes are unlikely to be steady trends, since the most intense hurricanes strike the mid-Atlantic region only rarely and the effects of global warming will be superimposed on considerable short-term variability. Historically, no Category 4 or Category 5 hurricane has ever struck in Virginia but climate change is making it more likely that one will eventually do so. The implication is that overall hurricane risks are increasing because historically Category 4 and 5 hurricanes have caused 86 and 48 percent of recorded hurricane damages respectively, even though they represented only 24 and 6 percent of hurricane landfalls in the United States.[16] Higher winds cause more devastation, persist longer at damaging levels and generally affect a wider area.

ECONOMIC DAMAGES FROM HURRICANES

In 2003, Hurricane Isabel did an estimated $5.5 billion dollars in damages to the Hampton Roads region, even though the region was not directly hit.[17] A recent analysis carried out by a risk management firm, First American Corporation, estimated that if the least intensive hurricane, a Category 1 storm, made landfall in Southeast Virginia, it would probably cause $7.4 billion in damages, in 2010 prices.[18] Another firm, CoreLogic made a similar estimate of $10 billion in damages to residential properties.[19] Moreover, while the probabilities of more intense hurricanes are increasing, Virginia's economy is changing in ways that put more people and value in harm's way. Population and commercial and real estate development are again increasing in the coastal zone after the great recession of 2008-2010. The potential loss from any given storm is expected to double in each decade.[20] Without a vigorous adaptation effort, Virginia is becoming more vulnerable to the effects of climate change.

When these projections of rising sea levels and storm surges, more frequent intense hurricanes, and increasing values at risk are brought together in an integrated analysis, using numbers that represent the best current scientific estimates, the results are ominous. The findings from such an integrated analysis for the coastal Virginia area are presented below.[21]

The National Hurricane Center, part of NOAA, estimates hurricane probabilities in each vulnerable region by fitting probability curves to historical data. Until now, the Center has neither estimated the effects of past climate change on hurricane frequencies nor predicted future effects. Nonetheless, the following table accepts the Center's estimates of hurricane return periods for 2010[22] and uses the scientific predictions discussed above to show the changing return periods from 2000 through 2060 of tropical storms and Category 1 through 5 hurricanes striking the Norfolk/Virginia Beach region. As the following table shows, though the probabilities of tropical storms and less intense hurricanes decline, the probabilities of major hurricane strikes increase by 50 percent over the period. By 2060 the hundred-year storm would be a Category 4 or 5 hurricane.

STORM OCCURANCE POSSIBILITY, IN YEARS

Year	Tropical Storm	Category 1 Hurricane	Category 2 Hurricane	Category 3 Hurricane	Category 4 Hurricane	Category 5 Hurricane
2010	5.0	15.0	43	84	210	500
2020	5.2	15.6	45	87	190	452
2030	5.4	16.2	46	91	172	409
2040	5.6	16.8	48	94	155	370
2050	5.8	17.5	50	98	140	334
2060	6.0	18.1	52	102	127	303

SOURCE: *The computations underlying this analysis were carried out by Dr. Robert Easton, Professor of Applied Mathematics emeritus, University of Colorado at Boulder.*

A study by Yale Economics Professor William Nordhaus, based on all recorded previous hurricanes striking the United States, found that damages increase exponentially as the maximum wind speed increases.[23] In order to construct an overall risk analysis, these return periods, expressed as annual probabilities, were combined with the damage function estimated by Nordhaus and the estimate of a $7.4 billion dollar loss from a Category 1 hurricane. Damage estimates also factored in the effects of rising sea levels and the increase in coastal population and value at risk.[24] Consequently, the damages to be expected from hurricanes striking the region increase dramatically over time, as the following table shows.

Expected losses are the damages that would be suffered from a storm of each intensity, multiplied by the probability of such a storm occurring, and then added up for all possible storms. These losses represent the actuarially fair value of hurricane damages to the region – the amount that insurers would have to collect in premiums (without overhead) to break even over time. As seen below, they rise dramatically, more than doubling in each decade because of the combined effects of global warming on hurricane intensities and sea level, along with the increase in value at risk. This perfect storm of heightened vulnerability and amplified risk will put Virginia's insurance sector under great pressure. Private insurers will have to raise rates dramatically or more will withdraw from the market. Coastal residents and communities also face an increasingly perilous future.

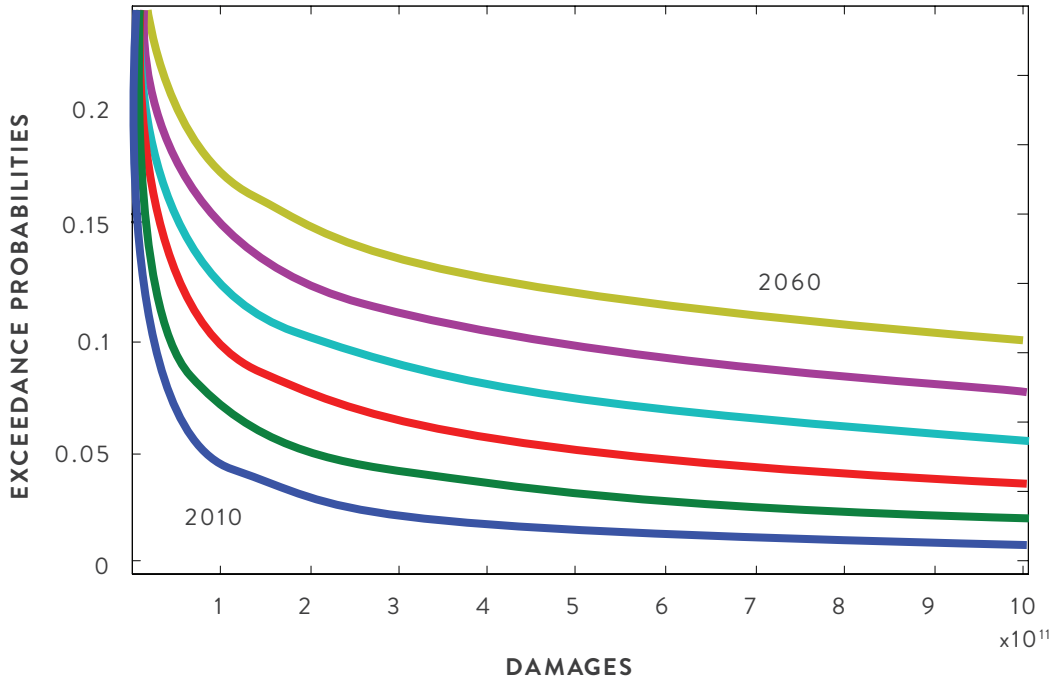
EXPECTED ANNUAL LOSSES FROM HURRICANES AND TROPICAL STORMS ($MIL)

Year	2010	2020	2030	2040	2050	2060
Expected Loss	517	1,539	4,226	11,090	28,286	70,879

SOURCE: *The methodology is further explained in Robert Repetto & Robert Easton, "Changing Climate, More Damaging Weather, Issues in Science & Technology," Winter 2010' accessed at http://www.issues.org/26.2/repetto.html.*

Another illustration of the increasing economic risks is to make use of loss exceedance curves, which are widely used in the insurance and other financial industries to measure risk exposure. A loss exceedance curve is the probability that a loss will be incurred that is equal to or greater than some amount. Loss exceedance curves for each decade from 2010 through 2060 for the Norfolk/Virginia Beach area are plotted in the following graph. Two things are immediately evident. First, the curves "flatten out" as loss amounts rise. Though probabilities of occurrence decline as maximum wind speeds rise, this is offset by the exponential increase in damages, so the probabilities of loss – combining the two – hardly fall. By 2050 there will be a 1 in 10 chance of a loss in coastal Virginia exceeding $9 billion dollars. Second, the loss exceedances rise rapidly over time. For example, the probability of damages exceeding $5 billion dollars rises from about 1 in 40 in the year 2010 to about 1 in 8 by the year 2050. The likelihood of even much greater losses rises almost as rapidly.

ANNUAL PROBABILITY OF LOSS DUE TO HURRICANES IN VIRGINIA, 2010-2060 ($BIL)



SOURCE: *The methodology is further explained in Robert Repetto & Robert Easton, "Changing Climate, More Damaging Weather, Issues in Science & Technology," Winter 2010' accessed at http://www.issues.org/26.2/repetto.html.*

The implication of these estimates, when put together, is that climate change is sharply amplifying the risks to Virginia's economy and citizens and substantially increasing the likelihood of a natural disaster.

IMPACTS ON VIRGINIA'S NATURAL ENVIRONMENT

Degradation of Chesapeake Bay and loss of its economic value

Among climate change's many environmental impacts, Virginians must be especially concerned about the consequences for Chesapeake Bay and other estuaries, which are incredibly valuable recreational and economic resources. Attempts to put an overall economic value on these resources, which include not only its fisheries and recreational uses but also its many ecological functions, are necessarily speculative though the billions of dollars and tens of thousands of jobs in fishery-related and recreational activities have been documented.[25] Nonetheless, the Chesapeake Bay Blue Ribbon Finance Panel put an overall value on the Bay in excess of a

trillion dollars.[26] Economists in Delaware estimated that a mere one percent of the Chesapeake Bay watershed generated economic benefits of $20 billion over a decade, which gives a perspective on the value of Virginia's much larger share.[27] Climate change will not only impair this value but also negate the billions of dollars currently being spent to rehabilitate the Chesapeake Bay resource.

Over the course of this century, scientists predict that the CO_2 content of Bay waters will increase by 50-150 percent, leading to higher acidity. Water temperatures will rise by two to six degrees C and water levels will increase by 0.7 to 1.6 meters and possibly much more if emissions grow rapidly.[28] Storm intensities in the watershed and some seasonal inflows from higher precipitation and runoff are likely to increase as well. The consequences are likely to be profound even though they are hard to predict due to the complex ecology of the Bay.

More than 50 percent of estuarine beaches and 25 percent of ocean beaches on Virginia's eastern shore will disappear. One consequence will be a loss of nesting areas for already endangered loggerhead and Kemp's ridley sea turtles.[29] The Chesapeake Bay could lose 50-80 percent of its tidal wetlands and marshes to inundation. An estimated 66 percent of the region's commercial fish species depend on these marshes for nursery and spawning grounds, including menhaden, bluefish, flounder and rockfish. The sport-fishing industry, which generates more than $1.5 billion dollars per year in expenditures, will be seriously affected. Salinity levels will increase, adversely affecting eelgrass, other aquatic plants and associated fish and shellfish species. Some of these changes are potentially irreversible, once ecological tipping points are reached.[30]

More intense storms will wash more non-point-source pollutants into the Chesapeake Bay, increasing turbidity and eutrophication.

Seagrass losses will be particularly devastating for duck species that depend on submerged aquatic vegetation for food, such as redhead, pintail, widgeon, black duck and canvasback. Duck hunting on the Eastern Shore, a popular activity for residents and visitors, will suffer. More intense storms will wash more non-point-source pollutants into the Chesapeake Bay, increasing turbidity and eutrophication. The occurrence of harmful algal blooms and oxygen deficits in Bay waters will increase.[31] Parasites that have helped to destroy oyster and crab populations will proliferate.[32] There are likely to be substantial changes in the mix of fish and shellfish species to be found in Chesapeake Bay waters and the productivity of the Bay, already severely impaired, is likely to be affected. The extent of these changes will be determined largely by the pace and degree of climate change.

Loss of Fish Stocks and Decreased Forest Productivity

Ecological impacts will not be limited to the coastal zone. In the upper reaches of Virginia's rivers and streams, warmer waters will reduce habitat for brook trout by up to 90 percent and reduce population numbers by more than half.[33] Brook trout cannot tolerate water temperatures higher than 70 degrees F. The numbers of fly fishermen will correspondingly decline. Virginia's forests will experience significant changes. Red spruce and balsam fir will almost disappear and the red maples, yellow poplars, and chestnut oaks will decline, to be replaced by loblolly and shortleaf pine. Forest pests will proliferate, such as the hemlock woolly adelgid, which is likely to eliminate all eastern hemlocks from Virginia's forests. Drought will encourage outbreaks of pine bark beetles and gypsy moths.[34] Whether overall forest productivity will rise or fall will depend on the balance between positive forces, such as CO2 fertilization, longer growing seasons and milder winters, and negative forces, such as more frequent droughts, fires, pest outbreaks and intense storms.

IMPACT ON HEALTH AND RELATED COSTS

Air Quality

The higher summer and fall temperatures are expected to affect air quality adversely. Release of pollen and other airborne allergens will increase with the changing seasons. Ozone and smog formation is likely to increase because higher temperatures heighten the underlying chemical reactions in the atmosphere and also increase volatile organic compounds released from trees and vegetation.[35] Atmospheric ozone exacerbates bronchitis, asthma and other lower respiratory tract diseases, which are among the leading causes of death in Virginia. Climate change will also raise concentrations of fine particulates, which are even more damaging to health.[36] The aggravated air pollution that typically accompanies heat waves especially harms children as they have a higher risk of developing asthma, lungs that are still developing and growing, and higher exposure because they breathe at a higher rate than adults do and often play outdoors.

National air quality standards for ozone are to be tightened eventually because of continuing health effects at the current level of standards. Recent EPA assessment concludes that allowable levels for fine particulates should be significantly lowered.[37] During 2011, Virginia's air monitoring systems recorded numerous violations of current ozone standards in the Richmond and Hampton Roads areas and across northern Virginia.[38] In addition, virtually all of northern Virginia violated the fine particulate standards in 2011.[39]

Climate change will make it even more difficult for Virginia to meet future air quality standards, particularly because hotter summers will increase summer peak electricity use, necessitating an escalation in the nitrogen oxide emissions that contribute to both ozone and particulate formation. Dominion Power is already scheduled to invest $500 million by 2015 in projects to reduce emissions from its coal-fired power plants in the state and will probably have to spend even more in the future. These amounts will be passed along in higher rates to electricity consumers in Virginia.

Health Impacts

These changes in climate will have significant impacts on the health and well being of Virginia's people, especially on the elderly and the very young, who together comprise nearly 20 percent of the population. For example, over the coming decades, Lyme disease, now confined to just one region, will spread across the state.[40] The seasonal feeding cycle of the main carrier of Lyme disease, ticks, is heavily influenced by climatic changes and warmer temperatures will result in more severe tick infections in Virginia and the propagation of Lyme disease in the state. Lyme disease can be extremely debilitating, affecting every tissue and every major organ system in the body and can even be fatal in severe cases. Studies have found that almost two-thirds of Lyme disease patients still experience significant symptoms months or years after the infection was treated, including persistent severe fatigue and pain.

The burden on the medical system from increased cases of Lyme disease alone will be substantial. A survey of over 2,000 people who had tested positive found that roughly 26 percent had been on disability or public support, with a majority receiving support for more than two years and 37 percent for more than five years.[41] Over half had visited an emergency room as a result of their illness, 15 percent had done so three to five times, and nine percent had done so six or more times. More than half of patients saw seven or more physicians to obtain a diagnosis; over a third saw 10 or more physicians.

In addition, three of the four leading causes of death in Virginia, heart disease, stroke, and chronic diseases of the lower respiratory tract, will be significantly exacerbated by climate changes. Episodes of extreme heat lead to increases in both illness and death.[42] Heat waves result in more heart attacks, strokes, and asthma attacks.

A recent study found that "heat wave mortality risk increased 2.49 percent for every one degree F increase in heat wave intensity and 0.38 percent for every 1-day increase in heat wave duration. Mortality increased 5.04 percent the first heat wave of the summer versus 2.65 percent in later heat waves, compared with non-heat wave days."[43]

In Virginia's cities, "heat island" effects will be intensified by higher nighttime temperatures. Elderly people, who are becoming a higher and higher percentage of the population, are particularly vulnerable because they are less able to effectively regulate body temperature, and often live alone without air conditioning. People who are obese, 25 percent of Virginia's population, are also at higher risk.

Adverse health effects of climate change will also add to Virginia's fiscal pressures. Health-related expenditures account for 30 percent of the state's budget, second only to education. [44] The largest category of spending is on Virginia's Medicaid program, serving children, the elderly and people with disabilities. Despite some of the most stringent eligibility criteria in the nation, the program's budgetary impact is growing, with the elderly and people with disabilities being responsible for the heaviest fiscal burden, largely because of the prevalence of chronic problems, such as heart disease and stroke.

CLIMATE CHANGE'S IMPACT ON TOURISM

Another important sector of the economy that will suffer from these environmental impacts is the tourism and travel industry, which is Virginia's 5th largest employer. Counting direct and induced employment, the industry generated 287,700 jobs in 2010 and more than $7.5 billion in payrolls. Total expenditures by tourists in 2010 exceeded $31 billion, more than seven percent of the state's gross domestic product.[45] The leading travel and tourist destinations are in Northern Virginia in Arlington, Fairfax and Loudoun counties, near the nation's capital. Of leisure travelers, 90 percent visited historic sites and battlefields and 84 percent visited beaches, national and state parks, or engaged in other nature-related activities, including hunting, fishing and bird-watching.[46]

This industry is at risk as climate change threatens many vacation destinations. Historic Jamestown Island could be completely inundated and popular Chincoteague could be battered and lose 80 to 90 percent of its beaches.[47] Most tourists arrive in the summer months and their travel plans will be affected by higher heat and humidity, more frequent heat waves, and more frequent intense storms. Families walking with children around urban sites in 100 degree heat and humidity do not greatly enjoy their sightseeing experience. One out of five families whose beach vacations are interrupted by heavy storms cancels their plans to return in the following year.[48]

THE WAY FORWARD

Near the end of 2007, then Governor Tim Kaine formed a broadly based Climate Change Commission to consider the potential impacts of climate change on the state and to recommend specific actions both to mitigate and to adapt to those impacts. The Commission consulted widely among public, industry and scientific groups and put forward a Climate Change Action Plan in December 2008.[49] It contained many well-founded recommendations for cost-effective actions to improve energy efficiency, to mitigate and sequester greenhouse gas emissions and to promote effective adaptation.

The Action Plan recognized that despite these opportunities for action within Virginia, climate change is a problem that requires national and international action as well as state and local participation.[50] The succeeding administration has shown little interest in implementing those recommendations. According to a very recent

report in the Roanoke Times, "This week, the Virginia secretary of natural resources said Gov. Bob McDonnell has no interest in reviving a climate-change commission created by his predecessor, Gov. Tim Kaine."[51]

The rising risks to Virginia's economy, its people and its irreplaceable natural resources cannot be avoided simply by denying that they exist. Virginia's leaders should recognize the increasing dangers that global warming poses and support implementation of the useful recommendations made by the Climate Change Action Plan or adopt equally effective policies of their own. In particular, Virginia's leaders should follow the example of former Republican Senator John Warner and support strong state, national and international action to reduce greenhouse gas emissions.

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ABOUT DĒMOS

Dēmos is a non-partisan public policy research and advocacy organization founded in 2000. Headquartered in New York City, Dēmos works with policymakers around the country in pursuit of four overarching goals—a more equitable economy with widely shared prosperity and opportunity; a vibrant and inclusive democracy with high levels of voting and civic engagement; an empowered public sector that works for the common good; and responsible U.S. engagement in an interdependent world.

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