CLIMATE CHANGE

"Careful and comprehensive scientific assessments have clearly demonstrated that the Earth's climate system is changing in response to growing atmospheric burdens of greenhouse gases (GHGs) and absorbing aerosol particles." (IPCC, 2007) "Climate change is occurring, is caused largely by human activities, and poses significant risks for—and in many cases is already affecting—a broad range of human and natural systems." (NRC, 2010a) "The potential threats are serious and actions are required to mitigate climate change risks and to adapt to deleterious climate change impacts that probably cannot be avoided." (NRC, 2010b, c)

This statement reviews key probable climate change impacts and recommends actions required to mitigate or adapt to current and anticipated consequences.

CLIMATE CHANGE IMPACTS

The Earth's climate is the product of complex, highly dynamic, and often nonlinear, interactions among physical, chemical, and biological processes occurring at many scales in the atmosphere; at terrestrial, fresh water and marine surfaces; and in the depths of the oceans and landforms. While recent research advances in Earth systems science have greatly strengthened our understanding of prior and current climate properties and processes, our ability to quantitatively predict how the future climate will respond to continued and increasing greenhouse-gas and fine-particle emissions is still limited. Even more limited is our ability to precisely predict how the Earth's ecological and human systems will respond to climate changes.

However, comprehensive scientific assessments of our current and potential future climates clearly indicate that climate change is real, largely attributable to emissions from human activities, and potentially a very serious problem. This sober conclusion has been recently reconfirmed by an in-depth set of studies focused on "America's Climate Choices" (ACC) conducted by the U.S. National Academies (NRC, 2010a, b, c, d). The ACC studies, performed by independent and highly respected teams of scientists, engineers, and other skilled professionals, reached the same general conclusions that were published in the latest comprehensive assessment conducted by the International Panel on Climate Change (IPCC, 2007). Recently, some errors in the IPCC (2007) reports have been acknowledged and questions about the transparency of the IPCC process have been raised. An independent review by the InterAcademy Council (IAC), a collaboration of the world's leading national science academies, found "that the IPCC assessment process has been successful overall and has served society well," and that "through its unique partnership between scientists and governments, the IPCC has heightened public awareness of climate change, raised the level of scientific debate, and influenced the science agendas of many nations." (IAC, 2010) The IAC also recommended managerial and procedural improvements that would strengthen future assessments.

The range of observed and potential climate change impacts identified by the ACC assessment include a warmer climate with more extreme weather events, significant sea level rise, more constrained fresh water sources, deterioration or loss of key land and marine ecosystems, and reduced food resources— many of which may pose serious public health threats. (NRC, 2010a) The

effects of an unmitigated rate of climate change on key Earth system components, ecological systems, and human society over the next 50 years are likely to be severe and possibly irreversible on century time scales.

RECOMMENDATIONS

1. Earth and Societal Systems Research

Successfully addressing the challenges of global, regional, and local climate change requires enhanced understanding of Earth system dynamics at many scales. Climate change is a very complex phenomenon involving the coupled physical, chemical, and biological processes affecting the atmosphere, land and fresh water surfaces, and the oceans. (NRC, 2010a) The United States has been a leader in Earth system and climate change research, and, after a reduction in support at mid-decade, federal funding has recently increased. This enhanced research funding is required to support increased activities addressing a range of vital topics, including atmospheric chemistry, dynamics and radiative transport; cloud and aerosol chemistry and physics; ocean biogeochemistry and dynamics; glacial, ice cap and sea ice dynamics; hydrology; terrestrial and ocean ecology; soil microbiology; multi-scale Earth system modeling and other key disciplines. The ability to quantify trends in climate parameters and resulting impacts on geological and ecological systems at relevant scales will require the enhancement and maintenance of sophisticated Earth observation satellites as well as comprehensive in situ atmospheric, oceanic, and ecological sensor systems. Earth systems research must thoroughly investigate the rate, extent, and consequences of changing ocean acidity (NRC, 2010e) and to evaluate the effectiveness and consequences of geoengineering schemes to manipulate solar radiation reaching the Earth's surface and to remove and sequester greenhouse gases from emissions streams or the ambient atmosphere.

However, the research challenge is not only to develop a more comprehensive understanding of the Earth systems that create and respond to climate, but to develop the scientific understanding necessary for society to develop, evaluate, and wisely adopt strategies capable of mitigating drastic climate change and to adapt to the inevitable climate changes that are already occurring and will evolve before successful mitigation strategies can be effective. Thus, "climate research needs to be integrative and interdisciplinary," encompassing many societal components and activities that are profoundly influenced by climate, including fresh water resources, agriculture; fisheries and food production, public health, transportation, the built environment, energy production and use, and economic well-being. (NRC, 2010a)

Recommendation 1a - Maintain robust and uninterrupted federal funding for a comprehensive U.S. Earth systems research program to better define and document current and predict future impacts of climate change on local, regional, national and global scales. Cooperation and collaboration with other nations on both a wide-ranging Earth systems research agenda and the maintenance and enhancement of necessary Earth observing systems that detect and track key climate parameters should be emphasized.

Recommendation 1b – Expand the current U.S. climate research program to more fully investigate the interactions of Earth systems with vital societal systems' components and activities. The aim is to better inform the systematic analyses required to develop and evaluate potential climate change mitigation and adaptation strategies and to measure the effectiveness and consequences of implemented policies.

2. Greenhouse Gas Emission Reduction

It is unquestioned that greenhouse gas emissions and levels have been increasing over the past 150 years, as fossil fuels have become the dominant fuels worldwide. Although we cannot precisely

predict the effects on the earth's climate, scientific consensus expects increased global temperatures resulting in adverse consequences throughout much of the world. Even in the face of uncertainty, the most prudent action by the United States and other nations is to minimize greenhouse gas emissions using current technologies to avert the most severe projected effects of climate change while also gaining the benefits of reduced fossil fuel combustion (NRC, 2010b).

Transportation and electricity generation account for almost three quarters of the carbon dioxide generated in the United States and thus should be a focus for reducing emissions. Opportunities to reduce carbon dioxide emissions in the transportation sector include enhanced fuel economy for on- and off-road vehicles and more convenient and available mass transit. Adopting non-combustion energy sources based on solar thermal, solar photovoltaic, wind, tidal power, or nuclear energy can reduce carbon dioxide emissions produced by fossil fuel combustion for electricity generation. Nuclear generation of electrical power is already technologically mature, but issues of fuel diversion prevention, spent fuel disposal, and power plant security hinder the expansion of this technology. Conservation of energy can be accomplished through better insulated, more efficiently heated and cooled buildings and more efficient lighting—often at reduced life cycle cost. However, a complete life cycle analysis of the greenhouse gas emissions and other environmental impacts—as well as the potential costs, savings, and safety concerns of each alternative energy source—must be objectively evaluated before large-scale adoption.

Fossil-fueled electrical power generation systems may also be part of carbon dioxide reduction strategies if effective and economic means to sequester carbon dioxide emissions from coal combustion or advanced coal processing are developed. Successful efforts to reduce petroleum and natural gas consumption through conservation or sustainable-fuel substitution will not only reduce net carbon dioxide emissions, but also reduce reliance on fuel sources that are increasingly insecure for both economic and geopolitical reasons. Reduced reliance on traditional combustion-driven energy systems will also contribute to both better air quality and reduced acidification of the ocean. Many opportunities also exist to reduce non-carbon dioxide greenhouse emissions—including biogenic methane from landfills, agriculture, and other land-use practices—and biogenic nitrous oxide from agricultural and non-agricultural fertilizer use, air pollutant deposition, and waste disposal. Enhanced research in the fields of energy efficiency and conservation, alternative and renewable energy sources, climate change adaptation, pollution prevention, and carbon sequestration will also support other important national goals: energy security, economic prosperity, and environmental protection.

Recommendation 2a – The United States should develop a portfolio of subsidies, tax, regulatory, and other incentives to reduce greenhouse gas emissions and allow advanced energy technologies, as they mature, to operate on an even playing field with current energy sources. "A carbon pricing strategy is a critical foundation of the policy portfolio for limiting future climate change. It creates incentives for cost-effective reduction of GHGs and provides the basis for innovation and a sustainable market for renewable resources" (NRC, 2010b). This carbon-pricing strategy should take into consideration the full life-cycle costs and sustainability implications of the carbon effects from various energy options. The United States should also work closely with all major greenhouse-gas emitter nations to secure their commitment to similar greenhouse-gas emission reductions.

Recommendation 2b – The United States should significantly raise its public and private sector investments in technologies to mitigate climate change through economically viable energy conservation, sustainable fuel substitution for fossil fuels, carbon sequestration, and non-fossil fuel based energy sources with significantly reduced life cycle impacts on the environment. The following key actions should be included:

- Encouragement to share best practices for business and industry using private sector funding for development of enhanced low-emission, energy technologies and energy-efficient processes—especially since many of these are cost effective. Encouragement of additional venture funding to commercialize new energy-efficient technologies. The growing international demand for advanced, sustainable energy and energy-efficient process technologies in both developed and developing countries represents a major market that U.S. based companies should make every effort to serve, reaping economic benefits for themselves and environmental benefits for everyone.
- Comprehensive evaluation of the life cycle environmental, health, safety, economic and social impacts of new and existing technologies and processes before and during new technology implementation to ensure they help solve climate change issues without creating unanticipated problems.
- Enhanced federal R&D funding to develop both innovative energy sources with low net greenhouse gas emission and energy-efficient technologies and processes for the industrial, agricultural and transportation sectors.
- Federal government revaluation of subsidies and tax, regulatory and other incentives to allow advanced energy technologies, as they mature, to operate on an even playing field with current energy sources.

3. Adaptation to Global Change

The current levels of long-lived atmospheric greenhouse gases and the levels of increased CO_2 and heat absorbed by the world's oceans ensure that the climate will almost certainly continue to increase for decades, even if greenhouse gas and absorbing particle emissions are scaled back to more sustainable levels (IPCC, 2007; NRC, 2010a; 2010c). Thus, our nation and the world must be prepared to adapt to changes in water supplies, agricultural productivity, severe weather patterns, sea-level rise, ocean acidification and ecosystem viabilities.

The enhanced research and development activities called for in Recommendations 1a and 1b, above, will help us better predict the circumstances to which we must adapt. Additional research will be needed to understand how to enable society to survive and thrive under new climate conditions. In cooperation with local, state and regional government, community, business, environmental and academic leaders the federal government will need to develop a collaborative national climate change adaptation strategy (NRC, 2010d). The White House Council on Environmental Quality (CEQ) has issued a progress report on the progress of a federal interagency task force charged to recommend actions to support a national climate change adaptation strategy (CEQ, 2010).

Recommendation 3a – Collaboration at every level of government and with other nations should be encouraged to assess current and probable future climate change impacts at local, state, regional, national and global scales and to share ways to successfully cope with climate change effects.

Recommendation 3b – Local, state, and regional entities should identify relevant climate change threats and develop and evaluate appropriate adaptation strategies that meet the needs of their communities. The federal government, working collaboratively with local, state, and regional governments and appropriate stakeholders, should integrate these adaptation strategies into a national climate change adaptation strategy.

4. Climate Change Literacy and Education

As described above, climate science is highly complex, requiring a multi-temporal and multi-spatial understanding of the interrelationships of intricate chemical, physical, and biological systems.

Evaluating policy alternatives requires an understanding of engineering trade-offs associated with risk, life-cycle, and cost-benefit analyses. Decisions involve many factors beyond climate science, including economics, social values, competing priorities, and the risk of uncertainty. Climate change education requires a risk-management approach that integrates diverse and complicated disciplines to account for the inherent uncertainties about the timing, likelihood, and severity of the impacts, as well as the human dimensions that greatly influence making decisions. As described by the Climate Literacy Guide (USGRP, 2009), a climate-literate person

- understands the essential principles of Earth's climate system,
- knows how to assess scientifically credible information about climate,
- communicates about climate and climate change in a meaningful way, and
- is able to make informed and responsible decisions with regard to actions that may affect climate.

To make informed decisions, people need a basic understanding of the causes, likelihood, and severity of the impacts of climate change, and the range, cost, and efficacy of different options to limit or adapt. Transparency, accountability, and fairness in the measurement, reporting, and verification of data on climate change risks and vulnerabilities, sources of GHG emissions, and climate policy are priorities. Climate educators and communicators at all levels of society should set a tone of respect for diverse perspectives and an open and honest consideration of the implications of various responses to climate change. When discussion moves from core scientific concepts to more complex issues involving societal values, students should learn how to engage in responsible, respectful discourse and debate, as well as critical thinking and analysis skills (NRC, 2010d).

Climate change education for the public is essential to informed rational personal choices. Informal science education can play a critical role in reaching broad and diverse audiences and is well situated to help improve public climate change awareness, understanding, and informed decision-making.

As thought leaders in their communities, public institutions such as schools, museums, and universities must take a lead role in demonstrating sustainable technologies and reducing their own emissions footprint. In an era of decreasing financial resources, such investment can also pay significant dividends in reducing the cost of education. Properly implemented, these initiatives provide living laboratories for students, teachers, parents, and the broader public to explore, learn, and understand what sustainability means and how this relates to reducing the risk of climate change.

Recommendation 4a: Develop a national strategy to support climate change education and communication that both involves students, technical professionals, public servants and the general public, as well as being integrated with state and local initiatives. A national climate education act could serve as a catalyzing agent to reinvigorate science, technology, engineering, and mathematics (STEM) education across the nation. Such a strategy should include an integrated approach to sustainability education that connects science with social science, risk management, and economic issues. Such a policy must also include integrated support for informal science education.

Recommendation 4b: Provide federal support to facilitate the implementation of green and sustainable technologies that transform our educational environment. Specific supported activities should include efforts to recover or retain green space, retrofit programs to enhance energy efficiency or encourage the use of sustainable energy technologies, conservation of water resources, the use of renewable resources, and other efforts that reduce greenhouse gas emissions (including emissions from electrical power generation, heating, commuting, and air travel).

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