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Setting the Foundation to Transform the U.S. Energy System

THREE FEDERAL ACTION PLANS FOR NEAR- AND LONG-TERM SUCCESS

December 2008

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Setting the Foundation to Transform the U.S. Energy System

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Executive Summary

The new administration is already setting the broad outlines of an energy and environment policy framework to reduce carbon emissions, modernize the electricity infrastructure, drive early adoption of renewables, improve efficiency, and reduce dependence on fossil fuels—all in a context that strengthens the U.S. economy and competitive position globally. This document outlines what we believe to be the essential first steps for making rapid progress toward these goals while establishing the enabling conditions for long-term success.

"We're calling for urgent action from science, industry, and government to ensure our nation's energy sustainability, security, and economic prosperity. This challenge is enormous, but not out of reach."

— Mike Davis, Associate Laboratory Director
Pacific Northwest National Laboratory

Transforming the Nation's Electric Power Network

Our nation needs the 21st century electric grid, an intelligent infrastructure that incorporates modern monitoring, communication, and computing technologies. Immediate and aggressive investments in modernizing the electricity transmission and distribution grid will enable substantial and lasting gains in energy efficiency and reliability, facilitate rapid adoption of renewable energy and hybrid cars, and open new markets that act upon a transparent view of the national energy system. This serves important national goals while stimulating major new economic growth analogous to the markets, jobs, and efficiencies created by the inception of the Internet and the development of the interstate highway system. A successful transition to the 21st century electric grid depends upon setting the conditions for massive private investment in new infrastructure and electricity markets while serving the national public good. The three federal actions described later in this document set those conditions.

Decarbonizing the Energy Economy

Economically transitioning from today's fossil-based economy, where virtually all of the resulting carbon dioxide (CO_2) and other emissions are vented into the atmosphere, to an energy economy where non-emitting sources provide significant portions of energy demand will require decades. Consequently, CO_2 capture and storage (CCS) technologies are arguably one of the most important classes of technology needed in the 21st century to successfully retain a reliable supply of affordable energy while addressing the threat of climate change. Immediate and aggressive steps to reduce carbon emissions from coal-fueled plants and other

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Energy demands, environmental impacts, and national security are some of America's toughest challenges. At the Pacific Northwest National Laboratory, we are driven to provide science and solutions to meet these challenges. We accomplish this mission through the power of our interdisciplinary teams, bringing together experts from multiple disciplines to tackle complex problems.

Everything we do promotes scientific discovery, provides educational opportunities, and benefits from PNNL's most valuable assets—our expertise, premier facilities, and a passion for science.

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fossil fuel-intensive elements of our energy system will enable industries in the United States and around the world to meet carbon emission reduction goals while minimizing economic disruption and large-scale stranding of productive capital-intensive energy production assets. The U.S. has an opportunity to quickly cement its international leadership in CCS technology, providing tangible evidence of our intent to achieve near-term progress toward reducing carbon emissions while laying the foundation for implementing longer-term replacement technologies. The new administration can take four actions, described in the second section of this document, to accelerate immediate progress and long-term success in this important area.

Creating Better Assessment Tools for Climate Policy

Policy makers have used integrated assessment tools for decades to gain essential insights into the complex interplay of policies, technologies, capital, markets, and climate change. There is significant capacity to enhance the value of these tools for immediate and expanded use as the nation reengages in international negotiations and demonstrates policy leadership at home. An early investment in integrated assessment will increase the likelihood that policy choices lead to long-term success, and that the billions in federal and private investments that are committed based on these decisions are wisely stewarded. The third section of this document defines two actions that the federal government can take to enhance the value and broad accessibility of these tools for decision makers across the federal, state, and private sectors, allowing decision making to proceed on both a national and international level with urgency, credibility, and confidence.

TAKE ACTION

The actions outlined in this document will require strategic partnerships and federal investments, assume cost sharing at levels of 25% to 50%, and engage the U.S. federal government, states, industry, universities, national laboratories, and other nations. In this document, we focus on the immediate federal investments required to set the conditions for rapid and sustained progress toward our national goals.

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Transforming the Nation's Electric Power Network

EFFICIENCY, INTELLIGENCE, TRANSPARENCY

New national energy priorities that call for increased renewable electricity generation, accelerated adoption of hybrid electric vehicles, and ambitious goals for end-use efficiency will transform the way the U.S. uses electricity. Making this transformation possible—while continuing to deliver highly reliable and affordable electricity—requires that we also modernize our electricity transmission and distribution infrastructure. We need the 21st century electric grid, an intelligent infrastructure that incorporates modern monitoring, communication, and computing technologies. This modernization will deliver new levels of efficiency, flexibility, security, resiliency, and transparency, serving the energy interests of our nation for decades. It also will spark major new economic growth analogous to the markets, jobs, and efficiencies created by the inception of the Internet and the development of the interstate highway system.[1] A successful transition depends upon setting the conditions for massive private sector investment in new electricity and energy markets while serving the national public good. The three federal actions outlined below are essential to setting those conditions.

The demand for electricity in the U.S. is projected to double by 2050. The system built to deliver this electricity was designed without the benefit of today's communication and information technology—it's time to build a modern grid that is smarter, stronger, and more secure.

–International Energy Agency

TAKE ACTION

Launched immediately, each of the following federal actions can either be completed or deliver material progress within the next four years. Together, these actions would set the conditions needed to realize the full promise of a modern infrastructure that enables the transformation of the entire U.S. energy economy.

Establish Authority and Resources for National Grid Planning

The first action establishes a strong federal role in planning the 21st century national grid, backed by a credible analytic capability. This action will result in the ability to plan transmission infrastructure development in the national interest and provide information that enables significant private sector capital investment in new transmission and generation infrastructure.

A key policy action involves issuance of executive orders and/or legislation establishing the Federal Energy Regulatory Commission

1 Grid modernization, which also accelerates development of wind energy, installation of distributed solar technology and creation of new businesses based on technology innovation, should lead to creation of up to 1 million new jobs within the next six to eight years.

…the electricity delivery system will need considerable capital investment to meet growing load, incorporate non-traditional power sources, and take advantage of technological advances to modernize the existing grid…

–2009 National Electricity Delivery Forum

(FERC) as the lead agency with clear responsibility for national transmission planning, a logical extension of the authority granted in the 2005 Energy Policy Act. This initial step will signal the administration's commitment to a comprehensive grid strategy that serves the national public interest by establishing a clear federal authority to address the complex transmission issues that transcend the boundaries of current public and private service territories and state regulators.[2] This commitment to develop a national infrastructure that serves the public good reflects the tenets upon which our original electricity system was built and can be accomplished without destabilizing or interfering with any existing business entities or regulatory authorities.

To effectively meet these new federal grid planning responsibilities, FERC will need access to analytic capabilities that can provide credible, unbiased information to support the planning of new interstate electricity transmission capacity and definition of performance metrics for new systems. Development of these supporting analytic capabilities should be a collaborative effort involving the North American Electric Reliability Corporation (NERC), the Department of Energy (DOE) and FERC focusing initially on two primary tasks:

- completing the development of comprehensive system models that represent each interconnection in the grid. These models should incorporate real-time monitoring data and load forecasts at a suitable level of detail to enable national planning as well as identification of areas where new policies, incentives, or performance standards might be needed.[3]
- establishing a data management and visualization infrastructure that provides the means to effectively share modeling, necessary grid performance data, and other information with interested parties in a fair and transparent manner, ensuring a level playing field for open competition while retaining the means for effective regulation to ensure that the national interest is served.[4]

Completing the tasks above will provide the capabilities needed to support national transmission planning. These tasks will require an initial investment on the order of $20 million per year over the next two years with funding of at least $5 million per year thereafter to sustain the analytic expertise and data management facilities to support future transmission planning.

Establish a Real-Time, Nationwide Grid Monitoring System

The second action creates the means to assess the performance of the grid nationwide (beyond a single interconnection). This capability is needed to identify economic opportunities for achieving nationwide transmission and distribution efficiency and to ensure continued reliability while incorporating significant amounts of new, intermittent renewable generating capacity. A federal investment is required to install a monitoring and communication infrastructure that provides real-time, wide-area measurements of grid function. This investment will provide a truly national

2 The necessity of this role is illustrated by the current need to define the means to connect rapidly developing renewable generation (often located in remote areas of the country) to the grid and transmit that electricity across state lines to major urban markets.

3 Examples of the need for sophisticated modeling are numerous. For national optimization, what is the best siting of capital infrastructure to reduce bottlenecks and serve new markets? How can public and private cooperation address risks such as time to deploy and system security? How can potential renewable generating capacity in remote regions be developed to serve needs in areas currently unable to achieve renewable portfolio standards? A model of the Texas system presently exists and a Western model is being developed; development of an Eastern model needs to be launched and the models need to be integrated.

4 Fair, transparent dissemination of information is best facilitated by public institutions that provide the necessary computing, data storage, cyber security and real-time nationwide view of the grid. One or more of our National Laboratories would be candidates and likely possess the essential elements needed for this capability.

view of the power system with real-time awareness of the performance of all three interconnections currently serving U.S. consumers.

Providing a transparent view to the relevant information generated from this infrastructure can then enable a level of grid performance not attainable in the existing operating model. With this new information, public and private sectors can take actions to reduce the costs associated with transmission congestion and outages that are passed on to consumers and the operating costs for utilities by saving time and improving capital efficiency. The key tasks supported by this federal investment are:

- accelerating the completion of the ongoing effort to build a national network of state-of-the-art grid monitoring technology—phasor measurement units (PMUs)—to assess and understand interconnection operations
- installing the data exchange and communication network needed to transmit the resulting measurements of real-time performance across the interconnections
- developing the systems needed to utilize these second-by-second measurements to assess the real-time operation of the grid nationwide.

Developing this essential infrastructure will require a federal investment on the order of $50 million per year for four years. FERC, through NERC, should make a priority of planning and managing this effort, for collecting the resulting performance data, and for using this data to define metrics that ensure nationwide improvements in grid performance.

Demonstrate National Benefits of Grid Intelligence

The first two actions are essential for expanding the transmission capacity and enhancing the performance of the national grid. The complete transformation of the electricity infrastructure and related energy markets requires incorporation of the full capability of modern information and communication technologies into the system from generation through transmission and distribution. This infusion of "smart grid" capability is the administration's greatest opportunity to create the flexibility, resilience, and demand-response capability that are the hallmarks of the 21st century grid. The intelligence enabled by two-way communication and advanced information technology can provide an energy system that adroitly communicates market signals to and from end users, optimizes load shape and load/resource balance, and opens major new markets based upon this information.

The DOE can make a significant contribution to launching this transformation by undertaking a number of large-scale demonstration projects that test the potential of new "grid transformation technologies" to deliver new aspects of performance while improving overall system efficiency, reliability, and security.[5] The information developed through these projects, conducted in partnership with the private sector and state regulators, will demonstrate the feasibility and benefits of grid intelligence and close critical knowledge gaps that are preventing the necessary capital movement to 21st century grid technology businesses. Priority should be given to the following demonstrations:

- reliable integration of renewables into the grid, such that 20% of delivered electrical energy is from renewable resources (as required to enable renewable portfolio policy initiatives at state, regional, and national levels) using wide-area monitoring, control, and communication systems
- real-time matching of capacity to aggregated demand using new technologies such as large-scale energy storage and advanced two-way communications

"Now is the time to make the long neglected investments necessary in our nation's electricity grid to increase its efficiency and reliability and to meet future demand growth."

–Senators Cantwell, Murray, Wyden, Crapo, Tester, and Merkley; December 19, 2008 letter to Majority Leader Reid, Minority Leader McConnell, Chairman Byrd, and Senator Cochran

5 Examples include many manifestations of advanced two-way integrated communications; numerous sensing, measurement and metering concepts; advanced control tools; and large-scale energy storage. Additional information is available from the authors.

NATIONAL BENEFITS

These near-term federal actions will set the conditions for significant market activity that is required to transform the electricity industry, serving the national public good and delivering the following benefits to the nation:

- a national infrastructure that meets future reliability standards and is resilient to natural disasters and malicious attacks
- much greater system efficiency spanning generation, transmission, distribution, and end use, enabled by new, real-time digital monitoring and two-way communication across the entire grid
- increased contributions of wind and other renewable generation resources by resolving inadequate grid connection and transmission capacity while addressing the intermittent nature of these resources
- electrification of a substantial fraction of the nation's transportation sector, opening new markets while reducing oil imports and carbon emissions
- new business options such as distributed generation, net metering, vehicle-to-grid feeds, and demand aggregation that open new energy markets while improving overall grid performance (e.g., load balancing and intermittence).

The 21st century grid will save American consumers billions of dollars annually by avoiding blackouts, reducing costs associated with transmission congestion, and increasing end-use efficiency. Further, the new national, intelligent infrastructure will unleash economic activity analogous to the new markets spurred by federal investments in the essential elements of the Internet and the interstate highway system.

- real-time control concepts for transmission systems that leverage the phasor measurement technology to substantially improve security, resilience, flexibility and asset utilization in critical transmission paths
- substantially increased end-use efficiency, combined with improved peak management and emissions reductions, using demand response and two-way communication systems that provide consumers with precise knowledge of pricing, demand, and cumulative carbon offsets
- addition of significant numbers of plug-in hybrid electric (PHEVs) and all-electric vehicles, utilizing grid intelligence to minimize increased generating capacity requirements to meet the new load and ensure reduced overall carbon emissions.

In addition to planning and executing these large-scale public-private demonstrations, DOE needs an expanded research program directed at rapidly defining new appliance standards to enable interaction of "smart" appliances with the emerging intelligent grid. Quickly developing these standards will drive private sector innovation that will take demand response and end-use efficiency to new levels by providing customers with the information and means to respond to real-time price and incentive signals. Additionally, the DOE program should move urgently to address the need for materials and manufacturing methods that can reduce the cost of large-scale energy storage systems. Together, the expanded research program and the demonstration projects will require an incremental federal investment on the order of $50 million per year over the next four years.

The timely definition of standards and completion of the demonstrations, followed by rapid dissemination of the resulting critical findings, will enable a clear understanding of the feasibility and limits of two-way, real-time communication between generation and end users. The information developed through these partnerships will enable regulatory innovation at the state level, providing investment incentives and price signals to consumers and utilities. Further, this action will provide critical information at an early stage of business activity, reducing uncertainty and minimizing the number of failed technology ventures. The result will be a dramatic acceleration of private capital investment in new services, new infrastructure, and new technology arising from both the current regulated industry and a wide array of new entrepreneurial entrants. It is this private sector investment that will truly transform the U.S. energy industry to a modern national asset that delivers significant national benefits.

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Decarbonizing the Energy Economy

CARBON CAPTURE AND STORAGE

Scientific evidence indicates that major decarbonization of the world's energy system is necessary to avoid irreversible climate change. Anthropogenic carbon emissions must be reduced by 50 to 80% by mid-century. This outcome must be achieved in the face of a vast carbon-based energy infrastructure in the developed world that cannot be transformed overnight compounded by continued unprecedented growth of carbon-based energy in the developing world.

Crafting climate legislation is perhaps one of the most difficult challenges facing Congress. Effective policy must balance the drive for action on carbon dioxide emissions with measures to minimize the economic cost that is inherent in moving the energy foundation of the U.S. economy away from free venting of carbon emissions. Economically transitioning from a fossil-based economy to an energy economy where non-emitting sources provide significant portions of energy demand will take decades. Consequently, carbon dioxide capture and storage (CCS) is arguably one of the most important technologies of the 21st century for successfully addressing the climate change threat while providing a reliable supply of affordable energy.

The availability of viable CCS technologies is critical to the success of a wide spectrum of market sectors, particularly, the electric utilities, petrochemicals, steel production, cement and fermentation industries, as well as the emerging biofuels production industry. It is estimated that a portfolio of CCS technologies will reduce the global cost of addressing climate change by more than $5 trillion over the century. Achieving this level of benefit will require federal investment in carbon capture and sequestration research, development, and demonstration (RD&D) on the order of $17 billion over the coming decade. This investment is in addition to significant private sector RD&D investments and federal deployment incentives.

Coal's share of world carbon dioxide emissions grew from 39% in 1990 to 41% in 2005 and is projected to increase to 44% by 2030. Coal is the most carbon-intensive of the fossil fuels, and it is the fastest-growing energy source in the IEO2008 reference case projection, reflecting its important role in the energy mix of non-OECD countries—especially China and India.

— Source: International Energy Outlook 2008

TAKE ACTION

Transitioning to an economy in which carbon emissions are reduced by 50 to 80% by mid-century—and on a path towards near elimination by the end of the century—requires immediate action to develop and demonstrate commercially viable CCS technologies. To accelerate this transition, CCS technologies need to begin penetrating niche commercial markets and ultimately

into the core of the nation's energy production infrastructure (e.g., large refineries and base load power plants) within the next two decades.

Public, private, and international partnerships are essential to leverage resources, share the risk of developing and demonstrating novel CCS technologies, and accelerate the availability of successful solutions. The federal government's role is to catalyze CCS research and development, and with U.S. industry, enable commercial deployment through appropriate policy and regulation. These public-private partnerships will need to develop new cost-competitive carbon capture technologies, validate the viability of large-scale carbon sequestration, and build and demonstrate first-of-a-kind cost-competitive commercial-scale CCS plants.

Existing coal-fueled units represent 90.1% cumulative coal-fueled CO_2 emissions between 2007 and 2030.

— Based on Annual Energy Outlook Reference Case

The following actions describe a framework, schedule, and the necessary federal investments for accelerating the development of CCS technologies. We assume a coordinated effort between states and federal agencies to establish the policy, legal, and regulatory framework needed for commercial deployment of CCS.

Accelerate the Development and Deployment of New Carbon Capture Technologies

Early and aggressive RD&D investments in new carbon capture technologies are necessary to ensure the availability of economically viable carbon capture (and coal conversion technologies) for widespread deployment by 2020 into the core of the national energy system. These investments should be designed to reduce the cost of post-combustion carbon capture processes compatible with existing power plants and industrial energy systems, as well as capture systems designed for the next generation of coal conversion technologies. Specific actions include:

- mobilizing both the U.S. public scientific base (universities and federal research institutions) and private industry to discover and develop new cost-competitive carbon capture materials and technologies
- initiating pilot-scale testing of new carbon capture technologies by 2012 that will enable the retrofit of the current coal-fueled plants
- initiating pilot-scale testing of new carbon capture technologies by 2012 that will enable the retrofit of industrial sources such as cement plants, iron and steel plants, fertilizer, refineries, and biomass plants
- expanding the engineering research and development that advances the integration of new technologies (capture, water recovery, high-temperature material, gas turbines, fuel cells) into the next generation of highly efficient coal-fueled plants.

This effort will require a total federal investment on the order of $3.5 billion through 2020. Of this total investment, $200 million is required in fiscal year 2010, increasing to $500 million by 2012, to accelerate technology development and foster pilot-scale retrofit testing of carbon capture at existing coal-fueled utility and industrial facilities.

Build the Scientific and Institutional Foundation for Large-Scale Geological Sequestration

Initial estimates suggest that the U.S. has geologic storage capacity well in excess of the likely CO_2 emissions projected for the next 100 years. This storage capacity is well distributed throughout much of the nation and is in close proximity to the vast majority of large power plants and other industrial facilities that would be prime candidates for commercial adoption of CCS. Assuring that carbon sequestration is a viable option for widespread deployment by 2020

requires rapidly establishing the optimal siting of large-scale storage locations along with the scientific and engineering basis to validate the long-term permanence and operating safety of these sites. Specific actions to be concluded by 2015 include:

- increasing coordination between federal agencies (including the Environmental Protection Agency, the Department of Interior, and the Department of Energy) to assess the viability of U.S. geological storage sites and develop the regulatory, federal land use policy, legal and liability framework for wide-spread, large-scale CO_2 geological storage
- validating long-term stability and viability of carbon sequestration by leveraging field data from existing DOE regional carbon partnerships to develop and validate subsurface modeling tools that provide the scientific basis and confidence needed for siting, designing, licensing, and regulating large-scale long-term geologic storage
- assessing the transportation infrastructure needed for large-scale carbon sequestration.

This effort will require a total federal investment on the order of $3 billion through 2020, with a fiscal year 2010 investment of $300 million.

Build Commercial-Scale Carbon Capture and Sequestration Demonstrations Through Partnerships

Commercial-scale public, private, and international demonstrations of integrated CCS plants will leverage the cost and reduce the risk associated with CCS deployment. Three classes of demonstrations need to be initiated immediately, with milestones and sustained funding to move rapidly towards full deployment:

- CCS retrofit technology demonstrations utilizing the existing coal fleet
- CCS retrofit technology demonstrations utilizing industrial facilities such as cement plants, iron and steel plants, fertilizer, refineries, and biomass plants
- first-of-a-kind commercial-scale coal-fueled plants with carbon capture and sequestration.

Additional demonstrations should be defined and supported as new technologies become demonstration-ready. This effort will require a total federal investment of $10 billion through 2020.

Establish International Partnerships to Reduce Carbon Emissions from Energy Production

International partnerships will leverage funding and mobilize the best scientists and engineers in the world to accelerate the development and deployment of CCS technologies globally. Outcome-based international commitments should be in place by 2012. Given that the U.S., China, and India are the largest potential markets for CCS technologies, special emphasis should be placed on U.S.-China and U.S.-Indo partnerships.

This effort will require a total federal investment on the order of $250 million over 10 years. Active and committed international partnerships will leverage international funding and reduce the U.S. federal investment required to demonstrate economically viable CCS technologies.

CCS can deliver cost-effective emissions reductions, but governments and industry must come forward to finance large-scale CCS demonstrations and to work together more widely. If we do not successfully demonstrate CCS soon, it will raise costs significantly for other climate mitigation options.

— International Energy Agency (IEA) News Release, October 2008

NATIONAL AND GLOBAL BENEFITS

These four near-term actions will establish the scientific, engineering, economic, policy, and regulatory foundation to:

- dramatically reduce anthropogenic carbon emissions from the combustion of fossil fuels
- enable the economically viable transition of the energy and industry sectors to low carbon intensity in the face of growing energy demand world-wide
- position U.S. industry to be the world leader in the emerging carbon capture and sequestration markets
- minimize the economic and environmental impact of climate change.

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Creating Better Assessment Tools for Climate Policy

"...it can be difficult to navigate...and understand what the true impacts of legislation will be. We are faced with the question: how can reasonable people and institutions analyze the same policy and find completely incompatible results about its impacts... I believe it is valuable for us to understand: First, the extent to which modeling can reliably inform our judgment about what to do. Second, the assumptions built into the various models about the availability of resources and the speed of technology development and proliferation. And third, the factors which most significantly affect the outcomes from the models."

— Chairman Bingaman, U.S. Senate Committee on Energy & Natural Resources, on reports analyzing the energy and economic impacts of climate change legislation, May 2008

The President-elect has called for ambitious emissions mitigation targets for the nation over the coming decades to support reengagement in international negotiation forums. Achieving these goals will require sweeping policies and substantial investments that will impact all sectors of the national energy system. Actions taken within the next several years will influence our options and obligations for decades. It is particularly important, then, that these investments of both time and resources be wisely stewarded. Science-based integrated assessment should serve as a primary tool for informing policy and investments by providing decision-makers in both public and private sectors with the best available information for understanding the implications of policy direction prior to committing current and future resources.

Policy makers have used integrated assessment tools for decades to gain essential insights into the complex interplay of policies, technologies, and climate change. There is significant capacity to enhance the value of these tools for immediate and expanded use as the nation reengages in international negotiation and demonstrates policy leadership at home. Along with increased federal support of climate science to advance our long-term understanding of climate change and its consequences, an emphasis on integrated assessment will allow decision making to proceed on both a national and international level with urgency, credibility and confidence.

TAKE ACTION

Integrated assessment of climate change is a body of research that examines interactions between energy, economic, and natural systems. It assembles scientific knowledge across the full range of sciences related to climate change, and provides tools and analyses that allow decision makers and stakeholders to explore the environmental, cost equity, technology, capital, and market implications of different policy directions. The data generated supports decisions that range from research and development investments, to broad regulations and international negotiations.

The science of integrated assessment is already providing important contributions to policy, including defining national and global emissions mitigation targets, incorporating risk management into near-term policy development, framing the national

technology program required to deliver emissions reduction goals, and understanding complex technical issues such as bioenergy and the competition for land and interactions with the global carbon cycle. However, opportunity exists to improve the value of integrated assessment in two important ways.

First, there are important features of the energy, environment, and economic systems that are not yet well represented in the integrating models, including the role of global water systems, the current energy infrastructure, and potentially important regional distinctions on both near- and long-term climate change impacts.

Second, access to the tools by decision makers in both the public and private sectors is limited, depending upon organizational relationships, funding and experience. Consequently, decision makers across agencies, states, or private organizations may proceed from widely different assumptions, arriving at conclusions at odds not only with one another but also with best available science. Accelerating development of these tools and expanding access to them is especially important as the U.S. begins to make substantial and long-lasting decisions on energy and climate change, with impacts at home and abroad.

Several actions can be launched immediately and completed or deliver material progress within four years with a federal investment on the order of $80 million per year.

Accelerate the Development of Integrated Assessment Science and Tools

The federal government currently spends approximately $3 million annually in the development of integrated assessment tools, the smallest among similar efforts worldwide. While this level of funding has generated world-class research, the capacity to accelerate both the science and model development is constrained and falls far short of the value that these tools can and should provide.

A national effort that builds on the current multi-disciplinary centers of excellence within the federal and university scientific community is needed. An immediate order of magnitude increase in federal investment on the order of $30 million annually is necessary to:

- enable a more complete, credible, and current description of climate change impacts through an expanded representation of the full environmental system, including a realistic accounting of the role of the global water system and the carbon cycle
- allow decision makers to better understand how changes in the cost, performance, and availability of technology and infrastructure will impact carbon emissions reduction targets. This will require a more complete representation of the existing energy infrastructure as well as of new technologies and their rate of dissemination around the world.
- deliver more sophisticated information about climate change impacts and potential adaptation strategies over the next few decades as well as over the very long term
- provide regionally specific information so that consequences of policies for different economic sectors and regions can be investigated jointly and decision makers can understand climate effects and interactions specific to their region
- strengthen our position in international negotiation by returning our capabilities in this area to a position of leadership.

These benefits can be realized in increments beginning in the first year, utilizing readily available expertise through broader partnerships[1] to deliver tools whose sophistication and credibility scale to the policy need.

Increase Access to Assessment Tools by Decision Makers in Both Public and Private Sectors

To gain the benefit of an investment in sophisticated and credible integrated assessment, decision makers need access to the resulting tools. We propose a national center that will accelerate development and substantially increase application of credible analysis by decision makers in policy agencies at the national and state level and in industry.

Similar to the National Center for Atmospheric Research (NCAR), a national center for integrated assessment of climate change would function as a clearinghouse for scientific data and tools developed by the research community. It would operate a user interface within which scenarios could be played out, and around which decision makers could query, challenge, and build insight necessary for sound action. The collected results would become available broadly, generating a large information base supporting a wide variety of decisions. A federal investment on the order of $50 million annually in such a center will:

- provide access to the best available scientific data, assessment tools, and analysis needed to understand the economic implications and environmental impacts of decisions ranging from internationally negotiated carbon reduction agreements to national- and state-level policy decisions and alternative infrastructure options

1 Integrated assessment modeling is inherently interdisciplinary and requires teams of researchers with a variety of specialized backgrounds in the physical and social sciences collaborating to maintain, develop, and exercise state-of-the-art research models. Increased funding would expand the range and reach of existing collaborations and sustain their analytical efforts over time.

- enable the new administration to direct its highest priority policy information needs to a central point, resulting in more timely, credible, and tailored information to support international negotiations and significant policy decisions at the federal level
- build a broad base of decision information, enabling an alignment of actions and investments across multiple sectors to accelerate progress towards national targets
- provide a focal point for collaborations across the scientific community that will accelerate integrated assessment research and tool development.

The information provided by this national center could serve to prevent the loss of billions of dollars as a result of well-intentioned but misguided investments and policy decisions.

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NATIONAL BENEFITS

Policy making in response to a broad and urgent call to action, but without best available scientific information, puts at risk an enormous opportunity to make rapid progress towards our national goals. As decision makers navigate complex tradeoffs and difficult negotiations, science-based integrated assessment tools offer the best available means to move forward with urgency while ensuring that our actions deliver the intended results. They will enable wise stewardship of public and private investments and provide invaluable aid in establishing U.S. credibility and leadership internationally.