2 Vision, Mission, Goals, and Approaches

Within the context of a comprehensive U.S. approach to climate change that includes near-term actions to reduce greenhouse gas emissions intensity, advancements in climate science, and promotion of international cooperation, this CCTP *Strategic Plan* articulates a vision for the role of new and advanced technology in addressing climate change concerns. Following through on the President's direction, the *Plan* defines an integrated mission for the multi-agency CCTP and its participating agencies and provides strategic direction for strengthening Federal leadership of science and technical innovation in related areas. The *Plan* establishes six strategic goals and seven approaches to be pursued toward their attainment. The *Plan* outlines a process for prioritizing R&D investments and lays out a management and reporting structure for CCTP to ensure accountability and mark progress. The vision, mission, goals and approaches will guide future CCTP activities, including those related to R&D portfolio planning and coordination.

2.1 Vision and Mission

CCTP Vision

The CCTP **vision** is to attain on a global scale, in partnership with others, a technological capability that can provide abundant, clean, secure and affordable energy and related services needed to encourage and sustain economic growth, while simultaneously achieving substantial reductions in emissions of greenhouse gases and mitigating the risks of potential climate change.

CCTP Mission

The CCTP **mission** is to stimulate and strengthen the scientific and technological enterprise of the United States, through improved coordination and prioritization of multi-agency Federal climate change technology R&D programs and investments, and to provide global leadership, in partnership with others, aimed at accelerating development of new and advanced technologies that can attain the CCTP vision.

CCTP seeks to attain on a global scale, in partnership with others, a technological capability that can provide abundant, clean, secure and affordable energy and related services needed to encourage and sustain economic growth, while simultaneously achieving substantial reductions in emissions of greenhouse gases (GHGs) and mitigating the risks of potential climate change (*CCTP Vision*). With leadership in R&D and progress in technology development, CCTP aims to inspire broad interest, within and outside of government, including enhanced international cooperation, in an expanded global effort to develop, commercialize and employ such technology toward attainment of the UNFCCC's ultimate objective.

As a multi-agency R&D planning entity, CCTP will strive to stimulate and strengthen the scientific and technological enterprise of the United States, through improved coordination and prioritization of multi-agency Federal climate change technology R&D programs and investments. By conducting multi-agency planning, portfolio reviews, interagency coordination, technical assessments and other analyses, and by formulating recommendations, CCTP will provide support to the Cabinet-level CCCSTI so that it can address issues, make informed decisions, weigh priorities on related science and technology matters, and provide strategic direction. CCTP will also continue to work with and support the participating agencies in developing plans and carrying out activities needed to achieve the CCTP's vision and strategic goals (*CCTP Mission*).

2.2 Strategic Goals

The ultimate objective of the U.N. Framework Convention on Climate Change, stabilizing greenhouse gas emissions at levels that would prevent dangerous anthropogenic interference, provides a planning context for CCTP's long-term technology development strategy. Two considerations arise from this that are relevant to long-term R&D planning and guidance for technology development. First, the level of stabilized concentrations of GHGs in Earth's atmosphere implied by the ultimate objective is not known and will likely remain for some time a key planning uncertainty.[1] Accordingly, CCTP's strategic goals are not based on any hypothesized level of stabilized GHG concentrations, but rather encompass a range of levels under conditions of uncertainty. Second, stabilizing GHG concentrations, at any atmospheric concentration level, implies that global *additions* of GHGs to the atmosphere and global *withdrawals* of GHGs from the atmosphere must come into a net balance. This means that growth of *net* emissions of GHGs would need to slow, eventually stop, and then reverse, so that, ultimately, *net* emissions would approach levels that are low or near zero. The technological challenge is to enable new systems that could help achieve this goal.

In addressing this challenge, opportunities for new and advanced technologies that can address multiple societal objectives, including greenhouse gas reduction, present themselves in a number of areas: reducing emissions of CO_2 from energy end-use and infrastructure and from energy supply; capturing and storing CO_2 from various emissions sources or otherwise sequestering it from the atmosphere; and reducing emissions of non-CO_2 GHGs. In addition, the technological capacity to measure and monitor emissions of GHGs needs to be available to mark progress and guide future work. Finally, underpinning any acceleration of technology development is an array of basic research activities required to illuminate technical barriers and expand knowledge for problem solving.

Countries from all regions will work to meet their climate objectives in the context of a number of other social goals, many of which will continue to have both immediate and urgent implications. For many developing countries the overriding goal will continue to be economic development to reduce poverty and advance human well-being. Increased global energy use is needed to help lift out of poverty the nearly 2 billion people who lack even the most basic access to modern energy services. Addressing this "energy poverty" is one of the world's key development objectives, as lack of energy services is associated with high rates of disease and child mortality. All countries will continue to seek to ensure that energy sources are secure, affordable and reliable, and will also seek approaches that address other environmental concerns, in addition to climate change, such as air pollution and conservation.

These opportunities form the basis, elaborated upon below, for CCTP's six strategic goals.[2] To the extent that agency missions and other priorities allow, each participating CCTP agency will align the relevant components of its R&D portfolio in ways that are consistent with and supportive of one or more of these six CCTP goals:

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[1] The UNFCCC states that additional scientific research is required to determine the level of GHG concentrations that would prevent dangerous anthropogenic interference with the climate system. The CCSP's principal aim is to improve understanding of climate change and its potential impacts, which will inform CCTP.

[2] The CCTP *Strategic Plan* focuses on mitigation of GHG emissions and atmospheric concentrations, consistent with the context of the UNFCCC. It does not address adaptation, reducing vulnerabilities to climate change, or alternative means for reducing radiative forcing, such as modification of the Earth's surface albedo, stratospheric sunlight scattering, or geo-engineering. The public is invited to comment on this focus and these other elements.

1. Reduce emissions from energy end-use and infrastructure
2. Reduce emissions from energy supply
3. Capture and sequester carbon dioxide (CO_2)
4. Reduce emissions of non-CO_2 greenhouse gases
5. Improve capabilities to measure and monitor GHG emissions
6. Bolster basic science contributions to technology development

CCTP Goal 1

Reduce Emissions from Energy End-Use and Infrastructure

Major sources of anthropogenic carbon dioxide (CO_2) emissions are closely tied to the use of energy in transportation, residential and commercial buildings, and industrial processes. Improving energy efficiency and reducing GHG-emissions intensity in these economic sectors through a variety of technical advances and process changes present large opportunities to decrease overall GHG emissions.

In addition, application of advanced technology to the electricity transmission and distribution (T&D) infrastructure (the "grid") can have dual effects on reducing GHG emissions. First, there is a direct contribution to energy and CO_2 reductions resulting from increased efficiency in the T&D system itself. Second, there can be an indirect contribution by enabling, through modernized systems, the expanded use of low-emission electricity generating technologies (such as wind, cogeneration of heat and power, geothermal, and solar power), including distributed energy systems; and better managing system-wide energy supply and demand. Emissions reduction from energy efficiency gains and reduced energy use could be among the most important contributors to strategies aimed at overall CO_2 emissions reduction. The types of technological advancements applicable to this goal include:

- **Efficiency, Infrastructure, and Equipment**. Development and increased use of highly efficient motor vehicles and transportation systems, buildings equipment and envelopes, industrial combustion and process technology, and components of the electricity grid can significantly reduce CO_2 emissions, avoid other kinds of environmental impacts, and reduce the life-cycle costs of delivering the desired products and services.

- **Transition Technologies**. So-called "transition" technologies, such as high-efficiency natural-gas-fired power plants, are not completely free of GHG emissions, but are capable of achieving significant reductions of GHG emissions in the near and mid terms by significantly improving or displacing higher GHG-emitting technologies in use today. Ideally, transition technologies would also be compatible with more advanced GHG-free technologies that would follow in the future.

- **Enabling Technologies**. Enabling technologies contribute indirectly to the reduction of GHG emissions by making possible the development and use of other important technologies. The example of a modernized electricity grid, mentioned above, is seen as an essential step, enabling the deployment of more advanced end-use and distributed energy resources needed for reducing GHG emissions. An intelligent electricity grid integrated with smart end-use equipment would further raise system performance. Another example is storage technologies for electricity or other energy carriers.

- **Alternatives to Industrial Processes, Feedstocks, and Materials**. Manufacturing, mining, agriculture, construction, services, and other commercial and industrial activities will require feedstocks and other material inputs to production.[3] In addition to energy efficiency improvements discussed above, opportunities for lowering CO_2 and other GHG emissions from industrial and commercial activities include replacing current feedstocks with those produced through processes (or complete resource cycles) that have lower or zero-net GHG emissions (e.g., bio-based feedstocks), reducing the average energy intensity of material inputs, and developing alternatives to current industrial processes and products.

CCTP Goal 2

Reduce Emissions from Energy Supply

Current global energy supplies are dominated by fossil fuels—coal, petroleum products, and natural gas—that emit CO_2 when burned. A transition to a low-carbon future would likely require the availability of multiple energy supply technology options characterized by low, near-net-zero, or zero CO_2 emissions. Many such energy supply technologies are available today or are under development. When combined with improved energy carriers (e.g., electricity, hydrogen), they offer prospects for both reducing GHG emissions and improving overall economic efficiency. Examples include the following:

- **Electricity**. Electricity will remain an important energy carrier in the global economy in the future. While substantial improvements in efficiency can reduce the growth of electricity consumption, the prospects of increased electrification and growing demand, especially in the developing regions of the world, still imply significant increases in electricity supply. Reducing GHG emissions from electricity supply could be achieved through further improvements in the efficiency of fossil-based electricity generation technologies, deployment of renewable technologies, increased use of nuclear energy, and development of fusion or other novel power sources.

- **Hydrogen, Bio-Based, and Low-Carbon Fuels**. The world economy will have a continuing need for portable, storable energy carriers for heat, power, and transportation. A promising energy carrier is hydrogen, which can be produced in a variety of ways, including carbon-free or low-carbon methods using nuclear, wind, hydroelectric, solar energy, biomass, or fossil fuels combined with carbon capture and sequestration. Hydrogen and other carriers, such as methanol, ethanol, and other biofuels, could serve both as a means for energy storage and as energy carriers in transportation and other applications.

CCTP Goal 3

Capture and Sequester Carbon Dioxide

Transforming fossil-fuel-based combustion systems into low-carbon or carbon-free energy processes would require further development and application of technologies to capture CO_2 and store it using safe

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[3] Producing feedstocks and materials can and does result in net emissions of GHGs.

and acceptable means, removing it from the atmosphere for the long term. In addition, large amounts of CO_2 could be removed from the atmosphere and sequestered on land or in oceans through improved land, forest, and agricultural management practices; changes in products and materials; and other means. Two focus areas are:

- **Carbon Capture and Storage**. Advanced techniques are under development that could capture CO_2 from such sources as coal-burning power plants, oil refineries, hydrogen production facilities, and various high-emitting industrial processes. Carbon capture would be linked to geologic storage — long-term storage in geologic formations, such as depleted oil and gas reservoirs, deep coal seams, saline aquifers, or other deep injection reservoirs.

- **CO_2 Sequestration**. Land-based, biologically assisted means for removing CO_2 from the atmosphere and sequestering it in trees, soils, or other organic materials have proven to be relatively low-cost means for long-term carbon storage. Ocean sequestration may also play a role as a carbon "sink," as science advances the understanding of its efficacy and the potential effects.

CCTP Goal 4

Reduce Emissions of Non-CO_2 Greenhouse Gases

GHGs other than carbon dioxide, including methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6) and others, are more potent per unit weight as radiant energy absorbers than CO_2. In addition, the atmospheric concentration of troposphere ozone (O_3), another GHG, is increasing due to human activities. The Intergovernmental Panel on Climate Change (IPCC) estimated that the cumulative effects of such gases since pre-industrial times account for about 40 percent of the anthropogenic radiative forcing[4] from GHGs. Reducing emissions of these other GHGs is an important climate change goal and key component of a comprehensive climate change technology strategy. Many categories of technologies are relevant to the attainment of this CCTP goal. Highlights include:

- **Methane Collection and Utilization**. Improvements in methods and technologies to collect methane and detect leaks from various sources, such as landfills, coal mines, natural gas pipelines, and oil and gas exploration operations, can prevent this GHG from escaping to the atmosphere. These methods are often cost-effective, because the collected methane is a fuel that can be used directly or sold at natural gas market prices.

- **Reducing N_2O and Methane Emissions from Agriculture**. Improved agricultural management practices and technologies, including altering application practices in the use of fertilizers for crop production, dealing with livestock waste, and improved management practices in rice production, are key components of the strategy to reduce other GHGs.

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[4] Radiative forcing is a measure of the overall energy balance in the Earth's atmosphere. It is zero when all energy flows in and out of the atmosphere are in balance, or equal. If there is a change in forcing, either positive or negative, the change is usually expressed in terms of watts per square meter (W/m^2), averaged over the surface of the Earth. When it is positive, there is a net "force" toward warming, even if the warming itself may be slowed or delayed by other factors, such as the heat-absorbing capacity of the oceans or the energy absorption needed for the melting of natural ice sheets.

- **Reducing Use of High Global-Warming-Potential (GWP) Gases**. Hydrofluorocarbons and perfluorocarbons have substituted for ozone-depleting chlorofluorocarbons in a number of industries, including refrigeration, air conditioning, foam blowing, solvent cleaning, fire suppression, and aerosol propellants. These and other high-GWP synthetic gases are generally used in applications where they are important to complex manufacturing processes or provide safety and system reliability, such as in semiconductor manufacturing, electric power transmission and distribution, and magnesium production and casting. Because they have high GWPs, methods to reduce leakage and use of these chemicals can contribute to UNFCCC goal attainment and include the development of lower-GWP alternatives to achieve the same purposes.

- **Black Carbon Aerosols**. Programs aimed at reducing airborne particulate matter have led to significant advances in fuel combustion and emission control technologies in both transportation and power generation sectors. Further advances can continue to reduce future black carbon aerosol emissions. Reduced emissions of black carbon, soot, and other chemical aerosols can have multiple benefits. Apart from improving public health and air quality, they can reduce radiative forcing in the atmosphere.

CCTP Goal 5

Improve Capabilities to Measure and Monitor GHG Emissions

Improved technologies for measuring, estimating, and monitoring GHG emissions and the flows of GHGs across various media and boundaries will help characterize emission levels and mark progress in reducing emissions. With enhanced means for GHG measuring and monitoring, future strategies to reduce, avoid, capture, or sequester CO_2 and other GHG emissions can be better supported, enabled, and evaluated. Key areas of technology R&D related to this goal may be grouped into four areas:

- **Anthropogenic Emissions**. Measurement and monitoring technologies can enhance and provide direct and indirect emissions measurements for various types of emissions sources using data transmission and archiving, along with inventory-based reporting systems and local-scale atmospheric measurements or indicators.

- **Carbon Capture, Storage, and Sequestration**. Advances in measurement and monitoring technologies for geologic storage can assess the integrity of subsurface reservoirs, transportation and pipeline systems, and potential leakage from geologic storage. Measurement and monitoring systems for terrestrial sequestration are also needed to integrate carbon sequestration measurements of different components of the landscape (e.g., soils versus vegetation) across a range of spatial scales.

- **Non-CO_2 Greenhouse Gases**. Monitoring the emissions of methane, nitrous oxide, black carbon aerosols, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride is important because of their high GWP and, for some, their long atmospheric lifetimes. Advanced technologies can make an important contribution to direct and indirect measurement and monitoring approaches for both point and diffuse sources of these emissions.

- **Integrated Measuring and Monitoring System Architecture**. An effective measurement and monitoring capability is one that can collect, analyze, and integrate data across spatial and temporal scales, and at many different levels of resolution. This may require technologies such as sensors and continuous emission monitors, protocols for data gathering and analysis, development of emissions accounting methods, and coordination of related basic science and research in collaboration with the Climate Change Science Program and the U.S. Integrated Earth Observation System.[5]

CCTP Goal 6

Bolster Basic Science Contributions to Technology Development

Advances arising from basic scientific research are fundamental to future progress in applied technology research and development. The dual challenges—addressing global climate change and providing the energy supply needed to meet future demand and sustain economic growth—will likely require discoveries and innovations well beyond what today's science and technology can offer. Science must not just inform decisions, but provide the underlying knowledge foundation upon which new technologies can be built. The CCTP framework aims to strengthen the basic research enterprise so that it will be better prepared to find solutions and create new opportunities. CCTP will focus on several ways to meet this goal:

- **Fundamental Research**. Fundamental research provides the underlying foundation of scientific knowledge necessary for carrying out more applied activities of research and problem solving. It is the systematic study of properties and natural behavior that can lead to greater knowledge and understanding of the fundamental aspects of phenomena and observable facts, but without prior specification toward applications, processes, or products. It includes scientific study and experimentation in the physical, biological, and environmental sciences; and many interdisciplinary areas, such as computational sciences. Related to CCTP, it is the source of much of underlying knowledge that will enable future progress in CCTP.

- **Strategic Research**. Strategic research is basic research that is inspired by technical challenges in the applied R&D programs. This is research that could lead to fundamental discoveries (e.g., new properties, phenomena, or materials) or scientific understanding that could be applied to solving specific problems or technical barriers impeding progress in advancing technologies in energy supply and end-use; carbon capture, storage, and sequestration; other GHGs; and monitoring and measurement.

- **Exploratory Research**. Innovative concepts are often too risky or multi-disciplinary for one program mission to support. Sometimes they do not fit neatly within the constructs of other mission-specific program goals. Therefore, not all of the research on innovative concepts for climate-related technology is, or should be, aligned directly to one of the existing Federal R&D mission-related programs. The climate change challenge calls for new breakthroughs in technology that could dramatically change the way energy is produced, transformed, and used in the global economy. Basic, exploratory research of innovative and novel concepts, not elsewhere covered, is one way to uncover such "breakthrough technology" and strengthen and broaden the R&D portfolio.

[5] http://ostp.gov/html/EOCStrategic_Plan.pdf

- **Integrated Planning**. Effective integration of fundamental research, strategic research, exploratory research, and applied technology development presents challenges to and opportunities for both the basic research and applied research communities. These challenges and opportunities can be effectively addressed through innovative and integrative planning processes that place emphasis on communication, cooperation and collaboration among the many associated communities and on workforce development to meet the long-term challenges. CCTP seeks to encourage broadened application of successful models and best practices in this area.

2.3 Core Approaches

Consistent with the principles established by the President, CCTP will employ seven core approaches to stimulate participation by others and ensure progress toward attainment of CCTP strategic goals: (1) strengthen climate change technology R&D; (2) strengthen basic research at universities and federal research facilities; (3) enhance opportunities for partnerships; (4) increase international cooperation; (5) support cutting-edge technology demonstrations; (6) ensure a viable technology workforce of the future through education and training, and (7) explore and provide, as appropriate, supporting technology policy. Chapter 10 outlines next steps for CCTP for each of these core approaches.

Approach 1: Strengthen Climate Change Technology R&D

The Federal Government is engaged in a wide range of research and technology development and deployment activities that directly or indirectly contribute to meeting the President's climate change goals, investing about $3 billion in Fiscal Year 2005 in related technology R&D (Appendix A). Strengthening R&D, however, does not necessarily mean spending more money—it can also mean spending available resources more wisely by appropriately prioritizing activities and reallocating resources, or by leveraging them with the work of others.

To strengthen the current state of the U.S. climate change technology R&D, the CCTP has made, and will continue to make, recommendations to the Cabinet-level CCCSTI to sharpen the focus of and provide support for climate change technology R&D in a manner consistent with the mix and level of R&D investment required by the nature of the technical challenge.

Approach 2: Strengthen Basic Research Contributions

A base of supporting fundamental research is essential to the applied R&D for technology development. The CCTP approach includes strengthening basic research in Federal research facilities and academia by focusing efforts on key areas needed to develop insights or breakthroughs relevant to climate-related technology R&D. A strong and creative science program is necessary to support and enable technical progress in CCTP's portfolio of applied R&D programs, explore novel approaches to new challenges, and bolster the underlying knowledge base for new discoveries.

Fundamental discoveries can reveal new properties and phenomena that can be applied to development of new energy technologies and other important systems. These can include breakthroughs in our understanding of biological functions, properties and phenomena of nano-materials and structures, computing architectures and methods, plasma science, environmental sciences, and many more that are currently on the horizon.

Approach 3: Enhance Opportunities for Partnerships

Federal research is but one element of the overall strategy for development and adoption of advanced climate change technologies. Engagement in this process by private entities, including business, industry, agriculture, construction, and other sectors of the U.S. economy, as well as by non-Federal governmental entities, such as the States and non-governmental organizations, is essential to make R&D investments wisely and to expedite innovative and cost-effective approaches for reducing greenhouse gas emissions.

Public-private partnerships can facilitate the transfer of technologies from Federal and national laboratories into commercial application. Partnering can also advise and improve the productivity of Federal research. Private partners also benefit, because those who are engaged in Federal R&D gain rights to intellectual property and gain access to world-class scientists, engineers, and laboratory facilities. This can help motivate further investment in the commercialization of technology.

Today, partnering is a common mode of operation in most Federal R&D programs, but the partnering process can be improved. Opportunities exist for private participation in virtually every aspect of Federal R&D. With respect to climate change technology R&D, the CCTP seeks to expand these opportunities in R&D planning, program execution, and technology demonstrations, leading ultimately to more efficient and timely commercial deployment. The Regional Carbon Sequestration Partnerships, initiated by DOE in November 2002, are examples of ongoing public-private joint efforts.

Approach 4: Increase International Cooperation

Given the global nature of climate change concerns, and in recognition of the contributions being made by others abroad, the CCTP seeks to engage other nations—government to government—in large-scale cooperative technology research initiatives. Such cooperation can prove beneficial to the success of U.S. technology development initiatives, through leveraging of resources, partitioning of research activities addressing large-scale and multi-faceted complex problems, and sharing of results and knowledge created.

Under the auspices of the Cabinet-level CCCSTI, the U.S. Government has contributed to several multilateral cooperative agreements, such as the International Partnership for a Hydrogen Economy (IPHE); the international Carbon Sequestration Leadership Forum (CSLF); the international Methane-to-Markets Partnership; and the International Thermonuclear Experimental Reactor (ITER), an international project to develop fusion as a commercially viable power source. In certain areas of climate change technology R&D, such as advanced wind turbine design, and nuclear fission and fusion energy research, many advanced technical capabilities reside abroad, as well as in the United States. Since June 2001, the United States has launched bilateral partnerships with Australia, Brazil, Canada, China, Belize, Costa Rica, El Salvador, Germany, Guatemala, Honduras, Nicaragua, and Panama, the EU, India, Italy, Japan, Mexico, New Zealand, Republic of Korea, the Russian Federation, and South Africa on issues ranging from climate change science to energy and sequestration technologies to policy approaches. The countries covered by these bilateral partnerships account for over 70 percent of global greenhouse gas emissions. In addition, the U.S. is a leader in the 58-member country Global Earth Observations System of Systems.

In related developments in July 2005, President Bush and the G-8 Leaders agreed on a far-reaching Plan of Action to speed the development and deployment of clean energy technologies to achieve the combined goals of addressing climate change, reducing harmful air pollution, and improving energy security in the U.S. and throughout the world. The G-8 will work globally to advance climate change policies that grow economies, aid development, and improve the environment.

Also in July 2005, the United States joined with Australia, China, India, Japan, and South Korea to accelerate clean development under a new Asia-Pacific Partnership on Clean Development. This partnership will focus on voluntary practical measures taken by these six countries in the Asia-Pacific region to create new investment opportunities, build local capacity, and remove barriers to the introduction of clean, more efficient technologies. This partnership will help each country meet nationally designed strategies for improving energy security, reducing pollution, and addressing the long-term challenge of climate change.

CCTP seeks to expand on these and other international opportunities to stimulate international participation in the development of new and advanced climate change technologies, foster capacity building in developing countries, encourage cooperative planning and joint ventures and, enable the more rapid development, transfer and deployment of advanced climate change technology.

Approach 5: Support Cutting-Edge Technology Demonstrations

Demonstrations of cutting-edge climate change technologies are an important aspect of the goal to advance climate change technologies. They can help advance a technology's progress from the research phase, where a concept may have been proven in principle or shown to work in the laboratory, but where performance in an operating environment and at a larger scale is still unknown or uncertain. Such performance characteristics are important to the viability of a technology, where a substantial investment, motivated by clear and expected financial returns, depends on having confidence in technical performance.

Technology demonstrations afford unique opportunities to reduce investment uncertainty. They unveil the parameters affecting a technology's cost and operational performance. They identify areas needing further improvement or cost reduction. Federal leadership through technology demonstrations can strongly influence decisions of private-sector investors and other non-government parties.

Approach 6: Ensure a Viable Technology Workforce of the Future

The development and deployment, on a global scale, of new and advanced climate change technologies will require a skilled workforce and an abundance of intellectual talent, well versed in associated concepts and disciplines of science and engineering. Workforce development and education are integral components of any sustained and successful scientific and technological undertaking of this scope and magnitude. The CCTP mission and goals provide a unique opportunity to strengthen Federal investments across all participating agencies in science, math, and engineering education and to attract talented individuals to focus their careers on this global endeavor. Such efforts could be coordinated with other countries, and particularly in emerging economies of the developing world, where much of 21st century emissions will be concentrated.

Approach 7: Provide Supporting Technology Policy

Should widespread adoption of advanced climate change technologies be pursued, as guided by science, it would likely need to be supported by appropriate technology policy, potentially including market-based incentives. While some CCTP-supported advanced technologies may be sufficiently attractive, for a variety of reasons, to find their way into the marketplace at a large scale without supporting policy or incentives, others would not. Even with further technical progress, technologies that capture or sequester CO_2, for example, or others that afford certain climate change-related advantages, are expected to remain more expensive than competing technologies that do not.

As Federal efforts to advance technology go forward, broadened participation by the private sector in these efforts is important to both the acceleration of innovation and the adoption of the technologies. Such participation, envisioned to extend beyond R&D partnering and demonstrations (Approaches 3 and 5 above), can be encouraged by appropriate and supporting technology policy. This is evidenced today, in part, by a number of market-based incentives already in place and by others proposed by the Administration.[6]

2.4 Prioritization Process

An important role of the CCTP is to provide strategic direction for and strengthen the Federal portfolio of investments in climate change technology R&D. The CCTP continues to prioritize the portfolio of Federally funded climate change technology R&D consistent with the President's National Climate Change Technology Initiative (NCCTI). The CCTP will also identify within its portfolio a subset of NCCTI priority activities, defined as discrete R&D activities that address technological challenges, which, if solved, could advance technologies with the potential to dramatically reduce, avoid, or sequester greenhouse gas emissions.

Prioritization of Federal technology R&D activities related to climate change is a dynamic process that has evolved over time in response to emerging knowledge. This evolution is expected to continue. Through coordinated interagency planning, the CCTP priorities will be reviewed periodically in conjunction with the Federal budget process, and recommendations will be made through the IWG to the CCCSTI.

This CCTP *Strategic Plan* provides a government-wide basis for guiding the formulation of the comprehensive Federal climate change technology R&D portfolio; identifying high priority investments, gaps, and emerging opportunities; and organizing future CCTP-related research. The CCTP planning activities will be informed by results of studies, inputs from many and diverse sources, technical workshops, assessments of technology potentials, analyses regarding long-term energy and emissions outlooks, and modeling by a number of groups of a range of technology scenarios over the next 100 years (see Chapter 3). These planning activities will be guided by several important portfolio planning principles and investment criteria.

2.4.1 Portfolio Planning Principles

The CCTP adheres to three broad principles. The first principle, given the many attendant uncertainties about the future, is that the whole of the individual R&D investments should constitute a balanced and diversified portfolio. Considerations include the realizations that (1) no single technology will likely meet the challenge alone; (2) investing in R&D in advanced technologies involves risk, since the results

[6] Federal Climate Change Expenditures Report to Congress, March 2005 http://www.whitehouse.gov/omb/legislative/fy06_climate_change_rpt.pdf

of these investments are not known in advance, and, among successful outcomes, some are not likely to be as successful as hoped; and (3) a diverse array of technology options can hedge against risk and provide important flexibility in the future, which may be needed to respond to new and potentially strategy-changing information. The CCTP portfolio also strives to balance short- and long-term technology objectives.

A balanced and diversified portfolio must address risk in a way that hedges that risk, for example, by investing in projects that will pay off under different states of the future world. Identifying what the major sources of uncertainty are helpful in this regard, such as the degree of future GHG emissions and reductions under varying assumptions, about energy prices, technology costs and performance, and other variables. CCTP's tools in this regard are partially addressed in Chapter 3, but further work in terms of portfolio analysis, and expected benefits and costs, will be required.

The second principle is to ensure that factors affecting market acceptance are addressed. In order to enable widespread deployment of advanced technologies, each technology must be integrated within a larger technical system and infrastructure, not just as a component. Market acceptance of technologies is influenced by a myriad of social and economic factors. The CCTP's portfolio planning process must be informed by and benefit from private sector and other non-federal inputs, examine the lessons of historical analogues for technology acceptance, and apply them as a means to anticipate issues and inform R&D planning.

Third, and perhaps most importantly, the anticipated timing regarding the commercial readiness of the advanced technology options is an important CCTP planning consideration. Energy infrastructure has a long lifetime, and change in the capital stock occurs slowly. Once new technologies are available, their adoption takes time. Some technologies with low or near-net-zero GHG emissions may need to be available and moving into the marketplace decades before their maximum market penetration is achieved.

2.4.2 Portfolio Planning and Investment Criteria

Within the planning framework of vision, mission, goals, approaches, and portfolio investment principles, the CCTP's prioritization process applies four criteria (see Box 2-1). Once the individual competing investments are identified, the CCTP will consider their merits based on maximizing expected benefits versus costs (Criterion #1), subject to consideration of the distinct roles of the public and private sectors in R&D (Criterion #2). In addition, because of the risk of spreading resources across too many areas, the CCTP focuses on technologies with potential for large-scale application (Criterion #3). Technologies that are expected to have limited impact on overall GHG emissions may still be given priority if they can deliver earlier in the century and/or are particularly cost-compelling. Finally, timing of investments is an important consideration in the decision process. The CCTP planning process gives weight to considerations of logical sequencing of research (Criterion #4), where the value in knowing whether a technological advance is or is not successful can have a cascading effect on the sequencing of later investments.

2.4.3 Application of Criteria

The CCTP's review, planning and prioritization process will rely on ongoing reviews of strategies for technology development, buttressed by analysis, and of the overall R&D portfolio's adequacy to make progress toward attainment of each CCTP strategic goal. There will be an emphasis on identifying gaps

Box 2-1

CCTP Portfolio Planning and Investment Criteria

1. Maximizing Expected Return on Investment. R&D investments that have the prospect to generate maximum expected benefits per dollar of investment receive priority in investment planning. Benefits are defined with respect to expected contributions to the attainment of CCTP goals, particularly GHG reductions, but also include other considerations, such cost-effectiveness, improved productivity, and reduction of other pollutants. Climate change benefits are long-term public goods. Discount rates must be appropriate to the context, particularly when applied to very long-term impacts. This criterion includes considerations of development and deployment risks, and the hedging of risks across multiple projects. Projects with high risk, but low emissions-reduction potential should be removed from the CCTP R&D portfolio.

2. Acknowledging the Proper and Distinct Roles for the Public and Private Sectors. The CCTP portfolio recognizes that some R&D is the proper purview of the private sector; other R&D may be best performed jointly through public-private partnerships; and still other R&D may be best performed by the Federal sector alone. In cases where public support of R&D is warranted, technology development and adoption require cooperation and engagement with the private sector. History demonstrates that early involvement in technology R&D by the business community increases the probability of commercialization. A key consideration in the investment process is the means for engaging the talents of the private sector using innovative and effective approaches.

3. Focusing on Technology with Large-Scale Potential. The scope, scale, and magnitude of the climate change challenge suggest that relatively small, incremental improvements in existing technologies will not enable full achievement of CCTP goals. Every technology option has limits of various kinds. Such limits need to be identified, explored, and understood early in the planning process. Technology options should be adaptable on a global scale and have a clear path to commercialization. High-priority investments will focus on technology options that could, if successful, result in large mitigation contributions, accumulated over the span of the 21^{st} century. For technologies on the lower end of this criterion, benefits should be deliverable earlier in the century and/or be particularly compelling from a marginal benefit/cost perspective.

4. Sequencing R&D Investments in a Logical, Developmental Order. Investments must be logically sequenced over time. Supporting a robust and diversified portfolio does not mean that all technology options must be supported simultaneously, or that all must proceed at an accelerated pace. Logical sequencing of R&D investments takes into account (i) the expected times when different technologies may need to be made available and cost-effective, (ii) the need for early resolution of critical uncertainties, and (iii) the need to demonstrate early success or feasibility of technologies upon which other technology advancements may be based.

and key opportunities for new initiatives, accompanied by periodic realignments. The process is not easily reduced to quantitative analysis due, in part, to the large number of variables and uncertainties associated with the nature of the climate change technology challenge and, in part, to the CCTP's century-long planning horizon. Nevertheless, the prioritization criteria discussed above will be applied by the participating agencies to the maximum extent practicable and augmented by inputs from various sources.

As a first step in the prioritization process, CCTP established a baseline, or inventory, of the existing portfolio of R&D activities across the participating agencies. Criteria for inclusion in this CCTP portfolio baseline are presented in Appendix A. They closely track CCTP strategic goals. As shown in Appendix A, the resulting multi-agency baseline inventory accounted for more than $3 billion in R&D activities in FY 2005. This inventory will need to be periodically updated.

The second step in the process is to identify and focus on the more important elements of a diversified strategy, assisted by insights gained from scenarios (see Chapter 3) and other analyses, and assess the portfolio both as a whole and as composed of potential contributions toward goal attainment associated with each activity in the portfolio. This assessment is intended to affirm some elements of the portfolio, challenge others, and identify gaps and promising opportunities. Once a full set of candidate investments is identified, including gaps and opportunities, the prioritization criteria can be applied to each proposed investment activity. This step will require continuing development of analytical tools and methods, including assessments of various technologies and their potentially limiting factors.

The CCTP portfolio of today reflects a “snapshot” in time of the results of a continuing and ongoing review and realignment in light of new and changing emphasis among competing national needs. In the years ahead, it is expected that the CCTP portfolio and planning emphasis will continue to evolve, as more studies and analyses are conducted, technology assessments are completed, additional gaps and opportunities are identified, and new developments and scientific knowledge emerge.

2.5 Management

The CCTP is multi-agency R&D planning and coordination activity. It accomplishes its work by engaging and assisting the Federal R&D agencies in their respective efforts to plan, prioritize, and coordinate research activities to meet CCTP goals. As the representative on CCTP-related matters of its participating agencies, CCTP also works with the Administration to formulate overall budget guidance and recommend adjustments, where appropriate, to the Federal R&D portfolio in order to better meet CCTP goals. As discussed below, the CCTP’s management functions include executive direction, inter-agency planning and integration, agency implementation, external interactions, and program support.

2.5.1 Executive Direction

The CCTP exercises executive direction through the Cabinet-level Committee on Climate Change Science and Technology Integration (CCCSTI), and its associated Interagency Working Group (IWG) on Climate Change Science and Technology. The IWG is populated by agency deputies, who can adopt coordinated plans, programs, and actions that will guide their respective agencies’ implementation. The IWG also provides guidance on strategy and reviews and approves CCTP strategic planning documents.

Executive direction is further facilitated by a CCTP Steering Group comprised of senior-level representatives from each participating Federal agency. The Steering Group ensures that all agencies have a means to raise and resolve issues regarding the CCTP and its functions as a facilitating and coordinating body. The Steering Group assists the CCTP Director in accessing needed information and resources within each agency. The Steering Group is briefed regularly on CCTP plans and activities and assists in developing agency budget crosscuts and proposals, conveying information and actions back to the agencies, and supporting accomplishment of the CCTP mission. The Steering Group ensures that consistent guidance and direction is given to the CCTP Working Groups, and formulates recommendations and advice back to the CCCSTI, through the IWG.

2.5.2 Interagency Planning and Integration

Six CCTP Working Groups (WGs), aligned with the six CCTP strategic goals (Box 2-2), are primarily responsible for carrying out the missions and staff functions of the CCTP in a coordinated multi-agency manner. The WGs are assisted by subgroups, as appropriate, and by technical staff drawn from the participating agencies, affiliated laboratories and facilities, and other available consulting staff. The WGs are expected to:

- Serve as the principal means for interagency deliberation and development of CCTP plans and priorities, and the formulation of guidance for supporting analyses in WG’s respective areas

- Provide a forum for exchange of inputs and information relevant to planning processes, including workshops and other meetings
- Engage, cooperate with, and coordinate inputs from the relevant R&D agencies
- Identify ongoing R&D activities and identify R&D gaps, needs, and opportunities—near and long term
- Support relevant interfaces with CCSP science studies and analyses
- Formulate advice and recommendations to present to the CCCSTI
- Assist in the preparation of periodic reports to Cabinet members and the President.

2.5.3 Agency Implementation

The CCTP relies on the participating Federal agencies and their respective R&D portfolios to contribute to CCTP goal accomplishment, recognizing that the agencies must balance CCTP priorities with other mission requirements. The CCTP relies on the agencies to place appropriate priority on CCTP program implementation. Priority setting is facilitated by appointing agency heads and deputies to the CCCSTI and IWG. Top agency officials make up the CCTP Steering Group. Agency executives and senior-level managers serve as chairs and members of the CCTP Working Groups. Once CCTP plans, programs, and priorities are set and approved by the Cabinet-level CCCSTI, the agencies are expected to follow through and contribute to their execution and completion.

2.5.4 External Interactions

The CCTP accesses expert opinion and technical input from various external parties, through advisory groups, program peer-review processes, conference participation, international partnerships, and other activities. In addition, CCTP staff convenes technical workshops and meetings with experts both inside and outside the Federal Government. The CCTP activities are of interest to a number of external parties, including State and local governments, regional planning organizations, academic institutions, national laboratories, and non-governmental organizations. They are of interest, as well, to foreign

Box 2-2
CCTP Working Groups

Energy End-Use – Led by DOE
- Hydrogen End-Use
- Transportation
- Buildings
- Industry
- Electric Grid and Infrastructure

Energy Supply – Led by DOE
- Hydrogen Production
- Renewable and Low Carbon Fuels
- Renewable Power
- Nuclear Fission Power
- Fusion Energy
- Low Emissions Fossil-Based Power

CO_2 Sequestration – Led by USDA
- Carbon Capture
- Geologic Storage
- Terrestrial Sequestration
- Ocean Storage
- Products and Materials

Other (Non-CO_2) Gases – Led by EPA
- Energy & Waste – Methane
- Agricultural Methane and Other Gases
- High Global-Warming-Potential Gases
- Nitrous Oxide
- Ozone Precursors and Black Carbon

Measuring and Monitoring – Led by NASA
- Application Areas
- Integrated Systems

Basic Research – Led by DOE
- Fundamental Research
- Strategic Research
- Exploratory Research
- Integrative R&D Planning

governments, and international organizations, such as the Organization for Economic Cooperation and Development (OECD), the International Energy Agency (IEA), various global and regional compacts, and the IPCC. CCTP needs to communicate its activities to such entities and provide coordinated support, through the relevant agency programs, for enhanced external and international cooperation by engaging with and supporting activities of mutual interest.

2.5.5 Program Support

The CCTP staff will provide technical and administrative support and day-to-day coordination of CCTP-wide program integration, strategic planning, product development, communication, and representation. The CCTP staff will (1) provide support for the Working Groups and the Steering Group; (2) foster integration of activities to support the CCTP goals; (3) conduct and support strategic planning activities that facilitate the prioritization of R&D activities and decision-making on the composition of the CCTP RDD&D portfolio, including conducting analytical exercises that support planning (such as technology assessments and scenario analysis); (4) develop improved methods, tools, and decision making processes for climate technology planning and management, R&D planning, and assessment; (5) develop products that communicate the CCTP's plans, as well as the progress of the CCTP and its Federal participants toward meeting the CCTP goals; (6) coordinate interagency budget planning and reporting; (7) assist and support the Administration in representing U.S. interests in the proceedings of the United Nations' IPCC Fourth Assessment Report (AR4) process; and (8) coordinate agency support of international cooperative agreements.

2.6 Strategic Plan Outline

In the chapters that follow, CCTP provides a century-long planning context, goal-oriented strategies for technology development, and a summary of conclusions and next steps. Chapter 3 provides a synthesis assessment, based on a number of representative works in the literature on economic modeling and forecasting of future global GHG emissions. This is accompanied by a number of insights regarding opportunities for advanced technologies gained from scenarios analyses. Chapters 4 through 9 focus in some depth, respectively, on each of the CCTP's six strategic goals. Each chapter outlines elements of a technology development strategy, highlights ongoing work and suggests promising areas for future research. Chapter 10 provides a summary of conclusions regarding CCTP and its strategic goals and identifies a series of next steps within the context of each of CCTP's seven approaches. Each approach is applicable, to varying degrees, to each of CCTP's six strategic goals.