Where Does Carbon Sequestration fit into a Comprehensive Greenhouse Gas Mitigation Strategy?

James Ekmann and Sarah Forbes, National Energy Technology Laboratory

The purpose of this talk is twofold. The first is to set the stage for discussion of the readiness of technology to support comprehensive (long-term) greenhouse gas mitigation strategies and the need for a portfolio of options to manage risks associated with any single option. The second is to offer one pathway for addressing greenhouse gas emissions from the utility sector while identifying those factors that must be addressed to manage the risk that this approach represents—factors being addressed in on-going research and development programs in advanced power systems and carbon sequestration.

A steady stream of observations of changing climatic patterns and shifts in plant and animal species in apparent response appear in the science press. Climate science research in the United States is exploring near-term impacts along with assessments of long-term trends in the climate. Adaptation has gained increasing attention as a parallel response to climate change alongside mitigation strategies. Recent changes in weather patterns and storm severity demand near term, and often quite expensive action. The recently concluded 8th Conference of the Parties meeting in Delhi, India placed greater emphasis on adaptation. In addition, other energy and environmental concerns, such as the reliability of the energy infrastructure, energy security, reducing environmental impacts of air and water pollution, and a number of other concerns not directly tied to energy or the environment demand attention and resources. How does one offer a sound mitigation and adaptation strategy (spanning decades) for climate change while confronted with numerous other immediate problems?

Energy and environmental issues (particularly climate change) are interrelated and often crosscut other policy issues to the extent that it can be difficult to measure the true benefit (or risk) of a strategy. Adaptation measures to clean up flooded areas or mitigation efforts to prevent flooding may both stall the spread of malaria, West Nile, and other vector-borne diseases. The effect of environmental action (or inaction) is also linked to social and economic health. For example, a region experiencing a severe drought, is at unrest and more susceptible to economic and social crisis. And technologies that mitigate criteria pollutants often reduce efficiency and result in a corresponding increase in greenhouse gas emissions. These linkages create a dynamic situation in which investments in any one area will likely have wider-scale implications.

A number of governmental and non-governmental organizations have explored greenhouse gas mitigation strategies either for the United States or for the world. At the same time, an equally comprehensive series of reports have emerged from a broad cross-section of society focused on other concerns such as energy security, infrastructure protection, water shortages, and a host of other equally important problems demanding attention. In December 2000, the National Foreign Intelligence Board published Global Trends 2015[1] in an effort to assess issues likely to affect national security globally and regionally through 2015. This report identified a series of issues that would demand attention and resources. Although global warming was recognized as a concern, it was not given a prominent place amongst the list of drivers and trends. Water scarcities and globalization were considered to have greater impact on societal decision-making and resource allocations during the period of time considered.

These urgent problems often demand immediate use of societal resources and may leave little opportunity to address long-term concerns. Integrated planning methodologies are reasonably new. Principles of industrial ecology, concepts for sustainable development, life cycle assessment tools, and innovative regulatory approaches such as emissions trading, have been explored and applied. It is not clear that enough time has elapsed to prove the utility of a given approach or to ensure that they contribute effectively to solution of the problems being addressed. Ruth Greenspan Bell of Resources for the Future[2] examined the efficacy of promoting market-based mechanisms as a means of addressing environmental problems in countries in transition. A fundamental difficulty revolves around the fact that these societies were confronted with "the enormity of the challenges on every possible front—depressed economies, badly frayed social safety nets, and widespread concerns about social unrest."

Returning to climate change, efforts to identify preferred mitigation strategies have often focused on finding a few technologies that could address the problem or rather the multitude of problems arising from individual technologies that emit greenhouse gases. Given the potential magnitude of climate change and uncertainty in the timing and severity of impacts, a broader approach seems indicated—one that takes advantage of existing strengths with enough flexibility to adjust as needed. A recent article by Edward A. Parson[3] suggested the need to enlist industry expertise and to focus on manageable goals for reducing greenhouse gas emissions. His argument was based in part on ensuring participation by industries that wanted to manage the risk posed by regulations on emissions of greenhouse gases or by the potential risk posed by potential regulations. He cites the Montreal Protocol for ozone-depleting chemicals as evidence of the value of such an approach—a situation in which the "…linked processes of assessment, innovation, and diffusion were so powerful they almost made the regulations appear superfluous, as private reduction efforts stayed consistently ahead of regulatory requirements".

The author recognized that "…There are large structural differences between climate and ozone issues, of course. The scale, diversity, and importance of the human activities causing environmental burden are much greater for climate…But these differences need not preclude the application of the model of technology assessment developed for ozone, so long as the corresponding conditions for success are present." In the case of ozone, the Technology and Assessment Panel was effective in soliciting meaningful participation by top industry experts in addressing environmental goals. This process was seen by industry as providing private benefits alongside the public ones. The most important of these may have been "…help in managing the business risk of regulations."

Great uncertainty surrounds the demographic, behavioral, economic and technological processes that will fundamentally change society by 2100. Over such a long time frame, both incremental innovations in the existing technological base and fundamental advances in the science underpinning new technologies could drastically reduce future emissions. In Parson's opinion, "…several assessments of greenhouse gas mitigation options have achieved little, either in reducing uncertainties or in providing useful policy advice."

Some mitigation strategies have been offered that focus on eliminating fossil fuels—especially coal. However, it is widely recognized that use of these fuels cannot be substantially reduced even in the mid-term (circa 2050). Annual reports by the Energy Information Agency show renewable energy technologies making slow and modestly increasing gains in the energy sector throughout their forecast period. Modeling studies by Edmonds et al.[4], demonstrate that fossil fuels combined with carbon sequestration are essential to any long-term strategy. That is, any strategy aimed at providing an adequate supply of energy while reducing greenhouse gas emissions consistent with the ultimate goal (established at the 1992 meeting in Rio) of stabilization of the atmospheric concentration of carbon dioxide at a level to prevent dangerous impacts on human societies.

The National Energy Technology Laboratory has been performing research and managing a portfolio of advanced power systems and carbon sequestration research and development activities for a number of years. Recently, we have performed a series of analyses for one technological system that offers the potential to substantially reduce carbon dioxide emissions from the utility sector—integrated gasification combined cycle (IGCC) power plants that include carbon dioxide capture and sequestration. Although other fossil fuel-based advanced power systems could also contribute, the current studies are focused on IGCC. In addition, our studies have focused on sequestration through use in enhanced oil recovery or enhanced coal bed methane recovery. Although enhanced resource recovery is considered a standard industry practice, of the 32 million tons of carbon dioxide injected for enhanced oil recovery each year, only 10% is "waste" from anthropogenic sources. And current practice does not seek to optimize sequestration and long-term storage of carbon dioxide in part, because the carbon dioxide must be purchased from someone who produces carbon dioxide either from a natural reservoir or a dedicated combustion source. In this case, the risks of investing in a mitigation activity are offset by the value of the extracted resource and costs saved through using waste carbon dioxide.

NETL staff is performing a series of modeling studies that look at transitioning existing power stations to and adding new capacity consisting of advanced power systems including sequestration[5]. These studies assess markets for the carbon dioxide and look at the potential capacity that may exist as a function of price—i.e. a supply curve. Generating a supply curve assumes that one can estimate cost, which also assumes reasonable understanding of all the factors that contribute to these costs. This paper will discuss some of these issues including safety, permanence, and projected capacity. We also compare the cost differential between this approach and the cost of renewable technology options.

U.S. electricity generating capacity is projected to increase 350GW over the next twenty years. Based on EIA data and assuming that technology development programs for IGCC and natural gas combined cycle systems (NGCC) achieve their R&D goals, approximately 200GW of this total will be captured by these technologies. This is an aggressive scenario—that is, a high fossil case—useful in matching demand with supply. The cost and availability of natural gas will determine the share of the total attributable to IGCC or to NGCC. In addition, between 2002 and 2060, essentially all of the existing coal-fired capacity is projected to retire. Replacement of existing capacity and addition of new generating capacity that includes capture and sequestration can significantly reduce emissions of greenhouse gases from this sector by 2050. Storage capacity for captured carbon dioxide may exist between sites amenable to enhanced oil recovery and to enhanced coal bed methane recovery to store approximately 4 gigatons of carbon dioxide. In addition, another 10 gigatons of captured carbon dioxide might be stored in saline aquifers. The amount of greenhouse gases to be captured from the utility sector under this scenario, over the sixty-year window we explored, is consistent with the projected new generating capacity capable of carbon dioxide capture and subsequent sequestration. Clearly both supply and demand are projections and the final potential for this pathway is a function of questions that we are just learning to ask.

Continued use of fossil fuels combined with permanent carbon sequestration represents a key technology option currently being explored. Successful development and demonstration of cost-effective sequestration would allow for the continued use of abundant, available, and affordable energy resources while significantly reducing emissions. It could do so using existing infrastructure at costs comparable to other options. Several key questions remain, including cost and performance of integrated power and sequestration technologies, global sequestration capacity and infrastructure, and proof of permanence. However, similar questions remain about performance of other options when deployed at levels sufficient to actually reduce total global GHG emissions**.**

Subsequent speakers will discuss a number of options from the perspective described above. What further development is needed to achieve sufficient levels of performance when fully deployed and what issues arise—both technological and societal—from such deployment? Pursuing a broad portfolio of mitigation and adaptation technologies should result in a balance between responding to immediate societal needs and addressing problems with longer time scales.

The complex nature of climate change—the fact that it is part of the larger issue of sustaining an ever-growing human population with expectations of an increasing quality of life—should remain in the forefront of our discussions today. We are discussing possible pathways to address aspects of mitigation of or adaptation to changes in the climate. Each pathway poses risks of its own and each depends on assumptions about the future to assess its real value as an option now—its share in contributing to a solution will only be determined by application at some future point. A recent submission by Braden Allenby[6] to the Green Business Letter captures the essence of uncertainty for a complex system: " …That is the assumption that climate-change negotiations represent the major initiative by humanity to respond to global climate issues… This implicit assumption reflects an important truth about the way humans and their institutions…approach all environmental perturbations: We admit to uncertainty about the natural systems involved—all the while continuing to act as if the systems were simple and manageable by a centralized control mechanism like a treaty… Moreover, for this to work, we also need to believe that we understand the impacts of such treaties—on natural systems, on economic, political, and cultural systems. Both assumptions are most likely wrong and demonstrate a profound inability to understand the way complex systems evolve."

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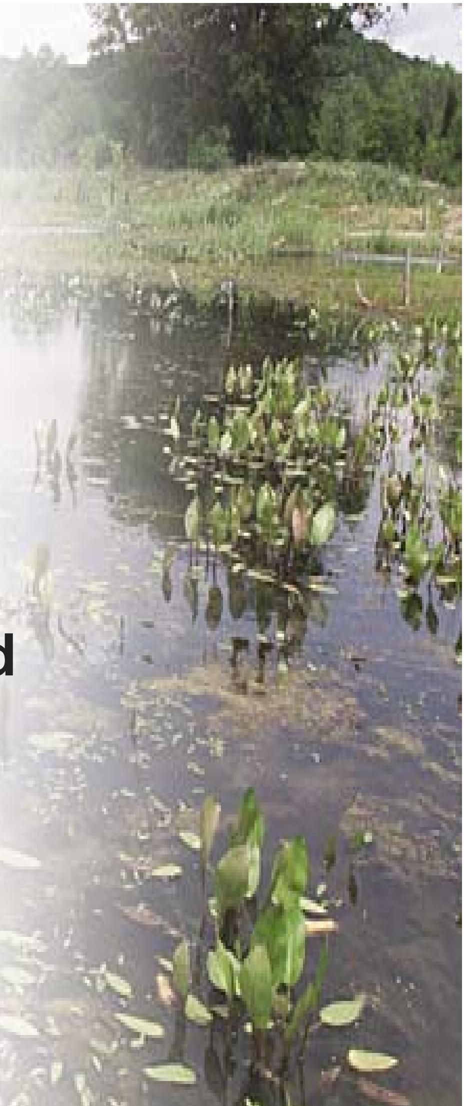
Where Does Carbon Sequestration Fit in a Comprehensive GHG Mitigation Strategy?

Annual AAAS Meeting

February 17, 2003
Denver, Colorado

Sarah M. Forbes- National Energy Technology Laboratory

Outline of Talk



Readiness of technology:

- **Do we have a portfolio of technologies available to reliably address mitigation and adaptation issues?**

One possible pathway:

- **Fossil fuel-based power systems combined with sequestration could significantly reduce carbon dioxide emissions, but we need to assure that it meets cost and performance goals**

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The World is a Complex System

Climate change is 500 million times more complicated than any other environmental problem we have faced. – Daniel Esty

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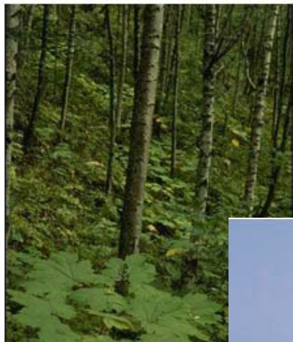
Flexibility is Key to Addressing Climate Change

Mitigation



Adaptation

No Single Approach Will Work

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Uncertainty is Inherent to Natural Systems

"We admit to uncertainty about the natural systems involved - all the while continuing to act as if the systems were simple and manageable by a centralized control mechanism like a treaty… Moreover, for this to work, we also need to believe that we understand the impacts of such treaties - on natural systems, on economic, political, and cultural systems. Both assumptions are most likely wrong and demonstrate a profound inability to understand the way complex systems evolve."

-Braden Allenby

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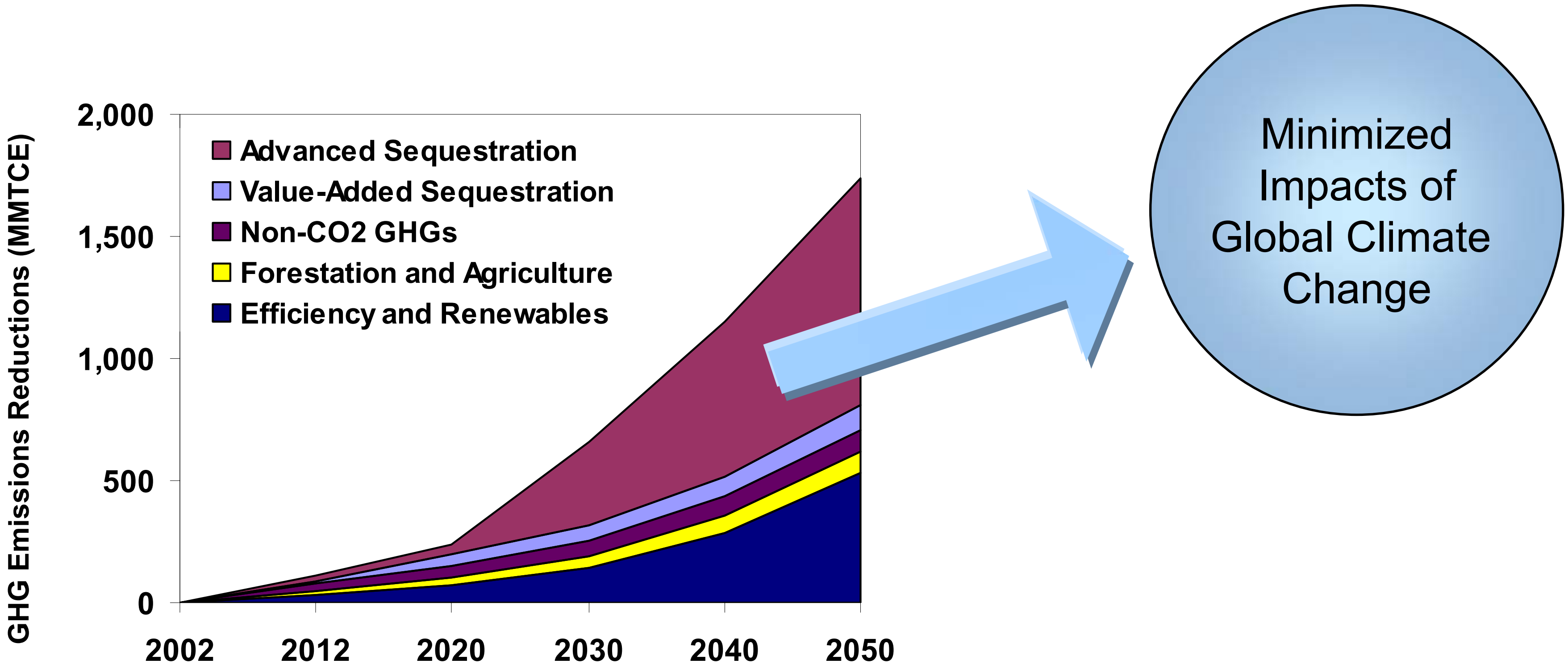
Portfolio Approach = Insurance to Balance Risk and Investments



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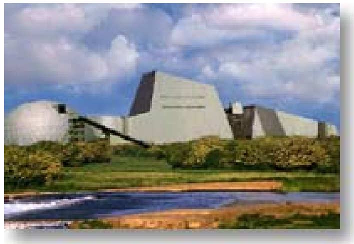
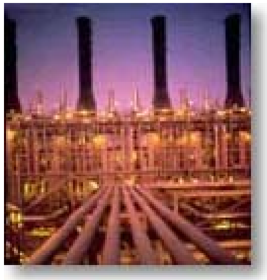
Capture and Sequestration Options

Direct Sequestration

< 10% Increase in Cost of Energy





Capture and storage

- Oil & Gas Reservoirs
- Unmineable Coal Seams
- Saline Formations
- Oceans

Indirect Sequestration

< $10/ton Carbon Sequestered

Remove CO_2 from atmosphere

- Forestation
- Mineralization
- Agricultural Practices
- Ocean Fertilization

Advanced Concepts

Convert CO_2

- Stable Solids
- Useful Products
- Fuels

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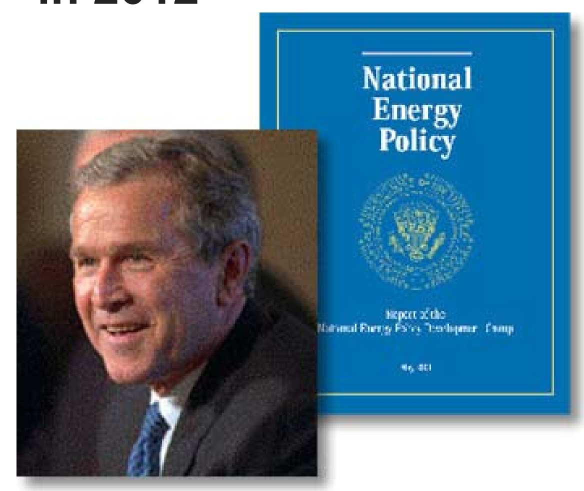
Presidential Direction

NCCTI
June 11, 2001

- Third option for global climate change
- Enables continued use of domestic energy resources and infrastructure
- Geologic formations have potential for essentially unlimited storage capacity
- Demonstrated industry interest, participation, and cost-sharing in public/private partnerships
- "We all believe technology offers great promise to significantly reduce emissions — especially carbon capture, storage and sequestration technologies."

GCCI
February 14, 2002

- Sustain economic growth
- Reduce GHG intensity by 18% in next 10 years
- Reevaluate science & path in 2012

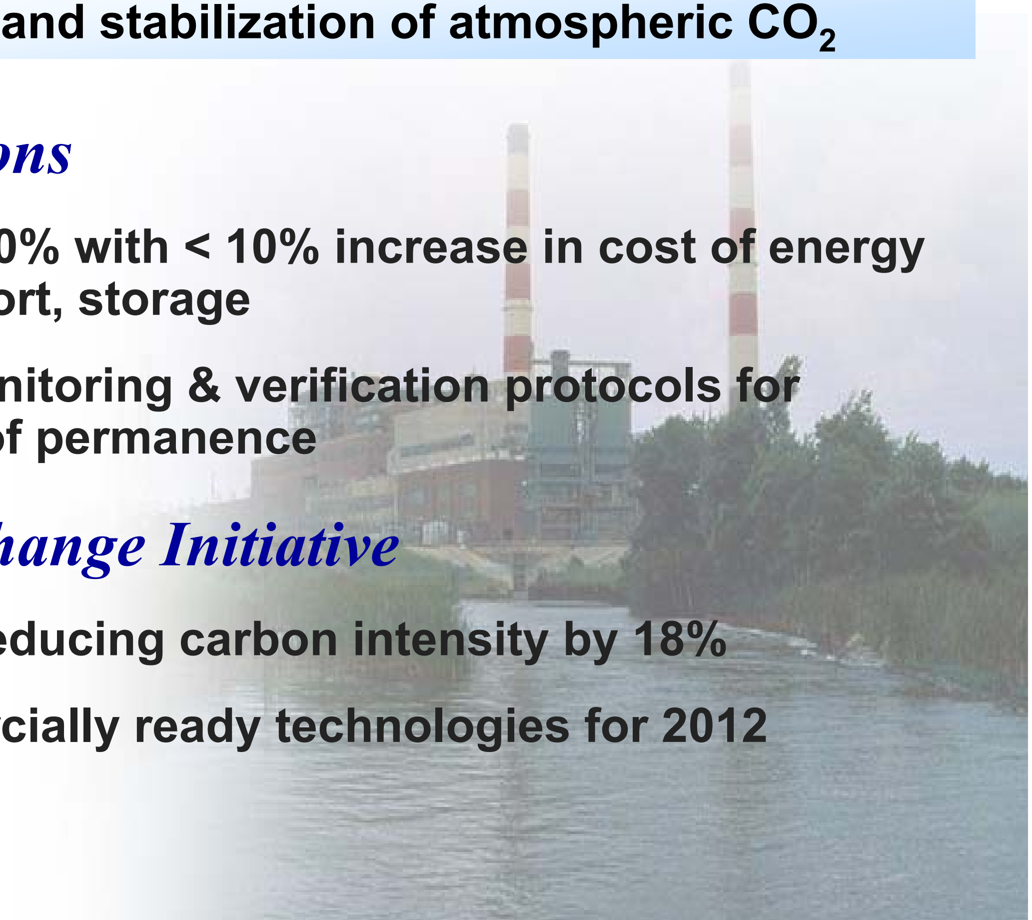


White House photo: Paul Morse

Program Goals

Technology Options for GHG Management

Possess scientific understanding of sequestration options and provide cost-effective, environmentally-sound technology options that lead to reduced GHG intensity and stabilization of atmospheric CO_2



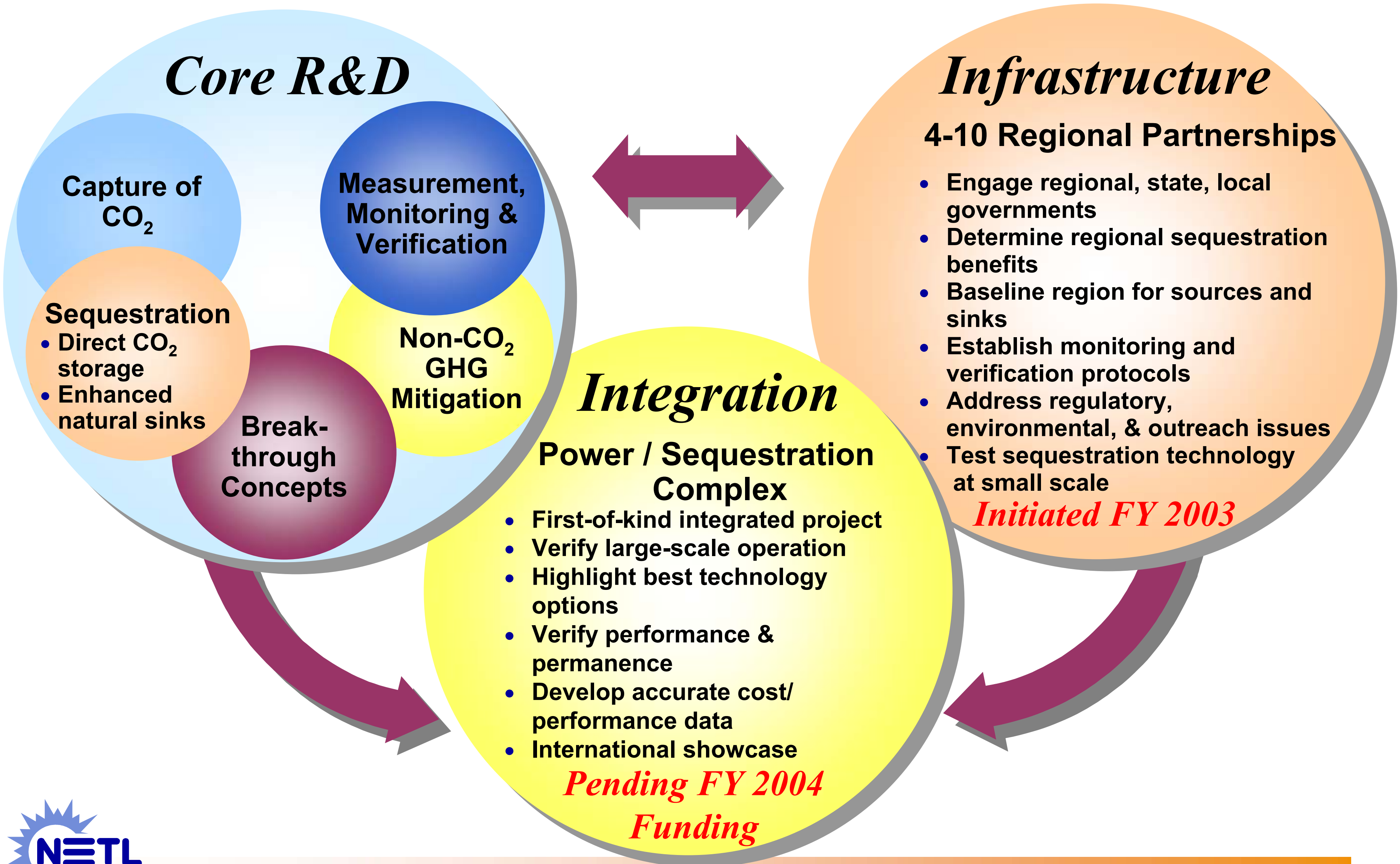
Create Sequestration Options

- Reduce CO_2 emissions by 90% with < 10% increase in cost of energy services for capture, transport, storage
- Establish measurement, monitoring & verification protocols for accounting and assurance of permanence

Support Global Climate Change Initiative

- Contribute to 2012 goal of reducing carbon intensity by 18%
- Provide portfolio of commercially ready technologies for 2012 assessment

Carbon Sequestration Program Structure



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161654 RAB 01/09/02

The Path to Significant Reductions of Carbon Emissions from Power Generation

- **Most of today's power plants will retire between 2015 and 2060 creating a window of opportunity to reduce carbon emissions**
- **This opportunity can be realized through construction of a portfolio of low-carbon emitting power plants**
  - Renewable energy sources
  - Nuclear power
  - Fossil power with carbon sequestration

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Conclusions

"I see the world in very fluid, contradictory, emerging, interconnected terms, and with kind of circuitry I just don't feel the need to say what is going to happen or not happen.“

- Jerry Brown