Economic Benefits Of A National Strategy And R&D Program In Carbon Sequestration

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Abstract. Carbon sequestration has been identified as one potentially important way to achieve stabilization of greenhouse gas concentrations in the atmosphere while maintaining economic growth and increasing domestic oil and gas production. Yet, this is a challenging new field of science and technology that will require substantial R&D investments over an extended period of time. But, how much is worth spending? Which options appear most promising? And, how might the industry participate and contribute?

For this, it is useful to examine the potential benefits to be achieved. The paper draws on projections of carbon-based and non-carbon energy consumptions to 2050 to frame the carbon emissions reduction challenge facing the nation. The paper then examines a series of technology advances and performance-based market incentives that would greatly reduce the economic impact to the nation of achieving a "pathway to stabilization" for carbon emissions. Among the options, "value-added" geologic sequestration - - injecting and storing carbon dioxide in oil reservoirs and deep coal beds - - offers one of the most promising alternatives.

Introduction. The benefits of a successful, science-based R&D technology program for carbon sequestration -- the "third option" for addressing climate change concerns – were set forth in 1998 and are summarized in the DOE Carbon Sequestration R&D Program Plan of 1999.[1] Recently, the analysis has been updated and expanded to address new information and developments in carbon sequestration of interest to the future supplies of oil and natural gas, particularly injecting carbon dioxide into reservoirs for enhanced oil recovery and into deep coal seams for enhanced coalbed methane production.

U.S. Carbon Emissions Scenarios. Our starting point is the EIA Annual Energy Outlook (AEO) 2001 Reference Case analysis to 2020.[2] This report projects carbon emissions (from energy use) to increase from 1,535 million metric tons (MMtc) in 2000 to 2,041 MMtc in 2020, Figure 1. We extrapolate the EIA projections to 2050. U.S. emissions grow over the analysis period due to an assumed sustained economic growth rate of 3% per year. However, it also assumed that the carbon intensity of economic activity will continue to decline over the analysis period so carbon emissions grow at a slower rate than GDP. As such, the Reference Case includes significant introductions of low-carbon intensity technologies, including energy efficiency (both
supply and end-use) and non-carbon based energy technologies, including renewables. Continuation of the reductions in carbon intensity per unit of GDP through 2050, as set forth in our Reference Case, will itself require dramatic capital stock turnover and substantial market penetration of advanced energy technologies.
Next, we include the projected CO_2 emissions from non-energy industries (eg. cement) as well as the non-CO_2 greenhouse gases (eg. methane) on a carbon equivalent basis. Considerable research is underway to capture the long term impacts of these non-CO_2 greenhouse gases.

Table 1 sets forth our Reference Case projections of carbon dioxide and other greenhouse gas emissions to 2050. To explore the effects of uncertainty on the benefits of the Carbon Sequestration R&D Program, we examine two other carbon emissions scenarios derived from AEO 2001, based on future expectations for economic growth.

- The low economic growth case shows carbon emissions reaching 1,916 MMtc in 2020, about 25 % higher than in 2000.

- In the high economic growth case, carbon emissions are projected to reach 2,193 MMtc in 2020, placing a major challenge on carbon management strategies.

Pathway To Stabilization. Significant emissions trading and voluntary emissions reduction programs are being undertaken by the private sector. One of the low-cost options being considered by industry is value-added geologic carbon sequestration. These actions provide the potential for significant reductions in carbon emissions by 2010.

To reflect this potential, the paper anticipates that with appropriate technology, field demonstrations and incentives, market-based initiatives and geologic sequestration have the ability to reduce the growth in carbon emissions by 50% versus the projections for year 2010 in the EIA Reference Case. After 2010, we anticipate that investments in advanced sequestration R&D, combined with value-added geologic sequestration, forestry and other actions, could provide a “pathway to carbon emission stabilization.” That is, no growth in aggregate carbon emissions beyond 2010 and reductions beginning in 2040.

For the longer term, we continue to use the Wigley, Richels, Edmonds (WRE 550 ppm emissions) scenario as the global reference case for CO_2 emissions.[3] Efforts are underway to develop new long-term global reference emissions scenarios and alternative methodologies that may more directly link to global warming impacts, and to incorporate multi-gas effects into atmospheric modeling. As these developments evolve, they will be incorporated into this analysis framework.

Emissions Reduction Options. Two low cost alternatives for reducing emissions—abatement of non-CO_2 greenhouse gases (GHGs) and low-cost carbon sequestration using forestry and other land use changes--are next examined by the analysis.

Non-CO_2 Greenhouse Gases. The projected emissions of non-CO_2 greenhouse gases, namely methane, nitrous oxide and a series of high global warming potential (HGWP) gases such as HFC, are taken from a series of studies and presentation by the Environmental Protection Agency (EPA). [4] These studies project that, under business as usual (BAU) conditions, about 400MMtc(e) (carbon equivalent) of annual non-CO_2 greenhouse gas emissions will occur in the 2010 to 2020 time period. This paper projects these emissions to reach 500 million MMtc(e) based on growth trends set forth in the EPA studies.

The estimated reductions for non-CO_2 greenhouse gas emissions are adapted data from the EPA studies, adjusted for a phase-in of industrial implementation. As a result, from 80 to 160 MMtc (e) of low-cost (<$50/tc) non-$CO_2$ greenhouse gas emission reductions are assumed in the 2015 to 2030 time. Beyond 2030, abatement of non-CO2 GHGs are scaled on expected growth in these emissions.

Sequestration Using Forestry and Other Land Use Changes. Planting trees or initiating land use changes are often cited as a sensible first step in offsetting carbon emissions. In the context of this analysis, these measures face several obstacles including the cost of measurement and verification and the need to prove that actions are incremental and additive (i.e., would not have happened anyway and are not off-set themselves by deforestation elsewhere). Application of these measures can also begin to compete with food crops and non-agricultural uses for arable land. R&D can address some of these issues. We assume that expanded use of existing practises will be implemented in the near to mid term, reaching a level of 50 MMtc of emissions reductions per year by 2030. Beyond that, increases are contingent upon successful R&D and are included in the advanced sequestration R&D program.

Carbon Sequestration. The next set of options for carbon sequestration used in the benefits analysis have been placed into two distinct categories:

- Value-added Geologic Sequestration is where industry injects CO_2 into depleted oil fields for enhanced oil recovery and into deep coal formations for enhanced coalbed methane recovery.[5, 6] These geologic sequestration options offer value-added co-products and represent significant volumes of low net cost (<$50/tc) carbon sequestration capacity. Currently, about 8 million tons of carbon (in the form of CO_2) is injected annually for enhanced oil recovery, mostly in West Texas, with about 2 million tons of this from high concentration industrial sources and natural gas plants.

- Advanced Capture and Sequestration consists of advanced technology forestry, land use changes, use of depleted oil fields, coal basins and gas fields, saline formations for geologic sequestration, and other advanced concepts. An aggressive program of R&D is expected to reduce the average costs of using this technology from $200/tc currently to about $25/tc in 2050. This is equal to an annual decrease in costs of 4%, consistent with high technology cost reduction assumptions used in portions of the EIA model.

The value-added geologic sequestration capacity and the technology are phased in over time, based on past technology introduction experiences and economics.

Increased Domestic Oil and Gas Production. Our projection is that with appropriate market-based incentives, CO_2-EOR based carbon sequestration could reach 16 million tons (carbon) in 2010, providing 300,000 barrels per day of additional oil production from the Permian Basin. Expanded application in other domestic basins could enable this process to sequester over 50 million tons (carbon) per year by 2030, adding 1 million barrels per day of domestic oil production.

Enhanced coalbed methane (ECBM) offers similar potential for sequestering carbon dioxide and increasing natural gas production. Our projection is that ECBM based carbon sequestration could reach 30 million tons (carbon) in 2015, providing 2 Bcfd (730 Bcf per year) of additional natural gas production in the San Juan Basin. Expanded application to other domestic coal basins could enable this process to sequester 60 million tons (carbon) per year by 2030, adding 4 Bcfd (1,460 Bcf per year) of domestic natural gas production. After 2030, we introduce the concept of enhanced gas shale recovery (EGSR) involving CO_2 injection and displacement of methane, reaching 1 Bcfd (365 Bcf per year) and storing 15 MMtc annually by 2040. As our understanding of the reservoir properties and sequestration capacities of deep coals and organically rich shales increases, we anticipate these estimates will also increase.

Preliminary Results. This analysis concludes that: (1) carbon sequestration is essential for achieving stabilization of carbon concentration in the atmosphere, and (2) sequestration technology combined with performance-based market incentives can provide significant benefits to the U.S. economy over using regulatory mechanisms or a carbon tax to achieving emissions stabilization between now and 2050. In calculating the economic benefits of sequestration technology, we compare the carbon prices required to achieve stabilization, based on the marginal cost of reducing energy-related carbon emissions (in the U.S.) analysis prepared by the EIA and published in AEO 2000, with the costs of using improving technology.[7] The difference between this "price" induced carbon sequestration and lower cost technology provides the basis for the incremental benefits of advanced R&D.

- In the Reference Case, where significant reductions are already assumed in carbon intensity, sequestration volumes reach nearly 300MMtc/yr in 2020 and 1,460MMtc/yr in 2050. The cumulative benefits by 2050 are over $4 trillion, consisting of $0.7 trillion from value-added geologic sequestration technology and $3.3 trillion from advanced capture and sequestration technology, as shown in Figure 2.

- Even in the Low Economic Growth Case sequestration is essential, reaching 170MMtc/yr in 2020 and nearly 950MMtc/yr in 2050. Cumulative benefits from both value-added and advanced sequestration technology to 2050 are estimated at $ 2.6 trillion.

- In the High Economic Growth Case, sequestration needs to provide 470MMtc/yr of emissions reduction in 2020 and 2,360MMtc/yr in 2050. Cumulative benefits to 2050 are estimated at $6.4 trillion from both value-added and advanced technology.

All three cases assume that aggressive industrial R&D will occur and that the 15-year DOE Carbon Sequestration R&D Program will be implemented.

Concluding Remarks. Three significant findings of interest emerge from the "economic benefits" paper and its supporting analysis:

- Carbon sequestration offers industry a major opportunity for a new, economic value-added industry, that simultaneously reduces CO_2 emissions and increases domestic oil and gas supplies.

- The volumes of additional domestic oil and natural gas production from value-added carbon sequestration are significant, reaching 1 million barrels per day of oil and 5 Bcf of natural gas per day.

- A combined program of R&D, technology demonstration and performance-based market incentives provide an efficient set of policy initiatives for accomplishing these ambitious goals for carbon sequestration, much as they did for domestic unconventional gas.

References

[1]Carbon Sequestration: Overview and Summary of Program Plans, U.S. DOE FE and NETL, April 2000.

[2]Energy Information Administration, Annual Energy Outlook 2001, December 2000.

[3]T.M.L. Wigley, R. Richels, J.A. Edmunds, "Economic and environmental choices in the stabilization of atmospheric CO_2 concentrations," *Nature*, Volume 379, January 18, 1996.

[4] Chesnaye, F., Harvey, R., "EPA's U.S. & Global Emissions and Cost Analyses of Non-CO_2 GHG", EMF 19- Technology and Climate Change Policies, [7]*Presentation by the EPA at EMF 19*, March 2000

[5]Stevens, S., Kuuskraa, V., Taber, J., "CO2 Sequestration in Depleted Oil and Natural Gas R&D Programme, 1998.

[6]Stevens, S., Kuuskraa, V., "Enhanced Coalbed Methane Recovery: Worldwide Application and CO_2 Sequestration Potential", Report prepared for IEA Greenhouse Gas R&D Programme, 1998.

[7]Energy Information Administration, Annual Energy Outlook 2000, December 1999.

Table 1. Projected U.S. Greenhouse Gas Emissions through 2050 (MMtc(e))

	2000	2005	2010	2015	2020	2030	2040	2050
CO_2 EMISSIONS								
Energy	1,535	1,690	1,809	1,928	2,041	2,345	2,695	3,097
Non-Energy								
Gas Flaring	5	5	6	6	7	8	8	8
CO2 in Nat. Gas	5	6	8	10	12	16	16	16
Cement Production	11	12	13	14	15	17	20	22
Other Industrial	8	8	9	9	10	11	12	13
Sub-total	29	31	36	39	44	52	56	58
Total CO_2	**1,564**	**1,721**	**1,845**	**1,967**	**2,085**	**2,397**	**2,751**	**3,155**
NON - CO_2 GHG EMISSIONS (CO_2 equivalent based on 100 years)								
Methane	174	180	186	185	184	184	184	184
N_2O	112	113	116	119	122	125	128	131
HGWP	45	67	90	110	130	150	170	190
TOTAL NON - CO_2 GHG	**331**	**360**	**392**	**414**	**436**	**459**	**482**	**505**
TOTAL U.S. GHG EMISSIONS	**1,895**	**2,081**	**2,237**	**2,381**	**2,521**	**2,856**	**3,233**	**3,660**
Target GHG Emissions	**1,895**	**1,988**	**2,066**	**2,066**	**2,066**	**2,066**	**2,066**	**1,965**
REQUIRED REDUCTIONS	**-**	**93**	**171**	**315**	**455**	**789**	**1,166**	**1,695**

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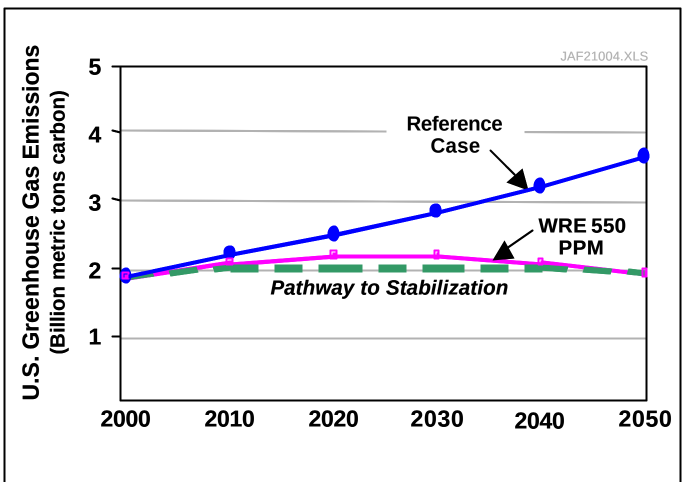
Figure 1. Carbon Emissions Pathways



Source: DOE/EIA 2000-2020.

Figure 2. Carbon Emission Reduction Options

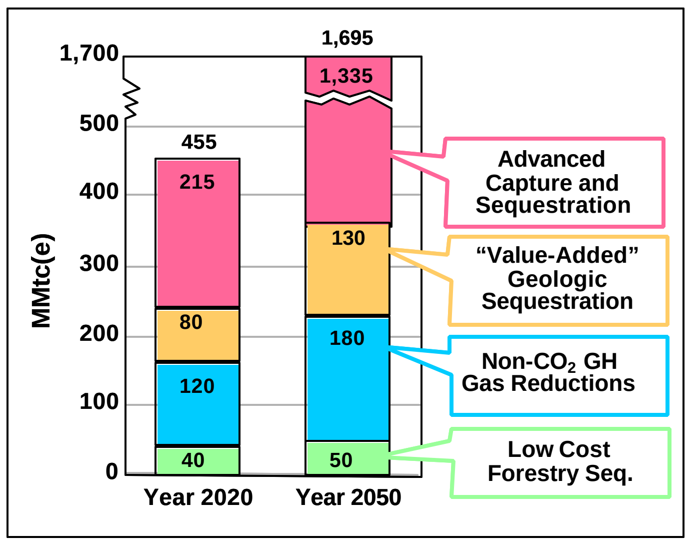


Figure 3. Increased Domestic Oil Production from Carbon Sequestration

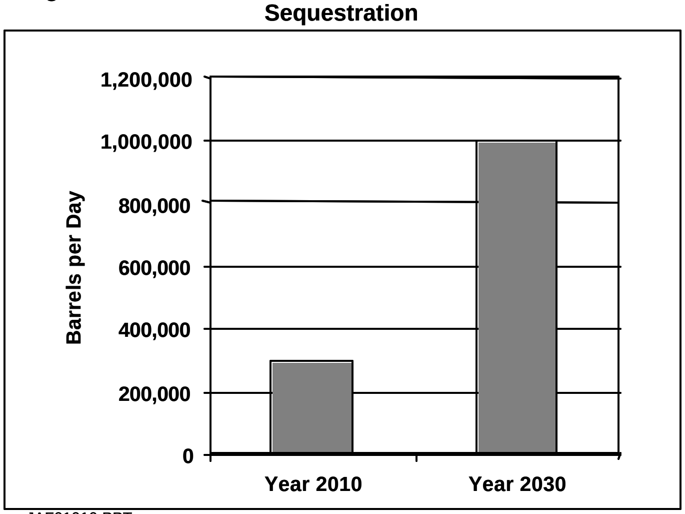
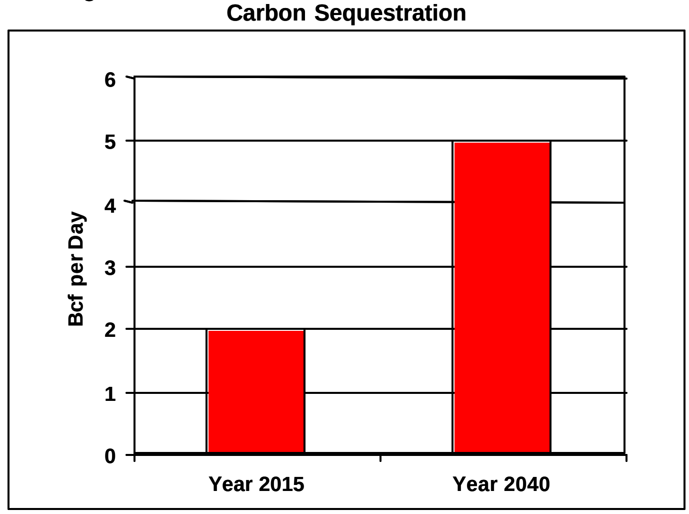


Figure 4. Increased Domestic Gas Production from Carbon Sequestration



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