U.S. POLICY

ANALYSIS FOR CARBON DIOXIDE ENHANCED OIL RECOVERY:

A CRITICAL DOMESTIC ENERGY, ECONOMIC, AND ENVIRONMENTAL OPPORTUNITY DETAILED METHODOLOGY AND ASSUMPTIONS

National Enhanced Oil Recovery Initiative

May 3, 2012

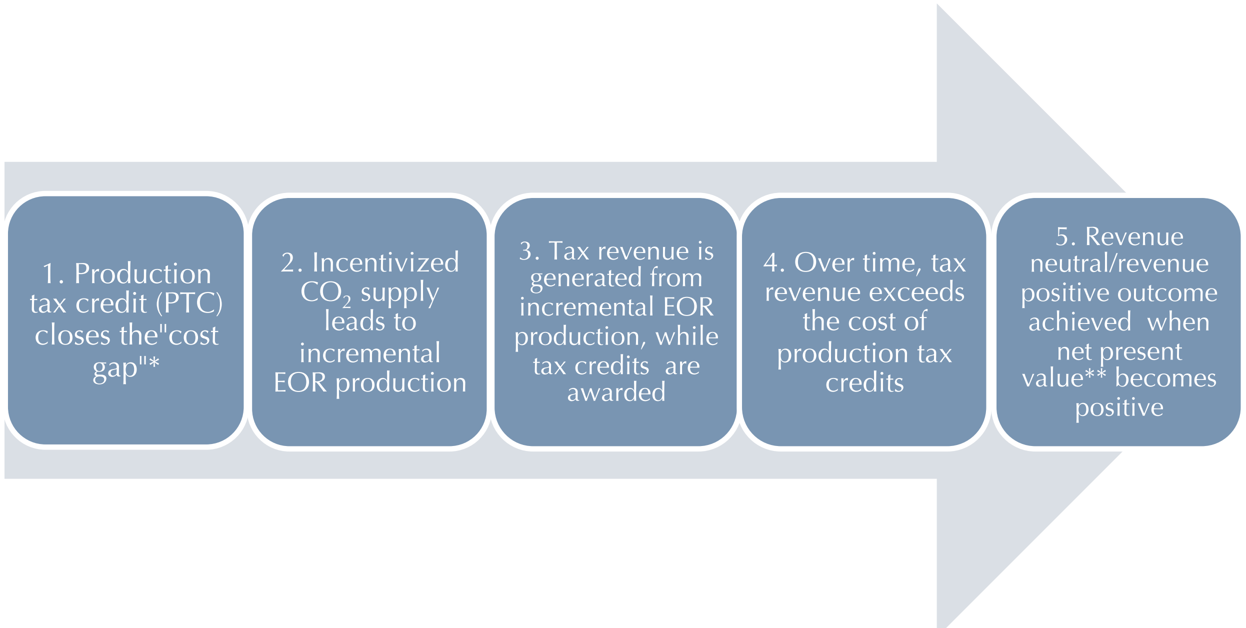
The Center for Climate and Energy Solutions (C2ES) and the Great Plains Institute (GPI) conducted an analysis, with extensive input from the participants of National Enhanced Oil Recovery Initiative (NEORI), to inform NEORI's recommendations for a federal production tax credit to support enhanced oil recovery with carbon dioxide (CO_2-EOR). In particular, C2ES and GPI explored the implications of the recommendations for CO_2 supply, oil production and federal revenue. This document describes the research, assumptions, and methodology used in the analysis. NEORI's recommendations report, *Carbon Dioxide Enhanced Oil Recovery: A Critical Domestic Energy, Economic, and Environmental Opportunity*, can be found at: http://neori.org/publications/neori-report/.

C2ES and GPI compared the likely cost of a federal tax credit for greater CO_2 capture and supply with the federal revenues expected from applying existing tax rates to the resulting incremental oil production. C2ES and GPI quantified two key relationships for CO_2-EOR development and a related tax credit program:

1) Cost gap – the difference between CO_2 suppliers' cost to capture and transport CO_2 and EOR operators' willingness to pay for CO_2. The goal of the tax credit is to bridge the cost gap. Thus, the cost gap determines the expected level of the tax credit in a proposed competitive-bidding process.

2) Revenue neutrality/revenue-positive outcome the federal government will bear the cost of a CO_2-EOR tax credit program, yet it will enjoy increased revenues from the expansion of CO_2-EOR oil production when existing tax rates are applied to the additional production. C2ES and GPI analyzed when the net present value of expected revenues would equal or exceed the net present value of program costs.

FIGURE 1: Illustration of the Cost Gap and Revenue Neutral/Revenue Positive Outcome of Federal Production Tax Credit Program



*The "cost gap" is the difference between the cost to capture and transport CO_2 and what EOR operators are willing to pay for CO_2

**Net present value is the sum of annual tax revenue minus annual production tax credit costs for each year of the production tax credit program, discounted for each year

C2ES and GPI calculated the tax credit required to bridge the cost gap, and the cost and revenue implications. C2ES and GPI developed input assumptions based on real-world physical and market conditions after consulting with NEORI participants and other industry experts and reviewing available literature. C2ES and GPI developed a core scenario based on "best guess" inputs and conducted several sensitivity analyses of key inputs. C2ES and GPI demonstrated that a program can be designed that will become "revenue positive" (defined as when the federal revenues from additional new oil production exceed the cost of a carbon capture tax credit program after applying a discount rate to both costs and revenues) within ten years after tax credits are awarded. Sensitivity analysis reveals that the program remains revenue positive using a realistic range of likely assumptions.

CO_2 TRANSPORTATION AND CAPTURE COSTS

Key Variables: CO_2 Capture Cost, CO_2 Transportation Cost, Total Price of CO_2

CO_2 capture and transportation costs determine the total price of CO_2.

- (Total Price of CO_2) = (CO_2 Capture Cost) *plus* (CO_2 Transportation Cost)

The ultimate size of a federal incentives program will be heavily influenced by the total price of CO_2 (capture costs plus transportation costs). Capture and transportation costs vary among CO_2 suppliers, who will bid for tax credits based on how much it costs to bring their CO_2 to market. Recognizing these cost differences among CO_2 suppliers, NEORI's recommended federal tax credit program establishes separate tranches to incentivize different CO_2 supply sources. After consulting publicly available literature

FIGURE 2: Assumptions Regarding Carbon Capture and Transportation Costs for Different Technology Tranches

	TRANSPORTATION COST	CORE SCENARIO CAPTURE COST	CORE SCENARIO + TRANSP. COSTS (A)	CO_2 MARKET PRICE (*STARTING 2013, WILLINGNESS TO PAY) (B)	REPRESENTATIVE EOR INCENTIVE (FOR ILLUSTRATION PURPOSE) (VARIES BY YEAR) (A-B)
POWER PLANT TRANCHE	**($/TONNE)**	**($/TONNE)**	**($/TONNE)**	**($/TONNE)**	**($/TONNE)**
		(30-year Payback)			
Pioneer - First of a Kind Projects	$10	$60	$70	$33	$37
Projects #2-#5	$10	$50	$60	$33	$27
Nth of a Kind (Projects #6-onward)	$10	$45	$55	$33	$22
INDUSTRIAL - LOW COST TRANCHE	**($/TONNE)**	**($/TONNE)**	**($/TONNE)**	**($/TONNE)**	**($/TONNE)**
		(15-Year Payback)			
Pioneer- First of a Kind Projects	$10	$28	$38	$33	$5
Projects #2-#5	$10	$28	$38	$33	$5
Nth of a Kind (Projects #6-onward)	$10	$28	$38	$33	$5
INDUSTRIAL - HIGH COST TRANCHE	**($/TONNE)**	**($/TONNE)**	**($/TONNE)**	**($/TONNE)**	**($/TONNE)**
		(15-Year Payback)			
Pioneer- First of a Kind Projects	$10	$55	$65	$33	$32
Projects #2-#5	$10	$45	$55	$33	$22
Nth of a Kind (Projects #6-onward)	$10	$35	$45	$33	$12

and consulting NEORI participants with industry expertise, C2ES and GPI made a best estimate of CO_2 capture and transportation costs for each CO_2 source for its core scenario. NEORI's core scenario used the capture and transportation costs for each CO_2 supply source in the table listed below. Sensitivity analysis increased and decreased capture and transportation costs to reflect how changes in these key variables affect the year in which a revenue neutral/revenue positive outcome is achieved.

CO_2 Transportation Costs

CO_2 transportation costs vary for different projects and across geographic regions. A literature review and consultation with NEORI participants suggested that the likely range of CO_2 transportation costs is $5 to $20 per tonne of CO_2, but likely closer to $10. The core scenario assumed that transportation costs were $10 per tonne of CO_2, and sensitivity analysis used $5 and $20 per tonne of CO_2 as low and high estimates of CO_2 transportation costs.

CO_2 Capture Costs

CO_2 capture costs vary by CO_2 source. This is because CO_2 capture technologies are in different stages of development and deployment. A literature review of publicly available sources and NEORI participant insight informed the selection of point estimates for CO_2 capture costs. Appendix Table 1 lists the publicly available studies that informed NEORI's analytic work. The following list shows additional assumptions regarding CO_2 cost.

Power Plant CO_2 Capture Costs - The CO_2 cost for a power plant with carbon capture can be calculated either as a cost of avoided CO_2 emissions or a cost of captured CO_2. Both calculations use incurred cost (the calculation numerator) as the difference in levelized cost of electricity ($/ megawatt-hour (MWhr)) between the plant with carbon capture and a reference plant (usually the same technology and configuration) without carbon capture. However, the two calculations differ in the quantity of CO_2 (the calculation divisor) associated with the cost. Avoided CO_2 (tonnes/MWhr) is the reduction in CO_2 emissions per net MWhr with CO_2 capture compared to the same reference plant without CO_2 capture. The amount of CO_2 captured per net MWhr will always be greater than the amount of CO_2 avoided per net MWhr because of the reductions in both net MWhr and efficiency when capturing CO_2. This also means that the capture cost per tonne of CO_2 will always be lower than the avoided cost per tonne of CO_2. As an example, for first-generation coal plants with carbon capture, captured CO_2 may be 30%-45% greater than avoided CO_2. Since revenue and incentives will be based on the quantity of CO_2 that is delivered to EOR, the costs provided by NEORI are for captured CO_2.

Learning - CO_2 capture costs are unlikely to remain static over time. After pioneer, first-of-a-kind projects, CO_2 capture costs are likely to fall as capture technology matures, and CO_2 suppliers learn from building multiple facilities of a given type. A literature review (see Appendix Table 2) and insight from industry experts helped to determine an appropriate estimate of cost decreases over time and with each generation of CO_2 technology development.

Low-Cost CO_2 Source Aggregation - Many of the lower-cost man-made sources are not much more expensive than the willingness-to-pay price for CO_2 at current oil prices. However, because the lower-cost sources also tend to be small in volume, it is impractical to construct dedicated pipelines to serve only lower-cost sources except in some niche applications. It is assumed that if an incentive were available at a sufficient level to bring on larger-volume, higher-cost sources, it would become possible to aggregate the lower-cost, smaller-volume industrial sources to bring them to market. NEORI's analytic work assumed that lower-cost CO_2 sources would receive a minimum tax credit amount depending on the observed willingness to pay.

CO_2 SUPPLY OVER TIME

Key Variables: CO_2 Supply by Source

Projecting likely CO_2 supply over time is important for projecting the size of an overall federal tax credit program. The availability of CO_2 is constrained by capture technology, pipeline capacity, time, and overall CO_2 potential. C2ES and GPI, with extensive input from NEORI participants, developed a realistic supply expansion scenario (See Appendix Tables 3a-3d). In terms of capture technology; power plants, low-cost industrial sources, and high-cost industrial sources each have different time horizons for development and deployment. For example, capture technology for low-cost industrial sources is closer to or already deployed at a commercial scale than capture technologies for power plant and high-cost industrial sources.

In terms of pipeline capacity, the federal production tax credit will help cover the cost of constructing new CO_2 pipeline networks across the country. Over time, these pipeline networks can accommodate additional CO_2 capture projects, reducing future transportation costs and the level of production tax credits needed for CO_2 capture.

In terms of time, CO_2 supply growth is constrained on an annual basis, at least in the early years of the incentive program. Power plants and industrial facilities take time and resources - material and financial - to complete, and, given current market conditions, it is unlikely for more than a few power plants or industrial facilities to go into operation in a given year during the early years of the program.

Over the longer term, capture technologies for both new-build facilities and retrofits are likely to become available more broadly and at lower costs. CO_2 supplies are projected to scale up rapidly after an initial deployment phase and approach the total available supply for a given CO_2 supply source.

CO_2 DEMAND/EOR OPERATORS' WILLINGNESS TO PAY FOR CO_2

Key Variables: Oil Price, EOR Operators' Willingness to Pay, Cost Gap, Annual Federal Production Tax Credit Costs

In general, EOR operators obtain CO_2 through long-term contracts to ensure a reliable supply and a predictable price. Contracted prices for CO_2 are generally set by tying the price of CO_2 to the price of oil by a certain percentage (costs are stated in mcf of CO_2; multiplying a given mcf quantity of CO_2 by a constant of 18.9 tonnes/mcf expresses the CO_2 amount in tonnes).

- EOR Operators' Willingness to Pay for CO_2 = (Oil Price) *multiplied by* (Contracted Percentage of Oil Price) *multiplied by* (18.9)

Oil Price - The U.S. Energy Information's Administration's Annual Energy Outlook's 2011 "Reference Case" provided annual forecasts for the price of oil per barrel. Forecasts are not made past 2035, so post-2035 oil prices are assumed to be the price of oil in 2035 (See Appendix Table 3). Sensitivity analysis increased and decreased the annual oil prices by 20% to account for moderate shifts in forecasted oil prices.

EOR Operators' Willingness to Pay - EOR operators base their willingness to pay for CO_2 on the price of oil and usually enter long-term agreements to buy CO_2 at a certain percentage of the oil price. NEORI's research and consultation with oil industry experts revealed that contracted percentages usually range from 1.5 percent to 2.5 percent of the price of oil (per mcf of CO_2), taking into account project-specific transportation costs and the availability of other CO_2 supply sources. The core scenario assumed a willingness to pay percentage of 2 percent, which is considered the industry's rule-of-thumb percentage. Sensitivity analysis assumed willingness to pay percentages from 1.5 percent to 2.5 percent of the price of a barrel of oil.

Cost Gap - The cost gap is the difference between EOR operators' willingness to pay for CO_2 and the total delivered price of CO_2 (expressed in dollars/tonne). NEORI's proposed production tax credit was designed to overcome the cost gap and enable CO_2 suppliers to bring man-made CO_2 to market.

- (Cost Gap) = (Total Price of CO_2) *minus* (EOR operators' Willingness to Pay for CO_2)

Multiplier - Capture cost estimates are based on a thirty-year operating period for power plants and a fifteen-year operating period for industrial facilities. However, NEORI recommends a 10-year production tax credit, and a CO_2 supplier is expected to bid for an incentive amount that will help cover operating costs of CO_2 capture, compression, and transport after the tenth year of CO_2 production. To calculate a 10-year incentive that would cover a longer payback period for CO_2 suppliers, the cost gap was increased by a multiplier. Each multiplier represents a 15% internal discount rate for CO_2 suppliers. Sensitivity analysis used multipliers that reflected lower and higher internal discount rates, or 10% and 20% respectively.

COST GAP MULTIPLIER	
Power Plants (30-Year Payback)	1.33
Industrial Facilities (15-Year Payback)	1.17

The equation below reflects the overall projected incentive to cover the cost gap.

- (Projected Tax Credits per Project) = (Cost Gap) *multiplied by* (Cost Gap Multiplier)

In sum, CO_2 suppliers will bid for production tax credits that will cover the difference between the EOR operators' willingness to pay for CO_2 and their cost to produce CO_2 and bring it to market. CO_2 suppliers' desired incentives are therefore a reflection of the cost of investing in CO_2 capture, transporting CO_2, and covering a longer payback period with a 10-year incentive.

- (Annual Production Tax Credit Costs) = Sum of (Projected Tax Credits per Project, for all projects across all tranches) *plus* Sum of (Projected Tax Credits per Project, awarded in previous years)

OIL PRODUCTION

Key Variables: Annual Oil Production

C2ES and GPI projected the incremental EOR oil production that results from incentivizing and increasing the supply of anthropogenic CO_2. Assumptions for oil supply and production resulting from new incremental CO_2 supply were based on research by the Natural Resources Defense Council and reviewed by Initiative participants. The analysis accounts for the multiple phases of EOR production to project when the federal government is likely to realize revenues from incremental EOR production. As indicated in the assumptions list below, a CO_2-EOR project's annual oil production will vary over its lifetime and reflect different development phases: initial injection, increasing production, plateau production, and declining production.

Key Assumptions:

Oil production:

- After initial CO_2 injection, 1 year lag before oil production commences;
- 5 year ramp-up in oil production volume follows;
- 5 year plateau in oil production follows;
- 20 year decline in oil production follows; and
- After 30 years, oil production ceases.

CO_2 purchase use:

- Purchased CO_2 injected for first 10 years at 100% (maximum level)
- Purchased CO_2 injections decline at 20% per year after peak oil production
- Purchased CO_2 continues to be injected at 10% for remainder of EOR project
- CO_2 injections cease at the end of 30 years

Once plateau oil production ceases, CO_2 that had been going to a project is redirected and used in different projects. The available amount of "redirected" CO_2 increases annually as an existing project uses less and less CO_2 in late stages of development. The addition of the redirected CO_2 supply to the CO_2 from a new source in a given year increases the amount of CO_2 available for initial injection in later years. This leads to expanding oil production over time.

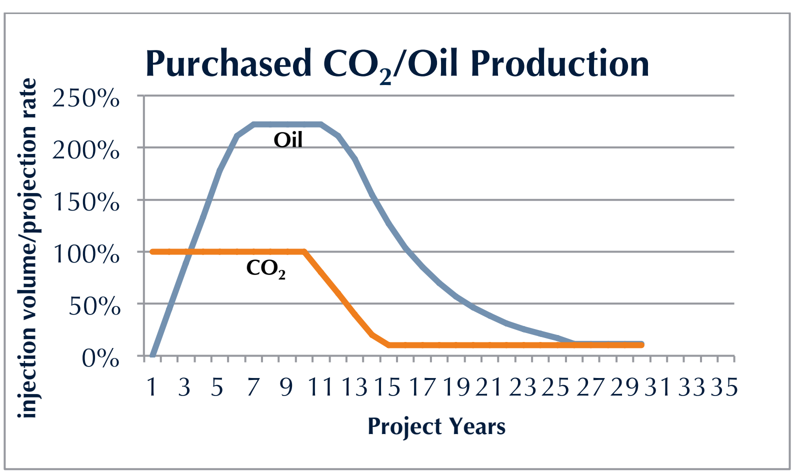
Net CO_2 Utilization Rate -Although EOR production takes place in several regions, most industry experience suggests CO_2-EOR oil production will follow the production characteristics of CO_2-EOR oil production in the Permian Basin. While the characteristics of individual CO_2-EOR projects vary, the core scenario assumes a CO_2 net utilization rate of 0.4 tonnes/barrel of oil, which is typical for the Permian Basin. The CO_2 net utilization rate is the amount of tonnes of CO_2 needed to produce one barrel of oil. Sensitivity analysis used a range of CO_2 net utilization rates, from 0.28 to 0.7 tonnes per barrel, reflecting the likely range of CO_2 utilization rates in projects across the country.

FEDERAL REVENUE

Key Variables: Annual Oil Sales, Annual Federal Revenue, Present Value of Federal Production Tax Credit Costs and Revenues

A federal tax credit program for CO_2-EOR will generate additional tax revenue as the new CO_2 supply enables additional oil production, which will be taxed at existing tax rates (the analysis assumes no tax changes other than the tax credit for CO_2 capture and transportation for EOR). Over time, the net present value of this new revenue far exceeds the net present value of the cost of the tax credits provided for CO_2-EOR.

FIGURE 3: Example of a Project's CO_2 Injection/EOR Production Timeframe



Expected federal revenue from CO_2-EOR production was estimated by multiplying the total value of oil sales by the expected percentage of the value of a barrel of oil that the federal government collects in revenue.

- (Annual Federal Revenue) = (Annual Oil Sales) m*ultiplied by* (Percentage of Oil Sales Revenue Received by the Federal Government)

Percentage of Oil Sales Revenue Received by the Federal Government - The federal government receives tax income from oil production through three main sources: corporate income taxes, royalties from oil production on federal land, and taxes on royalties going to private individuals. First, corporate income resulting from EOR oil sales is taxed at typical federal corporate tax rates. Second, the federal government receives royalty payments for EOR production on federal lands, which accounts for one in six barrels of oil produced in the United States. Finally, the federal government also taxes royalty income that private landowners receive from oil production on their land. Actual tax rates will vary for specific companies and individuals, but the estimated percentage of the sale of a barrel of oil that goes to the federal government is 20 percent. The core scenario used 20 percent as the percentage of a barrel of oil that is received by the federal government, and sensitivity analysis used 15 percent and 25 percent as the low and high range estimates for revenue received by the federal government.

Annual federal production tax credit program costs and annual federal revenue are discounted to calculate present value.

Present Value of Annual Costs and Revenue

- PV of Annual Tax Credit Program Cost = $Cost_n [1 / (1 + i)^n]$
- PV of Annual Revenue = $Revenue_n [1 / (1 + i)^n]$
  - i = discount rate
  - n = program year

Net Present Value of Federal Tax Credit Program:

- Sum of [(PV of Annual Revenue) - (PV of Annual Tax Credit Program Cost)] for all years of the program

Discount Rate - Both revenues and costs to the federal government were discounted to determine the net present value of a tax credit program. All costs and revenues are in constant 2009 dollars. The Energy Information Administration's Annual Energy Outlook 2011 Reference case provides oil prices in 2009 dollars, and capture costs from the range of available literature were usually presented in base year 2009 dollars. The Office of Management and Budget's official discount rate is based on the interest rates on Treasury notes and bonds for specified maturities. To match the 2009 time period of oil prices and capture costs and the ten-year window for an incentive, the real interest rate for 2009, 2.4 percent, was selected for this analysis. The core case scenario uses a 2.4 percent discount rate, and sensitivity analyses used discount rates of 2 percent and 3.5 percent.

Revenue Impact - The present value of annual federal costs and revenues was calculated to determine the production tax credit's overall impact on the federal government's budget. The tax credit program was considered to be "revenue-positive" in the year when the sum of present value annual revenues exceeded the sum of present value annual costs.

Additionality Sensitivity Analysis - In the core scenario, 100% of incremental oil production from CO_2-EOR is directly attributable to the federal production tax credit. Under sensitivity analysis, additional EOR production was reduced from 100% to 90%. The following equation was used in sensitivity analysis:

- (Annual Federal Revenue) = (Annual Oil Sales) *multiplied by* (Percentage of Oil Sales Revenue Received by the Federal Government) *multiplied by* (Percentage of Additional CO_2-EOR Incremental Oil Production)

APPENDIX

TABLE 1: Publicly Available Studies on CO_2 Capture Cost Reviewed by NEORI

REFERENCE	REFERENCE TITLE	CO_2 CAPTURE COST	LINK
EIA	Assumptions to the Annual Energy Outlook, Oil and Gas Module from NEMS	All CO_2 Sources	http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2011).pdf
IEA	Cost and Performance of Carbon Dioxide Capture from Power Generation	Power Plants	http://www.iea.org/papers/2011/costperf_ccs_powergen.pdf
CURC	TBD	Power Plants	Forthcoming, expected to be available Spring 2012
SPE International	The Potential for Additional CO_2 Flooding Project in the United States	All CO_2 sources	http://science.uwaterloo.ca/~mauriced/earth691-duss/CO2_General%20CO2%20Sequestration%20materilas/CO2_Mohan_Potential%20USA%20EOR%20CO2%20Projects_SPE-113975-MS-P.pdf
IPCC	Table 3.7, p. 47	All CO_2 sources	http://www.ipcc.ch/pdf/special-reports/srccs/srccs_chapter3.pdf
Lindsay	Carbon Capture and Storage in Industrial Applications (2010) (Synthesis from UNIDO)	All CO_2 sources	http://www.unido.org/fileadmin/user_media/Services/Energy_and_Climate_Change/Energy_Efficiency/CCS_%20industry_%20synthesis_final.pdf
RCI	CO_2 Capture Transport and Storage in Rotterdam (2009)	Hydrogen and Power Plants	http://www.rotterdamclimateinitiative.nl/documents/CO2%20capture%20and%20storage%20in%20Rotterdam%20-%20a%20network%20approach%202011.pdf
HKS Belfer Center	Realistic Costs of Carbon Capture	Power Plants	http://belfercenter.ksg.harvard.edu/publication/19185/realistic_costs_of_carbon_capture.html
Dooley	On the Long-term Average Cost of CO_2 Transport and Storage	Transportation and Storage	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17389.pdf

TABLE 2: Publicly Available Studies on the Effect of Learning on CCS Cost Estimates Reviewed by NEORI

REFERENCE	REFERENCE TITLE	LINK
Herzog	Scaling up carbon dioxide capture and storage: From megatons to gigatons	http://sequestration.mit.edu/pdf/Herzog_EnergyEconomics_2011.pdf
Hamilton, Herzog, Parsons	Cost and U.S. public policy for new coal power plants with carbon capture and sequestration	http://www.sciencedirect.com/science/article/pii/S1876610209009096
Chan, et al.	Expert elicitation of cost, performance, and RD&D budgets for coal power with CCS	http://www.sciencedirect.com/science/article/pii/S1876610211003663
Lipponen, et al.	The IEA CCS Technology Roadmap: One Year On	http://www.sciencedirect.com/science/article/pii/S1876610211008502
IEA	CO_2 Capture and Storage - A key carbon abatement option	http://www.iea.org/textbase/nppdf/free/2008/CCS_2008.pdf
Al-Juaied, Whitmore	Realistic Costs of Carbon Capture	http://belfercenter.ksg.harvard.edu/files/2009_AlJuaied_Whitmore_Realistic_Costs_of_Carbon_Capture_web.pdf
McKinsey & Company	Pathways to a Low-Carbon Economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve	https://solutions.mckinsey.com/ClimateDesk/default.aspx

TABLE 3A: Core Scenario CO_2 Supply Growth (2013-2022)

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Power Plants	**Pioneer - First of a Kind Projects ($/tonne)**			**$70**	**$70**	**$70**	**$70**	**$70**	**$70**	**$70**	**$70**
	CO_2 Supply			3.9	4.26	6.89	10.96	11.94	13.02	13.63	14.28
	Projects #2-#5 ($/tonne)								**$60**	**$60**	**$60**
	CO_2 Supply								12.85	12.85	16.35
	Nth of a Kind (Projects #6-onward) ($/tonne)										
	CO_2 Supply										
	Cumulative Total CO_2 Supply	**0.00**	**0.00**	**3.90**	**4.26**	**6.89**	**10.96**	**11.94**	**25.87**	**26.48**	**30.63**
Low Cost Industrial	**Pioneer - First of a Kind Projects ($/tonne)**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**
	CO_2 Supply	1	1	1	1	5.5	5.5	5.5	5.5	5.5	5.5
	Projects #2-#5 ($/tonne)	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**
	CO_2 Supply	0.85	0.85	8.45	17.45	17.45	17.45	17.45	17.45	17.45	17.45
	Nth of a Kind (Projects #6-onward) ($/tonne)						**$38**	**$38**	**$38**	**$38**	**$38**
	Natural Gas Processing CO_2 Supply						3	6	9	12	15
	Ammonia CO_2 Supply						2	2	4	4	6
	Ethanol CO_2 Supply						1	1	2	2	3
	SNG/Gasification CO_2 Supply						1	1	2	2	2
	CO_2 Supply Cumulative Total	**1.85**	**1.85**	**9.45**	**18.45**	**22.95**	**29.95**	**32.95**	**39.95**	**42.95**	**48.95**
High Cost Industrial	**Pioneer - First of a Kind Projects ($/tonne)**						**$65**	**$65**	**$65**	**$65**	**$65**
	Cement/Steel/Iron CO_2 Supply						1	1	1	1	1
	Hydrogen CO_2 Supply						0.5	0.5	0.5	0.5	0.5
	Refineries CO_2 Supply						1	1	1	1	1
	New Build Gasification CO_2 Supply						1	1	1	1	1
	Projects #2-#5 ($/tonne)								**$55**	**$55**	**$55**
	Cement/Steel/Iron CO_2 Supply								1	1	2
	Hydrogen CO_2 Supply								0.5	0.5	1
	Refineries CO_2 Supply								1	1	2
	New Build Gasification CO_2 Supply								1	1	2
	Nth of a Kind (Projects #6-onward) ($/tonne)										
	All High Cost Industrial CO_2 Supply										
	CO_2 Supply Cumulative Total	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**3.50**	**3.50**	**7.00**	**7.00**	**10.50**
	Total (All sources)	**1.85**	**1.85**	**13.35**	**22.71**	**29.84**	**44.41**	**48.39**	**72.82**	**76.43**	**90.08**

CO_2 supplies are listed in tonnes. Prices are the $/tonne capture costs. Capture costs are only listed for years when a production tax credit program might offer an incentive for a given CO2 supply source and technology development phase.

TABLE 3B: Core Scenario CO_2 Supply Growth (2023-2032)

		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Power Plants	**Pioneer - First of a Kind Projects**	**$70**	**$70**	**$70**	**$70**	**$70**					
	CO_2 Supply	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
	Projects #2-#5	**$60**	**$60**	**$60**	**$60**	**$60**	**$60**	**$60**	**$60**	**$60**	**$60**
	CO_2 Supply	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35
	Nth of a Kind (Projects #6-onward)								**$55**	**$55**	**$55**
	CO_2 Supply								7.75	9.68	12.09
	Cumulative Total CO_2 Supply	**31.05**	**31.05**	**31.05**	**31.05**	**31.05**	**31.05**	**31.05**	**38.80**	**40.73**	**43.14**
Low Cost Industrial	**Pioneer - First of a Kind Projects**	**$38**	**$38**	**$38**	**$38**						
	CO_2 Supply	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	Projects #2-#5	**$38**	**$38**								
	CO_2 Supply	17.45	17.45	17.45	17.45	17.45	17.45	17.45	17.45	17.45	17.45
	Nth of a Kind (Projects #6-onward)	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**
	Natural Gas Processing CO_2 Supply	15	15	15	15	15	15	15	15	15	15
	Ammonia CO_2 Supply	6	8	8	10	10	10	12	12	14	14
	Ethanol CO_2 Supply	3	4	4	5	5	6	6	7	7	7
	SNG/Gasification CO_2 Supply	3	3	4	4	5	5	6	6	7	7
	CO_2 Supply Cumulative Total	**49.95**	**52.95**	**53.95**	**56.95**	**57.95**	**58.95**	**61.95**	**62.95**	**65.95**	**65.95**
High Cost Industrial	**Pioneer - First of a Kind Projects**	**$65**	**$65**	**$65**	**$65**	**$65**					
	Cement/Steel/Iron CO_2 Supply	1	1	1	1	1	1	1	1	1	1
	Hydrogen CO_2 Supply	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Refineries CO_2 Supply	1	1	1	1	1	1	1	1	1	1
	New Build Gasification CO_2 Supply	1	1	1	1	1	1	1	1	1	1
	Projects #2-#5	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**
	Cement/Steel/Iron CO_2 Supply	2	3	3	4	4	4	4	4	4	4
	Hydrogen CO_2 Supply	1	1.5	1.5	2	2	2	2	2	2	2
	Refineries CO_2 Supply	2	3	3	4	4	4	4	4	4	4
	New Build Gasification CO_2 Supply	2	3	3	4	4	4	4	4	4	4
	Nth of a Kind (Projects #6-onward)						**$45**	**$45**	**$45**	**$45**	**$45**
	All High Cost Industrial CO_2 Supply						6.30	8.18	10.21	12.37	14.67
	CO_2 Supply Cumulative Total	**10.50**	**14.00**	**14.00**	**17.50**	**17.50**	**23.80**	**25.68**	**27.71**	**29.87**	**32.17**
	Total (All sources)	**91.50**	**98.00**	**99.00**	**105.5**	**106.50**	**113.8**	**118.6**	**129.45**	**136.5**	**141.26**

CO_2 supplies are listed in tonnes. Prices are the $/tonne capture costs. Capture costs are only listed for years when a production tax credit program might offer an incentive for a given CO2 supply source and technology development phase.

TABLE 3C: Core Scenario CO_2 Supply Growth (2033-2042)

		2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Power Plants	**Pioneer - First of a Kind Projects**										
	CO_2 Supply	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
	Projects #2-#5	**$60**	**$60**	**$60**	**$60**	**$60**					
	CO_2 Supply	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35	16.35
	Nth of a Kind (Projects #6-onward)	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**
	CO_2 Supply	15.06	18.71	23.17	28.59	35.12	42.91	52.07	62.73	74.90	88.55
	Cumulative Total CO_2 Supply	**46.11**	**49.76**	**54.22**	**59.64**	**66.17**	**73.96**	**83.12**	**93.78**	**105.9**	**119.60**
Low Cost Industrial	**Pioneer - First of a Kind Projects**										
	CO_2 Supply	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	Projects #2-#5										
	CO_2 Supply	17.45	17.45	17.45	17.45	17.45	17.45	17.45	17.45	17.45	17.45
	Nth of a Kind (Projects #6-onward)	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**	**$38**			
	Natural Gas Processing CO_2 Supply	15	15	15	15	15	15	15	15	15	15
	Ammonia CO_2 Supply	14	14	14	14	14	14	14	14	14	14
	Ethanol CO_2 Supply	7	7	7	7	7	7	7	7	7	7
	SNG/Gasification CO_2 Supply	7	7	7	7	7	7	7	7	7	7
	CO_2 Supply Cumulative Total	**65.95**	**65.95**	**65.95**	**65.95**	**65.95**	**65.95**	**65.95**	**65.95**	**65.95**	**65.95**
High Cost Industrial	**Pioneer - First of a Kind Projects**										
	Cement/Steel/Iron CO_2 Supply	1	1	1	1	1	1	1	1	1	1
	Hydrogen CO_2 Supply	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Refineries CO_2 Supply	1	1	1	1	1	1	1	1	1	1
	New Build Gasification CO_2 Supply	1	1	1	1	1	1	1	1	1	1
	Projects #2-#5	**$55**	**$55**	**$55**							
	Cement/Steel/Iron CO_2 Supply	4	4	4	4	4	4	4	4	4	4
	Hydrogen CO_2 Supply	2	2	2	2	2	2	2	2	2	2
	Refineries CO_2 Supply	4	4	4	4	4	4	4	4	4	4
	New Build Gasification CO_2 Supply	4	4	4	4	4	4	4	4	4	4
	Nth of a Kind (Projects #6-onward)	**$45**	**$45**	**$45**	**$45**	**$45**	**$45**	**$45**	**$45**	**$45**	**$45**
	All High Cost Industrial CO_2 Supply	17.12	19.71	22.44	25.32	28.33	28.33	28.33	28.33	28.33	28.33
	CO_2 Supply Cumulative Total	**34.62**	**37.21**	**39.94**	**42.82**	**45.83**	**45.83**	**45.83**	**45.83**	**45.83**	**45.83**
	Total (All sources)	**146.67**	**152.9**	**160.1**	**168.4**	**177.95**	**185.7**	**194.9**	**205.55**	**217.7**	**231.38**

CO_2 supplies are listed in tonnes. Prices are the $/tonne capture costs. Capture costs are only listed for years when a production tax credit program might offer an incentive for a given CO2 supply source and technology development phase.

TABLE 3D: Core Scenario CO_2 Supply Growth (2043-2052)

		2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
Power Plants	**Pioneer - First of a Kind Projects**										
	CO_2 Supply	14.7	14.7	8.7	8.7	5.3	5.3	5.3	0	0	0
	Projects #2-#5										
	CO_2 Supply	16.35	16.35	16.35	16.35	16.35	16.35	16.35	3.5	3.5	0
	Nth of a Kind (Projects #6-onward)	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**	**$55**
	CO_2 Supply	103.54	119.6	136.5	153.7	170.83	187.4	203.0	217.51	230.5	242.05
	Cumulative Total CO_2 Supply	**134.59**	**150.6**	**161.5**	**178.7**	**192.48**	**203.7**	**224.7**	**221.01**	**234.0**	**242.05**
Low Cost Industrial	**Pioneer - First of a Kind Projects**										
	CO_2 Supply	5.5	4.5	4.5	4.5	0	0	0	0	0	0
	Projects #2-#5										
	CO_2 Supply	17.45	16.6	8.5	0	0	0	0	0	0	0
	Nth of a Kind (Projects #6-onward)										
	Natural Gas Processing CO_2 Supply	15	15	15	15	15	12	9	6	3	0
	Ammonia CO_2 Supply	14	14	14	14	14	12	12	10	10	8
	Ethanol CO_2 Supply	7	7	7	7	7	6	6	5	5	4
	SNG/Gasification CO_2 Supply	7	7	7	7	7	6	6	5	5	4
	CO_2 Supply Cumulative Total	**65.95**	**64.10**	**56.00**	**47.50**	**43.00**	**36.00**	**33.00**	**26.00**	**23.00**	**16.00**
High Cost Industrial	**Pioneer - First of a Kind Projects**										
	Cement/Steel/Iron CO_2 Supply	1	1	1	1	1	0	0	0	0	0
	Hydrogen CO_2 Supply	0.5	0.5	0.5	0.5	0.5	0	0	0	0	0
	Refineries CO_2 Supply	1	1	1	1	1	0	0	0	0	0
	New Build Gasification CO_2 Supply	1	1	1	1	1	0	0	0	0	0
	Projects #2-#5										
	Cement/Steel/Iron CO_2 Supply	4	4	4	4	4	4	4	3	3	2
	Hydrogen CO_2 Supply	2	2	2	2	2	2	2	1.5	1.5	1
	Refineries CO_2 Supply	4	4	4	4	4	4	4	3	3	2
	New Build Gasification CO_2 Supply	4	4	4	4	4	4	4	3	3	2
	Nth of a Kind (Projects #6-onward)	**$45**	**$45**	**$45**	**$45**	**$45**	**$45**	**$45**	**$45**	**$45**	**$45**
	All High Cost Industrial CO_2 Supply	28.33	28.33	28.33	28.33	28.33	28.33	28.33	28.33	28.33	28.33
	CO_2 Supply Cumulative Total	**45.83**	**45.83**	**45.83**	**45.83**	**45.83**	**42.33**	**42.33**	**38.83**	**38.83**	**35.33**
	Total (All sources)	**246.37**	**260.6**	**263.3**	**272.0**	**281.31**	**282.0**	**300.0**	**285.84**	**295.8**	**293.38**

CO_2 supplies are listed in tonnes. Prices are the $/tonne capture costs. Capture costs are only listed for years when a production tax credit program might offer an incentive for a given CO2 supply source and technology development phase.