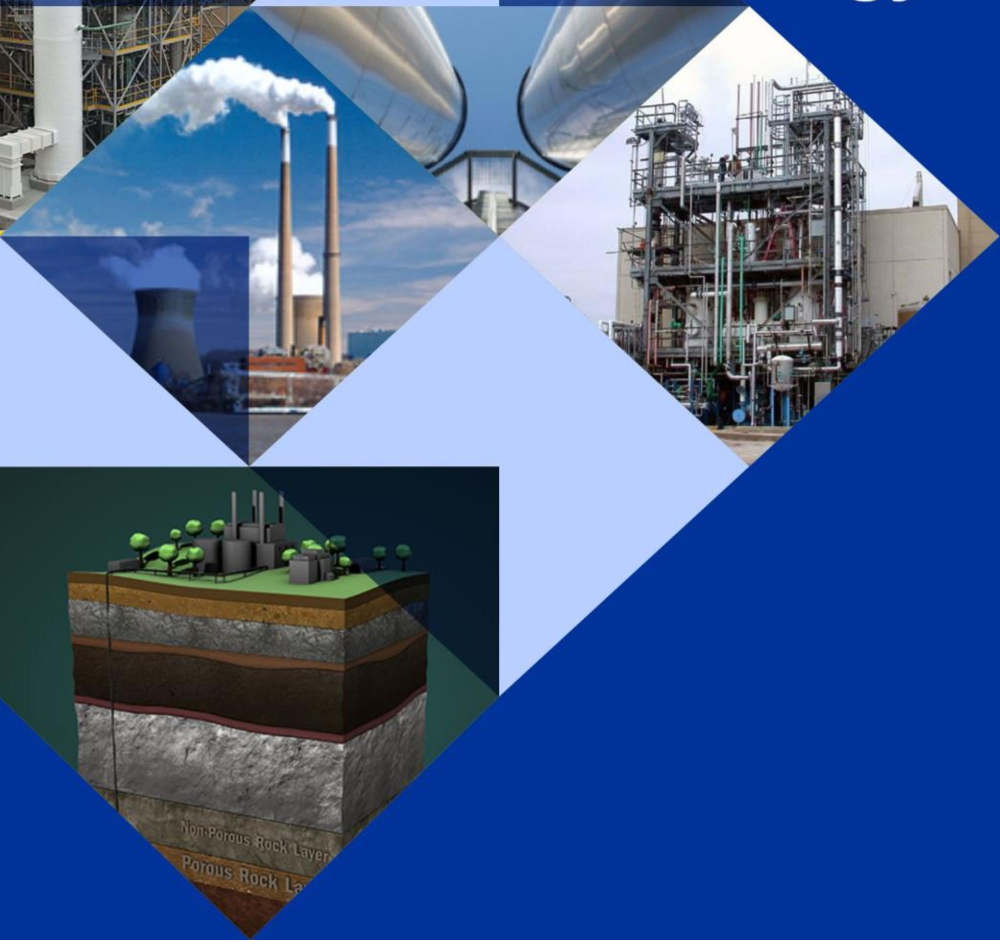
Carbon Capture, Utilization, and Storage: Climate Change, Economic Competitiveness, and Energy Security



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SUMMARY

Carbon capture, utilization, and storage (CCUS) technologies provide a key pathway to address the urgent U.S. and global need for affordable, secure, resilient, and reliable sources of clean energy. In the United States, fossil fuel-fired power plants account for 30% of total U.S. greenhouse gas (GHG) emissions and will continue to be a major part of global energy consumption for decades to come. CCUS technology is necessary to meet climate change mitigation goals at the lowest possible cost to society, but its widespread deployment will require continued improvements in cost and performance. In addition, key sources within the industrial sector, which accounts for 21% of total U.S. GHG emissions, cannot be deeply decarbonized without CCUS. A combination of tax incentives and research, development, demonstration, and deployment (RDD&D) will be critical to developing transformational carbon capture technologies and to driving down the costs of capture.

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BACKGROUND AND CONTEXT

Mitigating global climate change while creating economic opportunities and providing affordable, secure, resilient, and reliable clean energy is one of the preeminent challenges of our time. Advancing no- and low-carbon energy technologies to help meet these challenges is a primary goal of the U.S. Department of Energy (DOE). However, investment in and deployment of CCUS technology lags other clean energy technologies. Stronger policies would provide the financing and market certainty needed for deployment and to develop supply chains, commercial infrastructure, and ultimately, private sector investment in CCUS technologies. Continued RDD&D is also critical to improving performance and driving down the costs of CCUS technologies.

CCUS FOR CLIMATE CHANGE

There is international consensus that CCUS will play a critical role as part of an economically sustainable route to the emissions cuts needed to limit global warming to 2°C.[1] In 2014, the Intergovernmental Panel on Climate Change (IPCC) concluded that without CCUS, the costs of climate change mitigation could increase by 138%, and further, that realizing a 2°C scenario may not even be possible without CCUS technologies.[2] In dollar terms, the additional investment needed in the absence of CCUS in the electricity sector to limit warming to a 2°C scenario is estimated to total $2 trillion over 40 years.[3] International Energy Agency (IEA) models of the technology mix needed to meet a 2°C scenario show that CCUS will need to contribute about one-sixth of global CO_2 emission reductions in 2050, and 14% of the cumulative emissions reductions between 2015 and 2050 compared to a business-as-usual approach.[4]

In order to realize the level of mitigation from CCUS that IEA projects would be needed to limit warming to 2°C, industrial and power sector applications of CCUS would need to contribute a greenhouse gas reduction of 7 Gigatonnes per year by 2050.[5] IEA estimates that achieving these reductions would require a total global deployment of more than 950 GW of new and retrofitted power generation capacity with CCS, equivalent to roughly 2,000 500 megawatt coal-fired power plants, each emitting 3.5 million metric tons of CO_2.[6]

In addition to the critical role that CCUS plays in decarbonizing the electric power sector, deep decarbonization of key sources in the industrial sector will not be possible without CCUS.[7] In the IEA's 2°C scenario models mentioned above, approximately half (45%) of the total global emissions reductions between 2015 and 2050 are from industrial sector use of CCS in applications which cannot be replaced by renewable or other non-emitting energy technologies.[8]

Finally, IEA modeling of emissions scenarios to keep the temperature rise *below* 2°C reveal that the GHG emissions reductions needed could only be achieved "with bioenergy with CCS (BECCS) using sustainably produced feedstocks and afforestation, and/or with other CO_2 removal technologies that are deployed widely by the second half of the century."[9] As the world now works towards the 1.5°C goal agreed upon at the 21st UNFCCC Conference of the Parties in Paris in December, 2015, CCUS in the industrial and power sectors will become increasingly important.

Issue in Focus: Changing Trends in Power Generation Will Require CCUS Applications for Natural Gas and Bioenergy Projects

Natural gas is rapidly transitioning from a secondary fuel to a primary fuel for power generation in many regions. While combusting natural gas has roughly half of the CO_2 emissions of coal, emissions from natural gas power plants will ultimately need to be controlled in order to mitigate climate change. Indeed, according to the U.S. Energy Information Administration, in 2016 the share of U.S. electricity generation from natural gas is expected to exceed that of coal for the first time in history. [10]

While DOE's coal CCUS RDD&D program has many synergies with natural gas CCUS, there are also many areas unique to natural gas CCUS that will require additional RDD&D. As shown in the figure below, emissions from natural gas power systems have a higher oxygen content and lower carbon dioxide content relative to coal-based systems. Lower CO_2 content from natural gas systems requires a larger solvent-based absorber and demands more energy and surface area for a membrane-based capture system.

Higher oxygen content can also have a negative impact on solvent degradation rates and purity of permeate through a membrane system. Natural gas systems also tend to operate at higher temperatures, posing additional technical challenges.

A natural gas CCUS demonstration project would allow DOE to address the key issues associated with optimizing carbon capture systems for a natural gas power plant. The results of field testing under conditions relevant to natural gas power generation could then be used to inform the design basis, materials life, capital and operating costs of future demonstration and commercial projects. Because of the many similarities between natural gas and coal fired power systems, DOE's current CCUS program does address many natural gas issues. However, because natural gas CCUS does face some unique issues, more RDD&D is needed specifically for natural gas CCUS.

Similarly, many of the same technologies that are being developed to capture CO_2 from fossil fuel sources can also be applied to BECCS projects. BECCS plants can use the same pre- and post-combustion CO_2 capture, compression, transport and storage technologies being developed for fossil energy plants. BECCS provides one of the only large-scale methods to remove CO_2 from the atmosphere, and permanently store CO_2 underground—a potential source of *negative* CO_2 emissions. In many energy and economic modeling analyses, BECCS as a negative emissions pathway is essential to limiting warming to 2°C. [11]

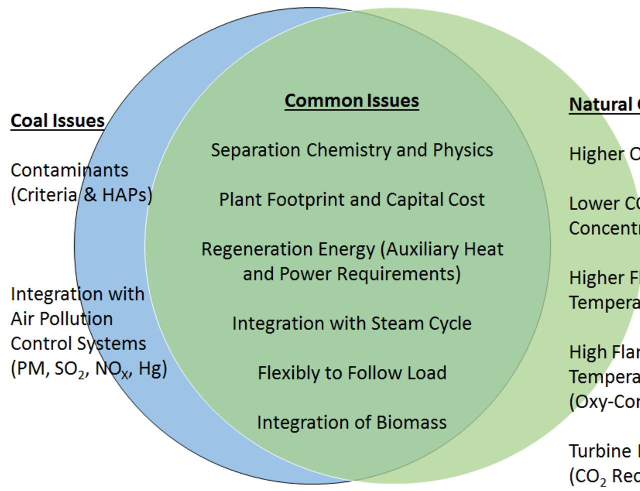
ENERGY SECURITY

With efforts to further control emissions from fossil fuels, ranging from state and local to national and international, it is clear that there is a sustained and growing demand for low-carbon energy. Indeed, action to mitigate climate change is likely to drive shifts in global energy use. Specifically, the global share of non-fossil electricity generation is expected to increase, and many countries are projected to shift away from coal. Looking forward, global coal demand is projected to remain a sizeable part of the global energy mix, with future growth in energy demand coming primarily from non-OECD countries.[12]

A diverse portfolio of energy resources is critical to U.S. energy and national security. A diverse energy system has the inherent benefits of being more robust and resilient in comparison to a system that is heavily dependent on a limited set of energy resources. A system that is diverse helps insulate the economy from certain risks, including price volatility and risks from supply disruptions that can affect the availability of particular energy resources or infrastructure.

There is already a commercial market for using captured CO_2 for enhanced oil recovery (EOR). CO_2-EOR has the important co-benefit of increasing domestic oil production, and doing so in existing oil fields, with less environmental impact than exploring new fields. CO_2-EOR also provides opportunities to significantly reduce the carbon footprint of coal-, gas-, or biomass-to-liquid fuels. Advanced CO_2 utilization concepts such as conversion of CO_2 to building materials, fuels and chemicals, and replacement of methane with CO_2 in methane hydrates, are also being explored.

Common and Distinct Challenges of Carbon Capture for Different Fuels



ECONOMIC DEVELOPMENT OPPORTUNITIES

CCUS brings with it significant economic benefits across a range of economic sectors, including mining and extraction, energy infrastructure, the manufacture of CCUS equipment, supply chains including component parts and raw materials, and the creation of a new CO_2 commodity industry for use in enhanced oil recovery (EOR), bio-refining, and other products.

Deployment of CCUS technologies not only creates a viable pathway to achieve the climate goals described above, but it also has the potential to catalyze domestic employment. The United States is a global leader in both CCUS and CO_2-EOR. If the United States can maintain its technological edge, there may be opportunities to export our CCUS technologies, products, and services to other countries. Given the necessity for these technologies to meet climate mitigation goals, the entities and the countries that succeed in developing CCUS technologies stand to play a significant role in the global market for clean energy.

The U.S. electric power generation and fuels production industries employed 1.6 million people in 2015. Of this total, just over 1 million people were employed in fossil fuel-based electrical generation and fossil fuel extraction and mining. Deployment of CCUS technology in the 55% of the electric power sector that the U.S. Energy Information Administration projects will rely on coal and natural gas in 2040 will keep these resources viable for the long term while significantly reducing carbon emissions.

Issue in Focus: Industrial Sector Opportunities for CCUS

Manufacturing plays an extremely important role in the U.S. economy. Manufacturing accounts for 12% of U.S. GDP or $2.1 trillion, and represents 31% of our total energy consumption, and about 8.5-9% of total employment. The United States produces the second largest share of the world's manufactured goods as measured by GDP, at 17.5% as compared to China's 22%.

According to DOE's Office of Energy Efficiency and Renewable Energy, 15 industrial sectors consume 95% of the energy used in the manufacturing sector.[13] Industrial activities account for about 21% of annual U.S. greenhouse gas emissions.[14] Many industrial facilities such as oil refineries, the chemical sector, and cement, aluminum, and steel production, among others, use fossil fuels for process heat as well as feedstocks. Blast furnace steel making, cement manufacturing, and some chemical production produce CO_2 directly in their production processes and indirectly through energy consumption.[15] Therefore, CCUS and energy efficiency strategies go hand in hand in manufacturing and can work together to offset the associated costs of carbon capture. CCUS can also provide a valuable revenue stream to manufacturing companies that sell CO_2 for EOR, or for other processes that utilize CO_2.

Industrial CCUS is the "low-hanging fruit" among CCUS project opportunities, because many industrial processes produce relatively pure streams of CO_2. For example, in many industrial processes (such as hydrogen production from steam methane reforming, ethanol production, and processing of natural gas, among others) the separation of CO_2 is an inherent part of the fuel production process. These facilities represent a low-cost pathway for stimulating CCUS deployment, as capture from these high-purity sources is less capital intensive in comparison to capture from diffuse sources of CO_2, such as power generation.

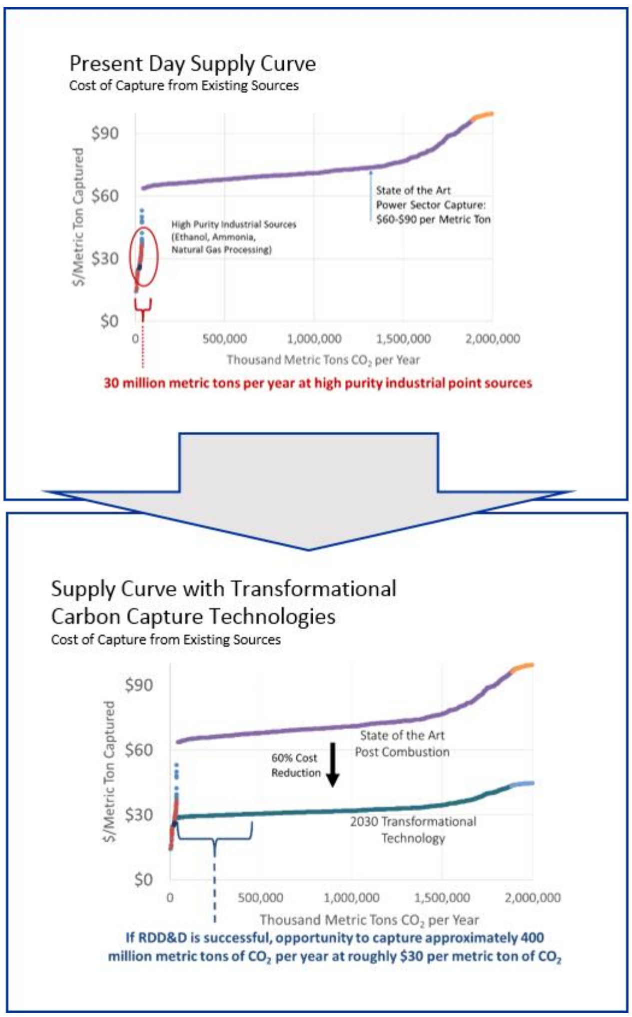
DOE analysis shows that approximately 30 million metric tons per year of pure CO_2 are currently being produced at industrial facilities located within 50 miles of existing CO_2 pipeline networks.[16] These sources provide valuable early permitting, infrastructure deployment and market opportunities, which in turn lower the cost of capturing CO_2 from future industrial and power sector projects.

Archer Daniels Midland Company: CO_2 Capture from Biofuels Production and Sequestration in the Mt. Simon Sandstone, Decatur, IL

In a 2011 Roadmap on Industrial CCUS, the IEA and the United Nations Industrial Development Organization called for governments to ensure adequate funding for CCUS demonstration projects at the scale of $27 billion, cumulatively, by 2020 in order to fund 60 large-scale projects in industrial and fuel transformation sectors.[17] Cumulative spending between 2007 and 2012 on projects that demonstrate CCUS – or component technologies in the CCUS chain – at large scale reached almost $10.2 billion.[18]

DOE has actively pursued CCUS demonstration projects in the industrial sector, with $1.4 billion in deployment funding from the American Reinvestment and Recovery Act committed to date.[19] A number of projects have or will soon enter operational stages, including Air Products, which applied CCUS to its Port Arthur hydrogen production facility, and has been capturing 1 million metric tons of CO_2 per year since 2013, with CO_2 used in an associated EOR project. The Archer Daniels Midland ethanol facility in Decatur, Illinois is expected to be fully operational in late 2016; it plans to capture 1 million metric tons per year, with CO_2 stored locally in a deep saline reservoir.[20] DOE investments have stored more than 12 million metric tons of CO_2 underground safely and effectively, equivalent to taking 2.5 million cars off the road for one year.[21]

CO_2 Capture Opportunities Exist at Less than $30 per Metric Ton of CO_2; Additional RDD&D Needed to Reduce Cost



CCUS TECHNOLOGY INCENTIVES

CCUS is a capital-intensive technology that is still high on the learning curve, and as such it will benefit from incentives that provide more early-stage support as well as more certainty over a longer period of time. For these reasons, incentives that are effective for other clean energy sources are unlikely to be successful for CCUS, and as such, direct comparison between incentives for different technologies is unlikely to be fruitful.

Many CCUS projects could be incentivized with revenue from CO_2 sales for uses such as EOR, with successful RDD&D, with targeted financial incentives, or with some combination of the three. To date, CCUS projects have been stimulated by all three, as well as by policies to better support infrastructure development.

Several CCUS demonstration projects have received Federal government funding through cooperative agreements as public-private partnerships. Some of these demonstrations have also been able to access additional incentives, such as the IRS Section 45Q tax credit, as well as private activity bonds (bonds that provide financing to specific projects, generally with favorable tax treatment). With the exception of the Archer Daniels Midland Decatur, Illinois biofuels processing plant, which stores its CO_2 underground in the Mount Simon sandstone formation, most CCUS demonstration projects have sold the captured CO_2 for use in EOR.

For power sector projects, the current cost of capture is estimated to be $60 to $70 per metric ton of CO_2.[22] DOE's goal is to reduce the cost of capture to $30-$40 per metric ton, which could be achieved through successful RDD&D. The figure to the left represents the cost per metric ton of CO_2 captured from industrial sector facilities as well as for coal fired power plants that are located within 50 miles of existing CO_2 pipeline networks (note, however, that these estimates do not take into account costs for CO_2 transportation and storage).

CCS in the Department of Energy's FY2017 Budget Request

The Fossil Energy Research and Development (FER&D) program advances technologies related to the reliable, efficient, affordable, and environmentally sound use of fossil fuels that are important to our Nation's security and economic prosperity. FER&D leads Federal research, development, and demonstration efforts on CCUS technologies to facilitate achievement of the President's climate goals.

In FY 2017, FER&D will continue to focus on CCS and activities that increase the efficiency and availability of advanced power systems integrated with CCS. It is important to demonstrate that electric generation technology with CCS can be deployed at commercial scale while maintaining reliable, predictable and safe operations. Therefore, the FER&D portfolio includes several major integrated CCS demonstration projects encompassing different technological approaches and applications of CCS.

Selected funding highlights within the CCS and Advanced Power Systems program for FY 2017 are as follows:

CARBON CAPTURE

The FY 2017 Budget Request proposes to have the Carbon Capture subprogram maintain priority on post-combustion and pre-combustion capture for fossil fuel-fired power plants. The subprogram would support a new emphasis on reducing the costs and technical challenges of natural gas carbon capture. Advanced Combustion Systems activities focus on the development of technologies such as pressurized oxy-combustion and chemical looping processes that facilitate carbon capture. For this reason, it is moved under the Carbon Capture sub program as part of the proposed restructuring.

The proposed Post-Combustion Capture activity would provide initial funding in FY 2017 for one additional (three total) post-combustion large pilot projects (10+ MWe) aimed at reducing costs and validating performance and operation for fossil fuel-fired power plants.[23] The new Natural Gas Carbon Capture activity would support the front end engineering and design (FEED) study for and initial construction costs of one large pilot specifically designed to capture CO_2 from a natural gas power plant.[24] The Advanced Combustion Systems activity would fully fund two additional (four total) FEED studies - 1 chemical looping (2 total) and 1 oxy-combustion (2 total).[25] The program would also accelerate the discovery of transformational carbon capture technologies for both pre- and post-combustion capture systems for both coal and natural gas. FY 2017 funding would also support the field testing of carbon capture systems at the National Carbon Capture Center.[26]

CARBON STORAGE

In the FY 2017 Budget Request the Carbon Storage subprogram portfolio priorities are rebalanced, moving from the large-scale injection operations of the Regional Carbon Sequestration Partnership (RCSP) projects to support for an on- and off-shore site characterization and technology validation efforts; commercial-scale site characterization and Brine Extraction Storage Tests (BEST) field activities; and lower-cost post injection monitoring technologies at RCSP field sites.[27] The FY 2017 Budget Request supports new and existing Carbon Storage subprogram projects and the Department's cross-functional Subsurface Science, Technology and Engineering RD&D (Subsurface) crosscut in developing laboratory-and bench-scale technologies for carbon storage and monitoring.[28] The Budget Request would support Energy Data Exchange (EDX) expansion and development of National Risk Assessment Partnership (NRAP) simulation toolsets.[29]

CCUS Incentive Proposals

Tax and financial incentives to support CCUS deployment are currently under consideration by policy makers and stakeholders and include:

- Incentives for CO_2-EOR, including expansion and/or modification of existing Section 45Q provisions, which provide a tax credit on a per-ton basis for CO_2 that is sequestered;
- CO_2 price stabilization, which provides long-term financial certainty on CO_2 prices;
- Master Limited Partnerships (MLPs), which provide the tax benefits of a limited partnership to qualified projects;
- Private Activity Bonds (PABs), which expand access to capital and reduce the cost of borrowing for qualified projects; and
- Investment tax credits (ITCs), which provide a tax credit for the installation of capture equipment and in some cases, supporting infrastructure.

Proposed CCUS Incentives

- **The President has proposed a refundable investment tax credit and sequestration tax credit as part of the FY 2017 budget**. The investment tax credit is for 30% of the cost of the CCUS equipment and is capped at $2 billion total, allocated by the Secretaries of Energy and Treasury. The sequestration tax credit is $50 per metric ton for CO_2 that is sequestered and not beneficially reused, and $10 per metric ton for carbon that is sequestered while beneficially reused, such as in enhanced oil recovery.
- **S. 3179, the "Carbon Capture Utilization and Storage Act,"** introduced by Sens. Heitkamp (D – ND) and Whitehouse (D – RI) in July 2016 proposes to amend the existing Section 45Q tax credit to increase the value of the credit to $35 per metric ton by 2026 for EOR and other types of CO_2 utilization, and to $50 per metric ton for CO_2 that is sequestered in saline storage. The proposal would also remove the cap on the tax credits, which would enable CCUS project developers to fully utilize the value of the tax credits for obtaining project financing and would allow the tax credits to be transferrable to the taker of the CO_2.
- **H.R. 4622, the "Carbon Capture Act,"** introduced by Rep. Conaway (R – TX) in February 2016 proposes making the existing 45Q tax credit permanent and increasing the value of the credit to $30 per metric ton by 2025. The bill also provides the same dollar per metric ton credit for CO_2 storage in saline formations and CO_2-EOR and makes the tax credits transferrable to the taker of the CO_2.
- **S. 2305, the "Carbon Capture Improvement Act,"** introduced by Sens. Portman (R – OH) and Bennet (D – CO) in November 2015, allows power plants and industrial facilities to use tax-exempt private activity bonds for finance. These bonds are exempt from certain regulatory restrictions and can lower the cost of capital and extend the time horizon for repayment.
- **S. 1285, the "Coal with Carbon Capture and Sequestration Act,"** introduced by Sens. Heitkamp (D – ND) and Manchin (D – WV) in May 2015, would allow the Secretary of Energy to enter into price stabilization contracts of up to 25 years for electric generation units that use coal-based generation technology and capture CO_2 and use it for CO_2-EOR or another commercial market.
- **S. 1656, the "MLP Parity Act,"** introduced by Sen. Coons (D – DE) with a number of bipartisan cosponsors, includes CCUS facilities as eligible for Master Limited Partnership (MLP) status, a tax-exempt corporate structure that allows the public trading of units (akin to shares), thus adding liquidity and potentially easier access to capital.

Options for CCUS Incentives and RDD&D

Given the importance of CCUS technology for the climate, energy security, and economic development goals described above, as well as the barriers that CCUS technologies face, the Administration supports tax incentives and RDD&D for CCUS technologies and supporting infrastructure. The President's proposed Budget of the U.S. Government for fiscal years 2016 and 2017 contains carbon dioxide investment and sequestration tax credits for projects that capture and permanently sequester CO_2.[30] Other efforts, such as S. 3179, the "Carbon Capture Utilization and Storage Act," and H.R. 4622, the "Carbon Capture Act," are described in the box above. In addition, the Administration supports "Mission Innovation," a landmark commitment by 20 countries and the European Union to dramatically accelerate public and private global clean energy innovation to address global climate change, provide affordable energy to consumers, and create additional commercial opportunities in clean energy.[31] The President's proposed Budget of the U.S. Government for fiscal year 2017 proposes a doubling of the Federal investment in clean energy by 2021 and includes expanded RDD&D for CCUS technology, as described earlier.[32]

Overview of Scenarios Considered

***Base Case*:** Variation of the AEO 2015 High Oil and Gas Resources Case. Includes one potential implementation of the Clean Power Plan, wind and solar tax credit extension legislation (December 2015), updated CCS costs (NETL Baseline Study, Case B12B), and updated renewable energy cost and performance data (consistent with AEO 2016).

***DOE-FE/NETL Program Goals ("R&D")*:** DOE-FE/NETL technology cost and performance goals for CCUS technologies are achieved.

***CCUS Incentives in the Administration's FY 2017 Budget Proposal ("Admin")*:** Refundable CO_2 sequestration tax credits (STC) of $10/metric ton CO_2 for EOR and $50/metric ton CO_2 for geologic storage, and a refundable 30% investment tax credit (ITC) for CCS capped at $2 billion in total credits.

***Sequestration Tax Credits ("45Q")*:** A hypothetical revision of the Section 45Q sequestration tax credits to provide a credit of $35/metric ton CO_2 for EOR and $50/metric ton CO_2 for geologic storage.

Administration's FY2017 Incentives and R&D Goals: ("Admin+R&D")*:** Combines the ***Admin-Incentives with ***R&D***.

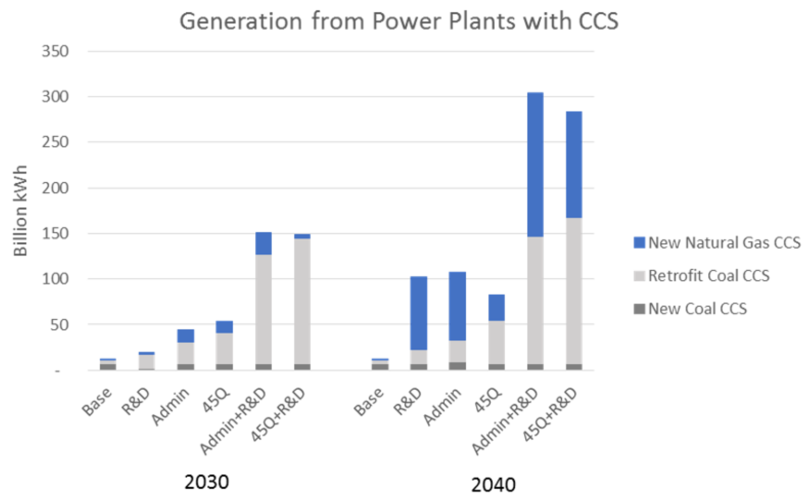
45Q Tax Credits and R&D Goals ("45Q+R&D"): Combines the ***45Q*** with ***R&D***.

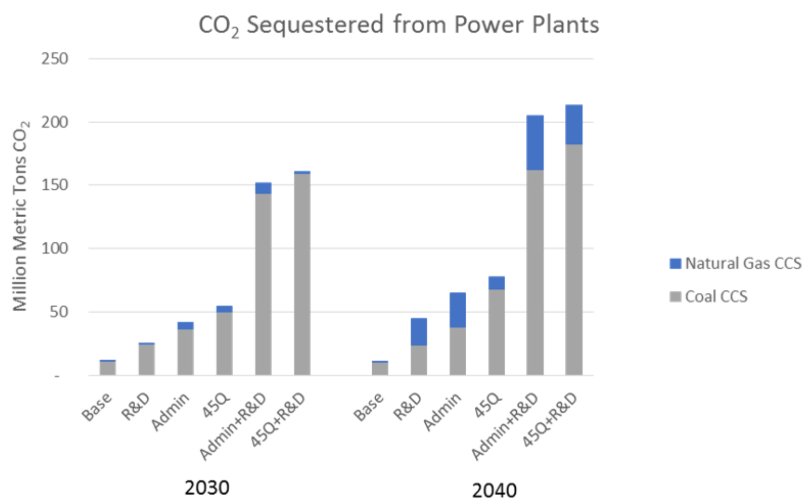
Issue in Focus: Analysis of CCUS Tax Incentives and RDD&D

DOE performed an analysis using a version of the National Energy Modeling System to explore the impact of RDD&D and tax incentives on the deployment of CCUS technologies.[1] The CCUS tax incentives proposed in the Administration's FY 2017 Budget, along with a hypothetical revision of the Internal Revenue Code Section 45Q sequestration tax credits, were considered. Additionally, the analysis investigated the impact of RDD&D on CCUS by incorporating the DOE Office of Fossil Energy and National Energy Technology Laboratory's (NETL) program goals for the cost and performance of CCS technology.
Analysis findings include the following:

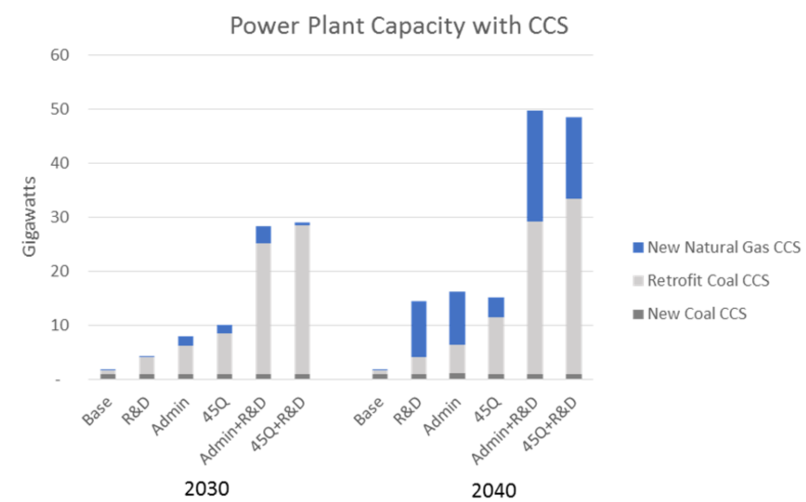
- CCUS can play an important role in reducing CO_2 emissions and meeting a carbon policy.
- Federal RDD&D combined with tax credits drive significant CCUS deployment.
- The market price of CO_2 for EOR combined with a sequestration tax credit ($35 per metric ton) makes EOR a more attractive option for captured CO_2 than saline storage despite the larger tax credit for saline storage ($50 per metric ton).
    - However, storing CO_2 in saline formations is preferred to EOR in cases where the EOR sequestration tax credit has a lower value ($10 per metric ton).
- To the extent that EOR production cannot absorb more CO_2, the package of policies and tax credits provide an incentive for saline storage of CO_2.

[1] The version of NEMS utilized in this analysis has been run by OnLocation, Inc., with input assumptions determined by DOE. This analysis was commissioned by DOE's Office of Energy Policy and Systems Analysis and uses a version of NEMS that differs from the one used by the U.S. Energy Information Administration (EIA). The results described here do not necessarily represent the views of EIA.

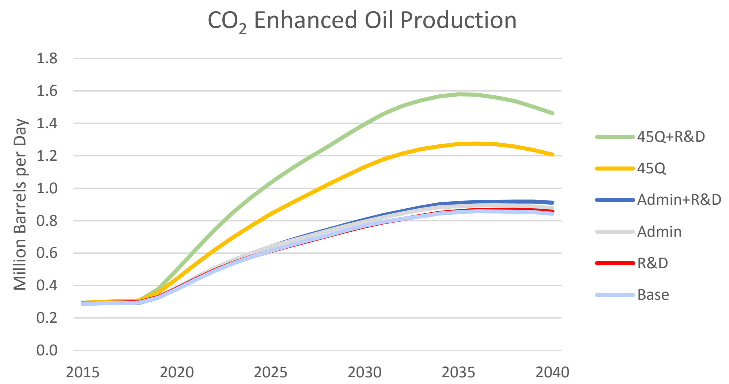




While more than half of the CCS generation is from new natural gas in Admin+R&D scenario, the CO_2 sequestered is largely from coal which produces more CO_2 per KWh. The higher proportion of natural gas CCS in the Admin+R&D case results in slightly less CO_2 sequestered than in the 45Q+R&D case.



The combination of improved technology performance and tax credits result in more retrofit coal and natural gas CCS capacity. The combination of the DOE-FE/NETL program goals and the tax credits significantly increase the amount of CCS generation and the associated CO_2 that is sequestered from power plants in comparison to the Base Case.



EOR is higher in the cases that have higher tax credits for EOR production. However, in the 45Q cases, industrial sources also receive the tax credit and are a major source of CO_2 for EOR. EOR production falls in later years as the best sites are depleted, and the remaining viable projects tend to be smaller. In all cases, as the EOR market becomes saturated additional CO_2 is captured and sent to saline storage. The increase EOR production predominately displaces crude from other sources, and total U.S. crude supply is similar across the cases.

[1] United Nations Economic Commission for Europe. The Role of Fossil Fuels in Delivering a Sustainable Energy Future. (Geneva, Switzerland: United Nations ECE, 2014), ECE/ENERGY/2014/5/Rev.1, 3, accessed June 27, 2016, http://www.unece.org/fileadmin/DAM/energy/se/pdfs/comm23/ECE.ENERGY.2014.5_e.pdf.

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[3] International Energy Agency. Energy Technology Perspectives 2012: Pathways to a Clean Energy System. (Paris, France: International Energy Agency, 2012), 11, accessed June 27, 2016, https://www.iea.org/publications/freepublications/publication/ETP2012_free.pdf.

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[11] United Nations Economic Commission for Europe. The Role of Fossil Fuels in Delivering a Sustainable Energy Future. (Geneva, Switzerland: United Nations ECE, 2014), ECE/ENERGY/2014/5/Rev.1, 2, accessed June 27, 2016, http://www.unece.org/fileadmin/DAM/energy/se/pdfs/comm23/ECE.ENERGY.2014.5_e.pdf.

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