

U.S. DEPARTMENT OF ENERGY INVESTMENT IN CARBON, CAPTURE AND STORAGE (CCS)



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The U.S. Department of Energy (DOE) oversees federal efforts to advance the deployment carbon capture and storage (CCS) technology. In addition to working on the research and development of CCS component technologies, DOE has provided financial support to multiple commercial-scale CCS projects in the power and industrial sectors. This brief examines DOE's support for CCS through the American Recovery and Reinvestment Act of 2009 and through its annual budget.

■ INTRODUCTION

The U.S. Department of Energy's [Office of Fossil Energy](#) (FE) is the Department's primary lead for CCS.¹ FE's key activities are funded through annual Congressional appropriations. In recent years, FE's overall annual budget for fossil energy research and development has fluctuated from approximately \$420 million to \$875 million dollars, of which \$270 to \$580 million has supported CCS-related activities.² Before 2009, FE's annual budget mainly funded CCS research and development, but it also provided support for the development of commercial-scale CCS projects, including the FutureGen project and Southern Company's Kemper County Energy Facility. The

Congressional Research Service report estimates that between FY1997 and FY2008, DOE provided \$900 million for activities related to CCS.³

In 2009, DOE greatly increased its funding for CCS by allocating approximately \$3.38 billion in funding for CCS under the American Recovery and Reinvestment Act of 2009 (ARRA).⁴ FE has used a large portion of this ARRA funding to support the development of multiple commercial-scale CCS projects in both the power and industrial sectors. Currently, DOE is involved in the development of eight active commercial-scale CCS projects, both in the industrial and electric power sectors (See **Figure 1**).

FIGURE 1: List of Active DOE-Supported Commercial-Scale CCS Projects

PROJECT	CAPTURE SOURCE	DOE PROGRAM	LOCATION	STORAGE	STATUS
<i>Air Products Port Arthur CCS Project</i> Factsheet	Hydrogen production	ICCS	Port Arthur, TX	EOR	Operational since 2012
<i>Archer Daniels Midland Company's Illinois Carbon Capture and Storage Project</i> Factsheet	Ethanol production	ICCS	Decatur, IL	Saline	Under construction, completion expected 2013-14
<i>Leucadia Energy, LLC: Lake Charles Carbon Capture & Sequestration Project</i> Factsheet	Coal gasification	ICCS	Lake Charles, LA	EOR	Not yet under construction; operations expected to begin in 2016-17 ⁵
<i>Southern Company's Kemper IGCC</i> Factsheet	Electric power	CCPI	Meridian, MS	EOR	Under construction, completion expected in 2014
<i>Summit's Texas Clean Energy Project</i> Factsheet	Electric power	CCPI	Penwell, TX	EOR	Not yet under construction; operations expected to begin in 2017 ⁶
<i>NRG Energy's Washington Parish Project</i> Factsheet	Electric power	CCPI	Richmond, TX	EOR	Not yet under construction; operations expected to begin in 2015 ⁷
<i>SCS Energy's Hydrogen Energy California</i> Factsheet	Electric power	CCPI	Kern County, CA	EOR	Not yet under construction; operations expected to begin in 2017 ⁸
<i>The FutureGen 2.0 project</i> Factsheet	Electric power	FutureGen	Meredosia, IL	Saline	Not yet under construction; operations expected to begin in 2017 ⁹

Note: The Industrial Carbon Capture and Storage (ICCS) program and the Clean Coal Power Initiative (CCPI) are the two DOE programs overseeing these commercial-scale projects.

As of September 2013, FE had awarded more than \$3.23 billion under ARRA to over 90 recipients, including companies, universities, national laboratories, and others in the private sector working on CCS. Of the \$3.23 billion awarded, approximately \$1.03 billion, or approximately 32 percent, has been spent to date.¹⁰ Approximately \$153 million in funding has not been awarded.¹¹

Beyond FE, DOE selected four commercial-scale CCS projects to receive loan guarantees in 2009 under

its 1703 program (though these projects have not moved forward), and the Advanced Research Projects Agency-Energy (ARPA-E) has funded numerous projects involving the research and development of next generation CCS technologies. In July 2013, DOE announced that it will be providing \$8 billion in new loan guarantees to CCS and other clean energy projects.¹²

Overall, DOE's financial support for the eight active commercial-scale CCS projects has been an important

factor in determining whether these projects have moved forward. Currently, only a small number of commercial-scale CO₂ capture projects, mostly natural gas processors, where the cost and difficulty of capturing CO₂ are relatively low have come online without DOE support. At the same time, despite DOE support, several of the active projects have been subject to delays and setbacks in progressing toward construction or financial close and in line with original estimates of overall cost. In addition, several commercial-scale projects have been cancelled despite being selected for DOE support.

While the track record of commercial-scale projects

receiving DOE support has been mixed, the perception among CCS stakeholders is that DOE's support for the research and development of CCS component technologies (particularly through the National Energy Technology Laboratory (NETL) and Regional Carbon Sequestration Partnerships) has been essential. Going forward, however, it is uncertain whether DOE and FE will have sufficient funding to support the development of the next generation of commercial-scale CCS projects, but its involvement in on-going research and development is expected to continue.

FIGURE 2: List of Active DOE-Supported Commercial-Scale CCS Projects

ARRA FUNDING CATEGORY (IN THOUSANDS OF \$)	AUTHORIZED / APPROPRIATION	AWARDED / OBLIGATIONS	SPENT/GROSS OUTLAY
<i>Carbon Capture and Storage*</i>	994,985	994,985	46,099
<i>Industrial Carbon Capture and Storage Applications</i>	1,510,216	1,486,658	695,949
<i>Expand and Extend Clean Coal Power Initiative Round III</i>	795,988	666,988	218,656
<i>Geologic Sequestration Site Characterization</i>	48,356	48,356	41,702
<i>Geologic Sequestration Training and Research Grant Program</i>	19,900	19,887	17,765
<i>Program Direction - FE</i>	10,000	9,925	9,812
<i>Sum for Office of Fossil Energy</i>	3,379,445	3,226,799	1,029,984

Source: DOE. "Recovery Act Recipient Data," Retrieved September 17, 2013 from: <http://energy.gov/downloads/recovery-act-recipient-data>; *Funding awarded under this category will support the FutureGen CCS power project.

ARRA SUPPORT FOR CCS

In comparison to FE's annual support for CCS, ARRA greatly increased DOE investment in CCS. As stated previously, Congressional Research Service report estimates that between FY1997 and FY2008, DOE provided \$900 million for activities related to CCS.¹³

ARRA funding for CCS can be broken down into several categories: a renewal of the FutureGen program, support for the Industrial Carbon Capture

and Sequestration program, Round III of the Clean Coal Power Initiative, geologic sequestration site characterization, geologic sequestration training, and internal DOE program direction. **Figure 2** lists ARRA funding by each of these categories and the status of the funding. For most categories, much of the total authorized funding has been awarded to projects, though for some categories, significant amounts of funding remain to be spent.

Carbon Capture and Storage (FutureGen)

In 2010, FE awarded \$1 billion in ARRA funding for a renewal of the FutureGen program,¹⁴ which aims to repower a coal-fired power plant with CCS as part of a collaborative effort with industry. This funding will be complemented by the FutureGen Alliance's commitment to provide approximately \$300 million in private investment.^{15,16} FutureGen will use oxy-combustion carbon capture technology, repower a 200 megawatt coal-fired power plant in Meredosia, Illinois, and capture 1.3 million tons of CO₂ per year for sequestration in a nearby saline aquifer.

Prior to ARRA support, FutureGen received funding from the annual FE budget. FutureGen was originally proposed in 2003,¹⁷ and the program has been subject to several setbacks since its inception. In 2008, DOE program cancelled the program all together, citing cost concerns.¹⁸ Since FutureGen's revival in 2009, it has faced additional challenges, including project redesigns and the departure of key project partners.^{19,20}

FutureGen's remaining project partners have made strides in pushing the project toward construction. In December 2012, the Illinois Commerce Commission approved a power purchase agreement to buy FutureGen's electric output,²¹ and in February 2013, DOE announced that it will enter Phase II of the FutureGen project.²² FutureGen's construction is expected to begin in 2014 with the facility becoming operational by 2017.

Industrial Carbon Capture and Storage Applications

ARRA directed DOE to provide \$1.52 billion for industrial carbon capture projects through competitive solicitation.²³ The majority of funding under this category has been awarded to three commercial-scale CCS projects, while the remaining funding has been awarded to efforts to research and develop CCS component technologies and utilize captured CO₂ in industrial processes.²⁴ Overall, approximately 40 different companies, research institutions, and universities have received funding under this category.

Using ARRA funding, FE expanded its existing Industrial Carbon Capture and Storage (ICCS) program to provide funding for three commercial-scale CCS projects:

- Air Products' CO₂ capture project involving two steam methane reformers (hydrogen producers) at Valero Energy's refinery in Port Arthur, Texas.²⁵ This project began carbon capture in December 2012 and is expected to capture one million tons of CO₂ per year.²⁶
- Archer Daniels Midland's capture CO₂ project at its ethanol production facility in Decatur, Illinois.²⁷ Construction began in August 2011, and carbon capture up to one million tons of CO₂ per year is expected to begin in late 2013 or early 2014.
- Leucadia Energy's CO₂ capture project involving synthetic natural gas production facility in Lake Charles, Louisiana. Construction has not yet started, but operations could begin by 2016.

Other funding recipients under this category include General Electric, Alstom, Praxair, Siemens, and Ramgen. As of September 2013, approximately 47 percent of the funding awarded under this category has been spent.

Expand and Extend Clean Coal Power Initiative Round III

Launched in 2002,²⁸ the Clean Coal Power Initiative (CCPI) established a cost sharing program for DOE and potential clean coal projects, including commercial-scale electricity generation projects with CCS. In 2003, Round I of CCPI awarded approximately \$316 million in funding,²⁹ while in 2004, Round II of CCPI awarded approximately \$331 million in funding.³⁰ Under Round II, Southern Company received \$270 million for an integrated gasification combined cycle (IGCC) power project with carbon capture that was eventually located in Kemper County, Mississippi.³¹ This project is expected to finish construction in 2014 and become one of the world's first two commercial-scale CCS power projects along with SaskPower's Boundary Dam project in Saskatchewan, Canada.^{32,33} For certain CCPI projects, DOE has agreed to share up to 50 percent of a project's overall investment cost.³⁴

ARRA funding enabled a new and expanded Round III of CCPI, which could ultimately provide more than \$800 million for commercial-scale CCS power projects.³⁵ While several Round III projects remain

active, several projects, which were initially awarded grants, withdrew from CCPI for various reasons. For example, American Electric Power (AEP) cancelled its Mountaineer Project in 2011 after being awarded Round III CCPI funding in 2009. AEP explained that its decision to cancel the project was a due to several factors, including uncertain U.S. climate policy, a weak economy, and difficulty securing rate payer recovery for the project’s costs.³⁶ **Figure 3** below lists the commercial-scale power projects selected for ARRA funding and the status of these projects.

As of September 2013, approximately 33 percent of awarded ARRA funding for CCPI Round III projects

has been spent, while approximately \$129 million of authorized funding remains to be awarded. Overall, DOE has agreed to provide up to \$1.29 billion to the remaining active CCPI commercial-scale projects: Kemper (\$270 million), Texas Clean Energy Project (\$450 million), Hydrogen Energy California (\$408 million), and NRG’s Washington Parish Plant (\$166 million).

It should be noted that each of the active CCPI commercial-scale projects will sell captured CO₂ for use in enhanced oil recovery, thus taking advantage of an additional revenue stream.

FIGURE 3: ARRA Funding for Round III of the Clean Coal Power Initiative

DATE AWARDED	PROJECT NAME	ORIGINAL GRANT AMOUNT	STATUS
July 2009	Basin Electric Antelope Valley	\$100 million	Withdrew from CCPI
July 2009	Hydrogen Energy California (HECA)	\$308 million	Carbon capture expected to begin in 2017
December 2009	AEP Mountaineer	\$334 million	Withdrew from CCPI
December 2009	Southern Plant Barry	\$295 million	Withdrew from CCPI
December 2009	Summit Texas Clean Energy Project	\$350 million	Headed to financial close, carbon capture expected to begin in 2015
March 2010	NRG Washington Parish Plant	\$154 million	Carbon capture expected to begin in 2017

Source: DOE. “Clean Coal Power Initiative Round III.” Retrieved September 17, 2013 from: <http://energy.gov/fe/clean-coal-power-initiative-round-iii>. DOE increased the amount of awarded grants to the active CCPI projects after the withdrawal of the listed CPPI projects.³⁷

Geologic Sequestration Site Characterization/Training Program

More than 40 organizations, mostly universities, received funding under the categories of Geologic Sequestration Site Characterization and Geologic Sequestration Training and Research Grant Program. Almost all of the ARRA funding authorized for these categories has been awarded and spent.

ANNUAL FE BUDGET AND OTHER DOE SUPPORT MECHANISMS FOR CCS

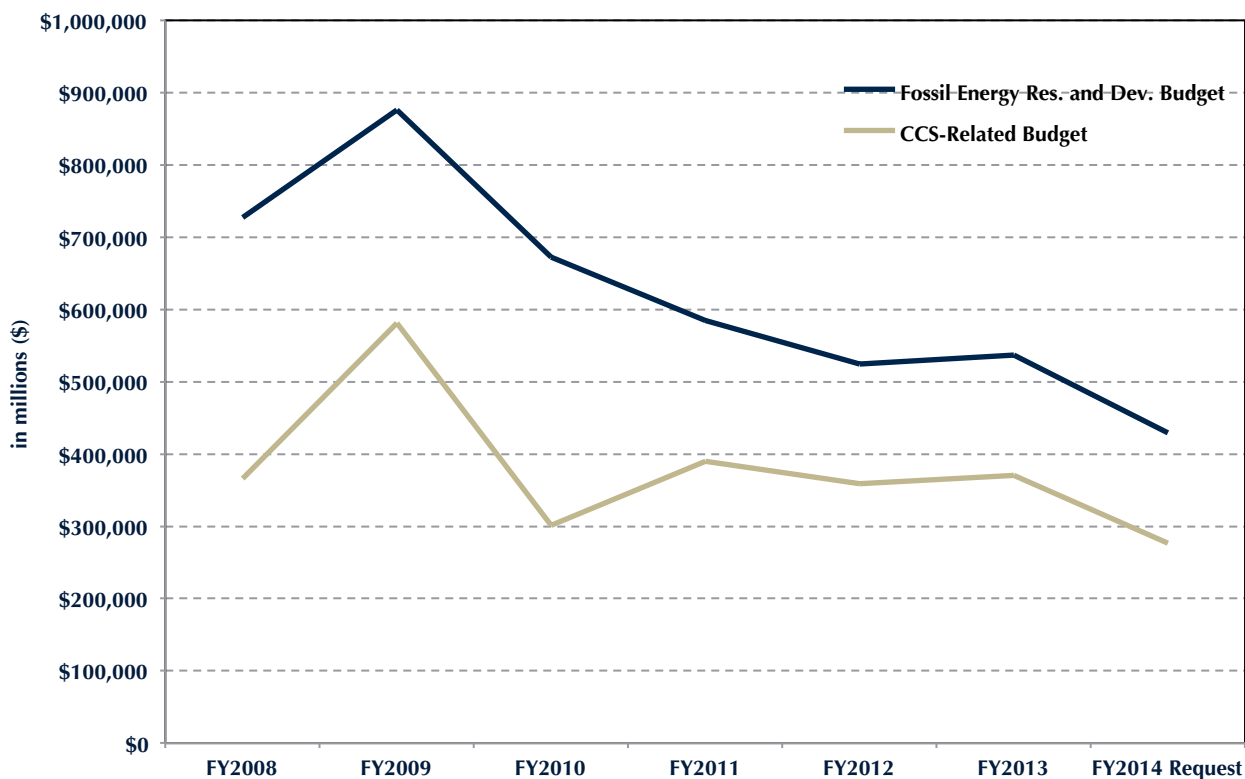
Prior to ARRA, FE’s annual budget provided some support for the development of commercial-scale CCS projects, but on a more limited scale. For example, the Office of Fossil Energy’s annual budget had allocations for the FutureGen program and for the Clean Coal Power Initiative, which would ultimately allocate \$270

million in support for the project that would eventually become Kemper IGCC.³⁸

The FY 2014 FE budget requests \$276.6 million for “CCS and Power Systems,”³⁹ an amount that takes into account of the fact that separate ARRA funding is still in the process of being awarded and spent. FE’s annual budget will continue to fund the research and development of CCS component technologies, mostly through the [National Energy Technology Laboratory \(NETL\)](#), and CCS-related activities such as the [Regional Carbon Sequestration Partnerships](#).

Currently, seven Regional Carbon Sequestration Partnerships foster public and private sector collaboration on CCS research and development and bring together a wide range of partners including: federal, state and local agencies; universities; national laboratories; non-governmental organizations; and industry representatives.⁴⁰ These partnerships have facilitated demonstration projects involving CO₂ injection into different geologic formations, and the field experience and lessons learned from these projects is intended to inform the broader deployment of CCS technology in the future.

FIGURE 4: Annual Budget for Fossil Energy Research and Development versus CCS-Related Budget under the Office of Fossil Energy



The Office of Fossil Energy’s annual budget has included funding for Fossil Energy Research and Development, a portion of which has support CCS-related activities. CCS-related budget amounts for FY2008 through FY2010 based on budget categories identified by P. Bolger in *Carbon Capture and Sequestration (CCS)*, 2009. CCS-related budget amounts for FY2011 through FY2014 request reflect the CCS and Power Systems budget categories listed in DOE’s FY2013 and FY2014 Budget Justifications for the Office of Fossil Energy. Though Fossil Energy.^{41,42} Budget rescissions and funding amounts carried over from a previous fiscal year are not reflected in this graph.

Section 1703 Loan Guarantees for CCS Projects

Beyond the Office of Fossil Energy, DOE has established additional mechanisms to support CCS projects. The Energy Policy Act of 2005 authorized the Section 1703 loan guarantee program, which allows DOE to provide loan guarantees to clean energy projects that may face difficulties in obtaining private sector financing due to technology risk.⁴³ In 2008, DOE announced a solicitation for up to \$6 billion in federal loan guarantees for coal-based electric power or industrial gasification projects that adopted CCS.⁴⁴ Funding was made available through the Omnibus Appropriations Act of 2009.⁴⁵

In 2009, DOE awarded loan guarantees to four CCS projects,⁴⁶ which as of July 2013, have not proceeded to financial close or construction. In July 2013, DOE announced a new round of loan guarantee solicitation.⁴⁷ Up to \$8 billion will be available for clean energy projects, including CCS projects.⁴⁸

ARPA-E Support for CCS

DOE has also supported the research and development of CCS component technologies through the Advanced Research Projects Agency-Energy (ARPA-E). Since its inception in 2009, ARPA-E has awarded \$42 million in grants to 17 projects conducting research related to CCS. Private companies,

and national laboratory researchers have received grants, ranging in size from approximately \$560,000 to \$5.3 million.⁴⁹

SUMMARY

In December 2012, Air Products' Port Arthur project became the first DOE-supported commercial-scale CCS project to begin operations. Two additional DOE-supported commercial-scale projects are under construction, and five additional projects are moving toward financial close. These projects represent important successes in the broader development of CCS in the United States. Some of these active projects have been subject to delays and other development challenges, and other DOE-supported projects have been cancelled. Yet, getting projects to the finish line is important for driving CCS technology along its learning curve and gradually reducing CCS costs. Going forward, it is not clear if DOE funding on the level provided by ARRA will be available in the future, and the development of the next generation of CCS projects is uncertain. Overall, DOE's role in the development of CCS will remain critical, not only in contributing to development of commercial-scale projects, but in supporting on-going research and development of CCS component technologies through NETL, the Regional Carbon Sequestration partnerships, and ARPA-E.

FIGURE 5: ARPA-E Projects Involving CCS

AMOUNT	STATUS	PROJECT NAME
\$2,684,881	Active	Alliant Techsystems) Supersonic Technology for CO ₂ Capture
\$4,657,045	Alumni	Codexis, Inc. Better Enzymes for Carbon Capture
\$1,266,675	Active	Columbia University Chemically Accelerated Carbon Mineralization
\$3,717,511	Active	GE Global Research Center, CO ₂ Capture with Liquid-to-Solid Absorbents
\$1,000,000	Alumni	Georgia Tech Research Corporation, Composite Membranes for CO ₂ Capture
\$3,867,851	Active	Lawrence Berkeley National Laboratory, Metal Organic Framework Research
\$3,632,000	Active	Lawrence Livermore National Laboratory, Synthetic Catalysts for CO ₂ Storage
\$560,809	Alumni	Lehigh University, CO ₂ Capture Using Electric Fields
\$1,000,000	Alumni	Massachusetts Institute of Technology, CO ₂ Capture Using Electrical Energy
\$887,609	Alumni	Oak Ridge National Laboratory High Surface-Area CO ₂ Sponge
\$1,153,975	Alumni	Porifera, Inc. Carbon Nanotube Membranes
\$2,480,000	Active	RTI International CO ₂ Capture and Regeneration at Low Temperatures
\$5,297,254	Active	Sustainable Energy Solutions (SES), Cryogenic Carbon Capture
\$1,019,874	Alumni	Texas A&M University, Stimuli-Responsive Metal Organic Frameworks
\$3,847,270	Active	University of Colorado at Boulder, Gelled Ionic Liquid-Based Membranes
\$2,011,578	Cancelled	University of Kentucky Center for Applied Energy Research, Hybrid Solvent-membrane CO ₂ Capture
\$2,559,562	Active	University of Notre Dame, Phase-Changing Ionic Liquids
\$41,643,894	Total Funding	

Source: ARPA-E Project Webpage (2013, September 9), Retrieved September 9, 2013 - <http://arpa-e.energy.gov/?q=projects/search-projects>



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The Center for Climate and Energy Solutions (C2ES) is an independent nonprofit organization working to promote practical, effective policies and actions to address the twin challenges of energy and climate change.

ENDNOTES

¹ Other core FE activities include maintaining the nation's strategic oil reserves and conducting research and development related to fossil fuels (for example, improving oil and natural gas extraction processes).

² For fiscal year 2014 (FY2014), DOE requested approximately \$430 million to support fossil energy research and development, though with \$8.7 million available from the previous fiscal year, the total request equaled \$420 million. (DOE. (2013). Office of Fossil Energy Detailed FY 2014 Budget Justification. Available at: http://energy.gov/sites/prod/files/2013/04/f0/fe_fy2014_volume3bj.pdf).

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³ Folger, Peter. 2009. Carbon Capture and Sequestration. Congressional Research Services. available at <http://www.fas.org/sgp/crs/misc/RL33801.pdf>.

⁴ DOE. "FE Implementation of the Recovery Act." Retrieved September 9, 2013 from: <http://energy.gov/fe/fe-implementation-recovery-act>.

⁵ Lake Charles Clean Energy. "Schedule." Retrieved September 17, 2013 from: <http://lakecharlescleanenergy.com/schedule/>.

⁶ Texas Clean Energy Project. "The Project." Retrieved September 17, 2013 from: <http://www.texascleanenergyproject.com/project/>.

⁷ Petro Nova Fact Sheet. "WA Parish CO2 Capture Project." Retrieved September 17, 2013 from: http://www.nrgenergy.com/pdf/factsheets/factsheet_waparish.pdf.

⁸ Hydrogen Energy California. "Executive Summary." Retrieved September 17, 2013 from: http://hydrogenenergycalifornia.com/wp-content/uploads/file_attachments/090520121854220/1_0ExecutiveSummary.pdf.

⁹ FutureGen Alliance. "Community Corner Archive." Retrieved September 17, 2013 from: <http://www.futuregenalliance.org/community-corner/2012/08/>.

¹⁰ DOE. "Recovery Act Recipient Data." Retrieved September 17, 2013 from: <http://energy.gov/downloads/recovery-act-recipient-data>.

¹¹ Several commercial-scale CCS power projects (American Electric Power's Mountaineer, Basin Electric's Antelope Valley, and Southern Company's Plant Barry projects) were awarded ARRA funding but later withdrew their applications.

¹² DOE Loan Programs Office. "Draft Advanced Fossil Energy Solicitation to Support Reductions in Greenhouse Gas and Other Pollution." Available at: <http://lpo.energy.gov/wp-content/uploads/2013/07/Advanced-Fossil-Fact-Sheet-7.2.13.pdf>.

¹³ Folger, 2009.

¹⁴ DOE. (September 28, 2010). "Department of Energy Formally Commits \$1 Billion in Recovery Act Funding to FutureGen 2.0." Available at: <http://energy.gov/fe/articles/department-energy-formally-commits-1-billion-recovery-act>

¹⁵ DOE. "FutureGen. 2.0." Retrieved September 17, 2013 from: <http://energy.gov/fe/science-innovation/clean-coal-research/major-demonstrations/futuregen-20>.

¹⁶ FutureGen Alliance (2011). "FutureGen. 2.0." Retrieved September 17, 2013 from: <http://www.futuregenalliance.org/pdf/FutureGenFacts.pdf>.

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- ²⁸ DOE. (November 2011). *Major Demonstration Programs: Program Update 2011*. Available at: http://www.netl.doe.gov/technologies/coalpower/cctc/resources/pdfsprog/cctupdat/DemoPrograms_CCTUpdate2011.pdf.
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³⁶ AEP. (July 14, 2011). “AEP Places Carbon Capture Commercialization On Hold, Citing Uncertain Status Of Climate Policy, Weak Economy.” Available at: <http://www.aep.com/newsroom/newsreleases/?id=1704>

³⁷ NETL’s project factsheet for Hydrogen Energy California lists DOE’s share of the project’s cost as \$408 million (\$308 million awarded initially). Source: NETL. (May 2013). “Hydrogen Energy California Project.” Available at: <http://www.netl.doe.gov/publications/factsheets/project/FE0000663.pdf>.

NETL’s project factsheet for NRG Energy’s Washington Parish Project lists DOE’s share of the project’s cost as \$166 million (\$154 million initially awarded). Source: NETL. (March 2012). “NRG Energy: W.A. Parish Post-Combustion CO₂ Capture and Sequestration Project.” Available at: <http://www.netl.doe.gov/publications/factsheets/project/FE0003311.pdf>.

The Texas Clean Energy Project’s webpage explains that DOE awarded the project an additional \$100 million in August 2010 in addition to the \$350 initially awarded. Source: Texas Clean Energy Project. “The Project.” Retrieved September 17, 2013. Available at: <http://www.texascleanenergyproject.com/project/>.

³⁸ DOE. “CCPI Round 2 Selections.” Retrieved on September 17, 2013.

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⁴¹ DOE. (2012). Office of Fossil Energy Detailed FY 2013 Budget Justification, Available at: http://energy.gov/sites/prod/files/FY13Volume3_0.pdf.

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