A

Report of the Interagency Task Force on Carbon Capture and Storage

August 2010

(pages omitted)

Executive Summary

Introduction

Carbon capture and storage (CCS) refers to a set of technologies that can greatly reduce carbon dioxide (CO_2) emissions from new and existing coal- and gas-fired power plants, industrial processes, and other stationary sources of CO_2. In its application to electricity generation, CCS could play an important role in achieving national and global greenhouse gas (GHG) reduction goals. However, widespread cost-effective deployment of CCS will occur only if the technology is commercially available and a supportive national policy framework is in place.

In keeping with that objective, on February 3, 2010, President Obama established an Interagency Task Force on Carbon Capture and Storage composed of 14 Executive Departments and Federal Agencies. The Task Force, co-chaired by the Department of Energy (DOE) and the Environmental Protection Agency (EPA), was charged with proposing a plan to overcome the barriers to the widespread, cost-effective deployment of CCS within ten years, with a goal of bringing five to ten commercial demonstration projects online by 2016. Composed of more than 100 Federal employees, the Task Force examined challenges facing early CCS projects as well as factors that could inhibit widespread commercial deployment of CCS. In developing the findings and recommendations outlined in this report, the Task Force relied on published literature and individual input from more than 100 experts and stakeholders, as well as public comments submitted to the Task Force. The Task Force also held a large public meeting and several targeted stakeholder briefings.

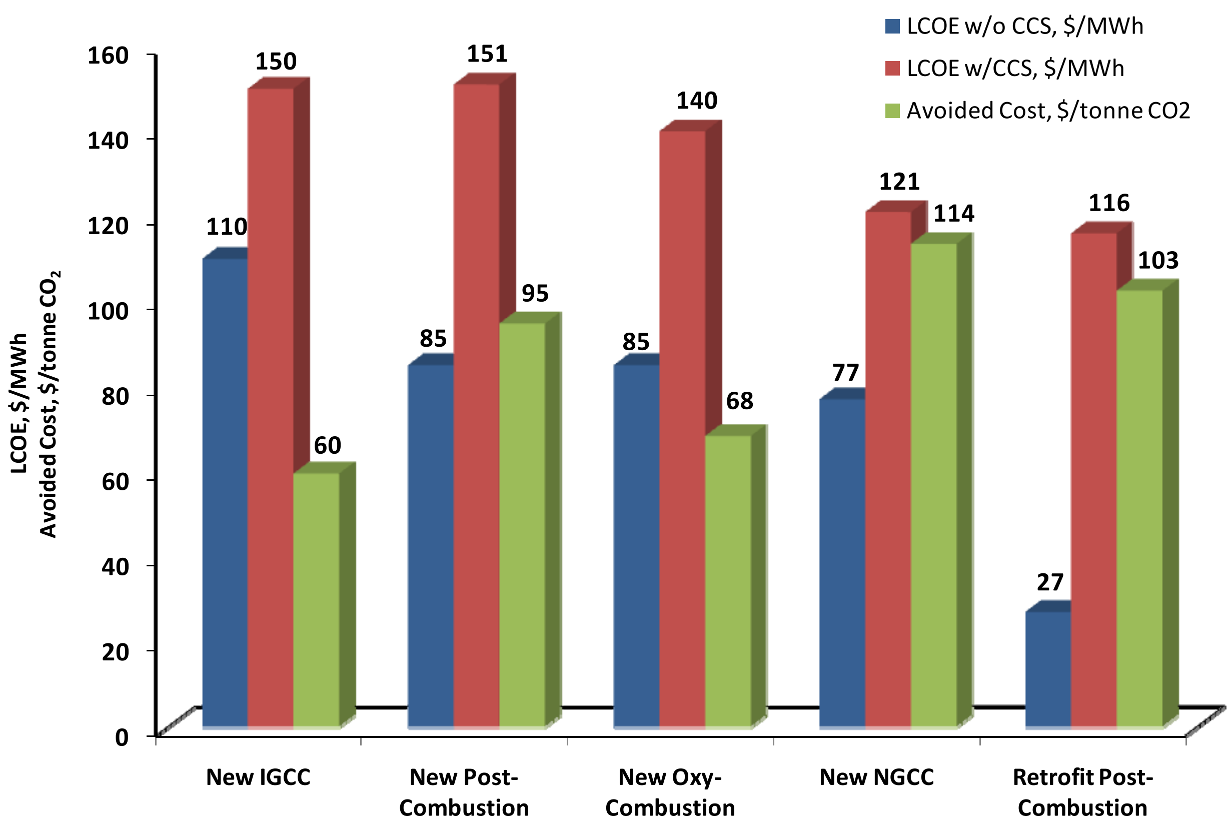
While CCS can be applied to a variety of stationary sources of CO_2, its application to coal-fired power plant emissions offers the greatest potential for GHG reductions. Coal has served as an important domestic source of reliable, affordable energy for decades, and the coal industry has provided stable and quality high-paying jobs for American workers. At the same time, coal-fired power plants are the largest contributor to U.S. greenhouse gas (GHG) emissions, and coal combustion accounts for 40 percent of global carbon dioxide (CO_2) emissions from the consumption of energy. EPA and Energy Information Administration (EIA) assessments of recent climate and energy legislative proposals show that, if available on a cost-effective basis, CCS can over time play a large role in reducing the overall cost of meeting domestic emissions reduction targets. By playing a leadership role in efforts to develop and deploy CCS technologies to reduce GHG emissions, the United States can preserve the option of using an affordable, abundant, and domestic energy resource, help improve national security, help to maximize production from existing oil fields through enhanced oil recovery (EOR), and assist in the creation of new technologies for export.

While there are no insurmountable technological, legal, institutional, regulatory or other barriers that prevent CCS from playing a role in reducing GHG emissions, early CCS projects

(pages omitted)

technology increases the capital cost of a new IGCC facility by $400 million and results in an energy penalty of 20 percent. For post-combustion and oxy-combustion capture, the increases in capital costs are $900 million and $700 million respectively, and the energy penalty would be 30 and 25 percent. For a natural gas combined cycle (NGCC) plant, the capital cost would increase by $340 million and an energy penalty of 15 percent would result from the inclusion of CO_2 capture. The costs associated with CO_2 capture in terms of increases in the LCOE or cost per tonne of CO_2 avoided are shown in Figure A-9. The LCOE ranges from $116/MWh to $151/MWh, depending upon the type of facility and whether the application is for a new plant or a retrofit of an existing plant. This compares to an LCOE of $85/MWh for a new supercritical PC plant and a $27/MWh LCOE for the existing fleet of power plants. In terms of costs per tonne of CO_2 avoided, values range from $60/tonne to $114/tonne.

Figure A-9. Comparison of Levelized Cost of Electricity for Different Types and Configurations of Power Plants



Source: (DOE, 2010a; DOE, 2010b)

A.3 Cost Estimating Methodology

A summary of the costing assumptions behind the levelized cost of electricity (LCOE) calculation referred to throughout the Task Force CCS report is contained here. A fully documented methodology can be found in DOE (2010a) and DOE (2010b).

<u>Capital Costs</u>

All capital costs are presented as "overnight costs" expressed in December 2009 dollars. Capital costs are presented at the total plant cost (TPC) level. TPC includes:

- equipment (complete with initial chemical and catalyst loadings),
- materials,
- labor (direct and indirect),
- engineering and construction management, and
- contingencies (process and project).

Owner's Costs

Owner's costs were subsequently calculated and added to the TPC. The result is defined as total overnight cost (TOC) and is the capital expenditure used in the calculation of LCOE. The owner's costs included in the TOC cost estimate are shown in Table A-4.

Table A-4. Owner's Costs Included in TOC

Owner's Cost	Comprised of
Preproduction Costs	• 6 months O&M, and administrative & support labor • 1 month maintenance materials @ 100% Capacity Factor (CF) • 1 month non-fuel consumables @ 100% CF • 1 month of waste disposal costs @ 100% CF • 25% of one month's fuel cost @ 100% CF • 2% of TPC
Inventory Capital	• 60 day supply of fuel and consumables @100% CF • 0.5% of TPC (spare parts)
Land	• \$3,000/acre (300 acres for greenfield IGCC and PC, and 100 acres for NGCC)
Financing Costs	• 2.7% of TPC
Other Owner's Costs	• 15% of TPC
Initial Cost for Catalyst and Chemicals	• All initial fills not included in bare erected cost (BEC)
Prepaid Royalties	• Not included in owner's costs (included with BEC)
Allowance for Funds Used During Construction (AFUDC) and Escalation	• Varies based on levelization period and financing scenario • 33-yr IOU high risk: Total As-Spent Capital Cost (TASC) = TOC * 1.078 • 33-yr IOU low risk: TASC = TOC * 1.075 • 35-yr IOU high risk: TASC = TOC * 1.140 • 35-yr IOU low risk: TASC = TOC * 1.134

The category labeled "Other Owner's Costs" includes the following:

- preliminary feasibility studies, including a Front-End Engineering Design (FEED) study;

- economic development (costs for incentivizing local collaboration and support);
- construction and/or improvement of roads and/or railroad spurs outside of site boundary;
- legal fees;
- permitting costs;
- owner's engineering (staff paid by owner to give third-party advice and to help the owner oversee/evaluate the work of the EPC contractor and other contractors); and
- owner's contingency: sometimes called "management reserve", these are funds to cover costs relating to delayed startup, fluctuations in equipment costs, unplanned labor incentives in excess of those for a 5 day, 10 hours per day work schedule.

Cost items excluded from "Other Owner's Costs" include:

- EPC Risk Premiums,
- transmission interconnection,
- taxes on capital costs, and
- unusual site improvements.

Operations and Maintenance

The production costs or operating costs and related maintenance expenses (O&M) pertain to those charges associated with operating and maintaining the power plants over their expected life. These costs include:

- operating labor,
- maintenance – material and labor,
- administrative and support labor,
- consumables,
- fuel,
- waste disposal, and
- co-product or by-product credit (that is, a negative cost for any by-products sold).

Thirty-Year, Current-Dollar LCOE

The revenue requirement method of performing an economic analysis of a prospective power plant has been widely used in the electric utility industry. This method permits the incorporation of the various dissimilar components for a potential new plant into a single value that can be compared to various alternatives. The revenue requirement figure-of-merit is a current-dollar, 30-year LCOE. The effective levelization period is the sum of the operational levelization period (30 years for all plants) and the capital expenditure levelization period (assumed to be 3 years for NGCC plants and 5 years for IGCC and PC plants). The sum results in an effective levelization period of 33 years for the NGCC cases and 35 years for the IGCC and PC cases. The LCOE is expressed in mills/kWh (numerically equivalent to \$/MWh). The current-dollar, 30-year LCOE was calculated using a simplified equation derived from the NETL PSFM (Power Systems Financial Model Version 5.0, 2006).

The equation used to calculate LCOE is as follows:

$$LCOE_P = \frac{(CCF_P)(TOC) + (LF)[(OC_{F1}) + (OC_{F2}) + \ldots] + (CF)(LF)[(OC_{V1}) + (OC_{V2}) + \ldots]}{(CF)(MWh)}$$

where:

$LCOE_P$ =	levelized cost of electricity over P years, \$/MWh
P =	levelization period (e.g., 10, 20 or 30 years)
CCF_P =	capital charge factor for a levelization period of P years
TOC =	total overnight cost, \$
LF =	levelization factor (a single levelization factor is used in each case because a single escalation rate is used for all costs)
OC_{Fn} =	category n fixed operating cost for the initial year of operation (but expressed in "first-year-of-construction" year dollars)
CF =	plant capacity factor
OC_{Vn} =	category n variable operating cost at 100 percent CF for the initial year of operation (but expressed in "first-year-of-construction" year dollars)
MWh =	annual net megawatt-hours of power generated at 100 percent CF

All costs are expressed in December 2009 year dollars, and the resulting LCOE is expressed in mixed year dollars.

Although their useful life is usually well in excess of 30 years, 33-year (NGCC) and 35-year (IGCC and PC) levelization periods (including the variable capital expenditure levelization periods as defined above) are the levelization periods used in this study.

The technologies modeled in this study were divided into one of two categories for calculating LCOE: Investor Owned Utility (IOU) high risk and IOU low risk. All IGCC cases as well as PC and NGCC cases with CO_2 capture are considered high risk. The non-capture PC and NGCC cases are considered low risk. The resulting CCF and LFs are shown in Table A-5.

Table A-5. Economic Parameters for LCOE Calculation

	High Risk 5 year construction	Low Risk 5 year construction	High Risk 3 year construction	Low Risk 3 year construction
Capital Charge Factor	0.1773	0.1691	0.1567	0.1502
Levelization Factor	1.42689	1.45104	1.41094	1.43262

The economic assumptions used to derive the CCFs are shown in Table A-6. The difference between the high risk and low risk categories is manifested in the debt-to-equity ratio and the weighted cost of capital. The values used to generate the CCFs and LFs in this study are shown in Table A-7.

Table A-6. Parameter Assumptions for Capital Charge Factors

Parameter	Value
TAXES	
Income Tax Rate	38% (Effective 34% Federal, 6% State)
Capital Depreciation	20 years, 150% declining balance
Investment Tax Credit	0%
Tax Holiday	0 years
FINANCING TERMS	
Repayment Term of Debt	15 years
Grace Period on Debt Repayment	0 years
Debt Reserve Fund	None
TREATMENT OF CAPITAL COSTS	
Capital Cost Escalation During Construction (nominal annual rate)	3.6%[1]
Distribution of Total Overnight Capital over the Capital Expenditure Period (before escalation)	3-Year Period: 10%, 60%, 30% 5-Year Period: 10%, 30%, 25%, 20%, 15%
Working Capital	zero for all parameters
% of Total Overnight Capital that is Depreciated	100% *(this assumption introduces a very small error even if a substantial amount of TOC is actually non-depreciable)*
INFLATION	
LCOE, O&M, Fuel Escalation (nominal annual	3.0%[2] COE, O&M, Fuel

---

[1] A nominal average annual rate of 3.6% is assumed for escalation of capital costs during construction. This rate is equivalent to the nominal average annual escalation rate for process plant construction costs between 1947 and 2008 according to the *Chemical Engineering* Plant Cost Index.

[2] An average annual inflation rate of 3.0% is assumed. This rate is equivalent to the average annual escalation rate between 1947 and 2008 for the U.S. Department of Labor's Producer Price Index for Finished Goods, the so-called "headline" index of the various Producer Price Indices. (The Producer Price Index for the Electric Power

Parameter	Value
rate) Escalation rates must be the same for LCOE approximation to be valid	

Table A-7. Financial Structure for Investor Owned Utility High and Low Risk Projects

Type of Security	% of Total	Current (Nominal) Dollar Cost	Weighted Current (Nominal) Cost	After Tax Weighted Cost of Capital
Low Risk				
Debt	50	4.5%	2.25%	
Equity	50	12%	6%	
Total			8.25%	7.39%
High Risk				
Debt	45	5.5%	2.475%	
Equity	55	12%	6.6%	
Total			9.075%	8.13%

A.4 Planned Demonstrations of CO_2 Capture Technologies

DOE/NETL is currently engaged in two major CCS demonstration programs.

The Clean Coal Power Initiative (CCPI) is an innovative technology demonstration program that fosters more efficient clean coal technologies for use in new and existing coal-based power plants. The intent of CCPI is to accelerate technology adoption and thus rapidly move promising new concepts to a point where private-sector decisions on deployment can be made.

CCPI is currently pursuing three pre-combustion and three post-combustion CO_2 capture demonstration projects (Table A-8). The pre-combustion projects involve CO_2 capture from IGCC power plants. The generating capacities at the demonstration facilities range from 257 to 582 MW. The capture efficiencies range from 67 percent to 90 percent, and total CO_2 captured ranges from 1.8 to 2.7 million tonnes per year. The demonstrations will be initiated between 2014 and 2016, and the projects will run for 2-3 years. The post-combustion projects will capture CO_2 from pulverized coal (PC) plant slipstreams representing the equivalent of 60 to 235 MW of power production. Each will capture 90 percent of CO_2 emissions with total capture of 0.4 to 1.5 million tonnes per year.

Generation Industry may be more applicable, but that data does not provide a long-term historical perspective since it only dates back to December 2003.)

(pages omitted)