

## **REPORT TO CONGRESS**

### **Required By Section 962 of the Energy Policy Act of 2005**

#### **Cost and Performance Goals for the Office of Fossil Energy Coal-Based Technologies**

##### **BACKGROUND**

Section 962 of the Energy Policy Act of 2005 (EPAct 2005) authorized the Department of Energy (DOE) to conduct a program of technology research, development, demonstration, and commercial application for coal and power systems, including programs to facilitate production and generation of coal-based power through: (1) innovations for existing plants (including mercury removal); (2) gasification systems; (3) advanced combustion systems; (4) turbines for synthesis gas derived from coal; (5) carbon capture and sequestration research and development; (6) coal-derived chemicals and transportation fuels; (7) liquid fuels derived from low rank coal water slurry; (8) solid fuels and feedstocks; (9) advanced coal-related research; (10) advanced separation technologies; and (11) fuel cells for the operation of synthesis gas derived from coal.

In carrying out these programs, DOE was also directed to: (1) identify proposed draft cost and performance goals for coal-based technologies that would permit the continued cost-competitive use of coal for the production of electricity, chemical feedstocks, and transportation fuels (section 962(b)(1)), (2) publish a notice of those proposed goals in the Federal Register for public comments (section 962(b)(2)(C)), and (3) submit to Congress a report describing the cost and performance goals for the technologies, including (i) a list of technical milestones and (ii) an explanation of how programs authorized in section 962 will not duplicate the activities authorized under the Clean Coal Power Initiative (CCPI) authorized under EPAct Title IV (section 962(b)(2)(D)).

##### **DOE'S COAL AND RELATED TECHNOLOGIES PROGRAM**

The DOE is conducting research and development on a broad portfolio of technologies to enable the continued use of coal as a valued energy resource for the Nation and to address energy security, clean air, climate change, and coal research. The portfolio of technologies in the DOE Coal and Related Technologies Program encompasses those program activities listed in Section 962(a) to facilitate production and generation of coal-based electric power and co-production of fuels. However, not all of the activities listed in Section 962(a) are funded. Cost and performance goals are provided for currently funded programs.

Also, some of the activities under DOE's Coal and Related Technologies Program encompass more than one of those listed in section 962(a) of EPACT 2005. For example, Advanced Power Systems includes gasification systems, turbines for synthesis gas derived from coal, and advanced separation technologies (oxygen). Carbon Sequestration includes advanced separation technologies (carbon dioxide) and research on advanced combustion technology, including oxy-combustion and chemical looping technologies. Hydrogen and Fuels activities are part of coal-derived chemicals and transportation fuels and also include advanced separation technologies (hydrogen). All of DOE's coal-based technology activities encompass some aspect of advanced coal-related research.

DOE's Coal and Related Technologies Program includes the following major program activities:

Innovations for Existing Plants

Develop advanced cost-effective environmental control technologies for mercury and particulate matter (PM).

Advanced Power Systems

Develop near-zero atmospheric emission, fuel-flexible gasification-based multi-product processes, and

Develop advanced air separation units (oxygen), gas cleaning, and turbines for electric power generation and coal-derived synthesis gas and hydrogen.

Carbon Sequestration

Develop CO<sub>2</sub> capture and separation technologies, including advanced combustion systems that produce concentrated streams of carbon dioxide,

Develop CO<sub>2</sub> storage options,

Develop cost-effective measurement, monitoring, and verification protocols,

Develop technologies to mitigate non-CO<sub>2</sub> fugitive emissions from energy systems, and

Develop infrastructure for deploying sequestration technologies.

Hydrogen and Fuels

Develop improved, novel technology for the production of hydrogen from coal, and

Develop hydrogen separation, delivery, and stationary storage technologies.

Fuel Cell Systems

Accelerate development of low-cost, high density solid-state, stationary fuel cells, and

Develop fuel cell/turbine hybrids integrated with coal gasification.

Advanced Research

Develop a sound understanding of critical process issues confronting new coal-based energy systems,

Conduct cross-cutting research on advanced materials, sensors, and controls, and

Provide new computational tools to assess and optimize design options and simulate operation of subsystems and components.

## **DRAFT COST AND PERFORMANCE GOALS and PUBLIC COMMENTS**

In compliance with section 962(b)(2)(C) of EPACT 2005, proposed draft cost and performance goals for the DOE's Coal and Related Technologies Program that would permit the continued cost-competitive use of coal for the production of electricity, chemical feedstocks, and transportation fuels were issued on November 30, 2005, and published in the Federal Register requesting public comments by December 27, 2005 (70 FR 72634, December 6, 2005). A copy of the Federal Register Notice is attached.

The Federal Register Notice clarified that the cost and performance goals for the various activities included in the DOE Coal and Related Technologies Program are aggressive and were established to guide technology development to provide the building blocks for a new generation of coal-fueled energy plants that are environmentally effective and fuel-efficient. The overarching objective of the DOE Coal and Related Technologies Program is to bring these building blocks together, in a fully operational, full-scale prototype by 2020, integrating coal-based, near-zero atmospheric emission energy systems to produce electric power and hydrogen, and have the capability to capture and sequester carbon dioxide (CO<sub>2</sub>).

In response to the Federal Register Notice requesting public comments on the proposed draft cost and performance goals, DOE only received comments from the Coal Utilization Research Council (CURC). In general, CURC provided recommendations and comments, and requested clarification on some of the draft cost and performance goals.

CURC requested clarification on how DOE: (1) measures efficiency, (2) defines CO<sub>2</sub> capture and sequestration, (3) determines technology research and development target dates, and (4) expresses costs. DOE's response to these requests for clarification as reflected in the cost and performance goals listed in the tables below are as follows:

1. Efficiencies are based on high heating value (HHV) and include energy content of useful energy exiting the system divided by the energy content of the coal entering the system.
2. CO<sub>2</sub> capture and sequestration costs include those costs associated with separation and capture, transport, sequestration, and measurement, monitoring, and verification. Carbon capture is defined as the quantity of CO<sub>2</sub> that would result if carbon in the carbonaceous feedstocks (excluding air), less carbon contained in solid by-products, was converted to CO<sub>2</sub>.
3. As noted in the tables below, all dates are meant to indicate the completion dates for ongoing research. The referenced technologies will still have to be commercially demonstrated before they are ready or available for commercial deployment.
4. Unless otherwise noted, all costs are expressed in 2003 dollars.

CURC also provided comments on and requests for clarification pertaining to specific cost and performance goals for activities in DOE's Coal and Related Technologies Program. DOE responses to CURC's comments and request for clarification regarding cost and performance goals have been included in the Cost and Performance Goals presented in the tables below. Also included in these tables are technical milestones for each activity that highlight critical subsystem development, indicate priority research pathways, and show progress towards meeting DOE's cost and performance goals.

### **FINAL COST AND PERFORMANCE GOALS**

The Cost and Performance goals for the activities in the DOE Coal and Related Technologies Program were based on the status of current technology development, feedback from technology providers and users, and the goal of producing near-zero atmospheric emission energy (power and fuels). DOE considered the CURC comments received in response to the Federal Register Notice. Additionally, DOE decided to focus the goals listed and include only those reported under the Government Performance Results Act (GPRA).

DOE recognizes the Cost and Performance Goals listed in following tables are aggressive and involve technology that does not yet exist. The goals may be difficult to achieve, but provide a basis for guiding technology development. They are not being proposed as a basis for present or future regulations or legally binding standards, nor do they attempt to project dates by which technologies will be commercially available. DOE also understands that achieving some of these goals will depend on successfully developing advanced technology components and subsystems, continued research partnerships with industry, academia, and other research organizations, and Congressional support. Further, the advanced coal-based technologies developed in the DOE Coal and Related Technologies program may need to be demonstrated at commercial scale, before they are ready for commercial deployment.

Section 962(b)(2)(D) required DOE in this Report describing the cost and performance goals to explain the differences between those program activities authorized by section 962 and those authorized under the Clean Coal Power Initiative (CCPI) under Title IV of EPCA 2005.

The CCPI authorized under Title IV of EPCA 2005, complements rather than duplicates the coal technology research, development, demonstration, and commercial application program authorized under section 962. The cost and performance goals for the Coal and Related Technologies Program in section 962, were established to guide technology development for a new generation of coal-fueled energy plants that are environmentally effective and fuel-efficient, and to show the potential of these technologies to achieve the cost and performance goals through future demonstrations. The technologies developed under section 962 are sub-commercial scale and, upon successful testing and evaluation, would be candidates for demonstration in integrated coal-based energy systems. As these technologies advance closer to commercialization, the private sector has more

information to decide whether to commercialize the technologies, and greater incentive to carry out the final steps to achieving commercial deployment on its own. There are also a variety of possible government incentives that can be used when there continues to be a market failure that prevents commercialization of a technology with significant public benefits. Government-industry cost-shared partnerships for demonstration projects carried out in the CCPI are one option for providing this incentive for technology demonstration.

The following tables describe the cost and performance goals and technical milestones for each of the five program activities under DOE's Coal and Related Technologies Program.

**Table 1**  
**Program Activity: Innovations for Existing Plants**

Performance Goals <sup>7</sup>		Cost Goals <sup>1</sup>	Technical Milestones
Efficiency	Environmental		
Maintain current plant efficiency while achieving the environmental performance and cost goals	50-70% mercury (Hg) reduction by 2007	For 2007 goal: cost = 75% of reference cost of \$50,000 to \$70,000/lb mercury <sup>8</sup> removed  For 2010 goal: cost = 75% of reference cost of \$50,000 to \$70,000/lb mercury removed	<ul style="list-style-type: none"> <li>2006 – Initiate pilot-scale field tests of technologies for 90% mercury removal at 75% of 2003</li> </ul>
	90 % mercury reduction by 2010		
Particulate Matter (PM <sub>2.5</sub> ): reduce fly ash emission levels by 99.99 percent by 2007	<\$50 to \$70 /kilowatt (kW)		

<sup>7</sup> All dates are meant to indicate completion dates for ongoing research. The referenced technologies will still have to be commercially demonstrated before they are ready or available for commercial deployment.

<sup>8</sup> Although cost goals could also be represented as \$/kWh, DOE has elected to use \$/lb because the EPA Hg rule will be implemented using a cap and trade program in which \$/lb is an important variable. Cost goals do not include the impact on sale or disposal of fly ash.

Table 2  
Program Activity: Advanced Power Systems

Performance Goals <sup>1,2</sup>		Cost Goals <sup>1</sup>	Technical Milestones
Efficiency	Environmental		
<p>2010 Goal: 45-50% high heating value (HHV) efficiency to electricity (without carbon capture)</p> <p>2015 Goal: Power and hydrogen capability with over 60% efficiency (without carbon capture)</p>	<p>2010 Goals:</p> <p>&gt;99% removal SO<sub>2</sub></p> <p>&lt;0.01 lb/million Btu NO<sub>x</sub> emissions</p> <p>&gt;90% mercury removal</p> <p>2012 Goal:</p> <p>&gt;90% CO<sub>2</sub> capture</p>	<p>2010 Goal:</p> <p>Cost = to \$1000/kW (2002 dollars)</p> <p>2012 Goal:</p> <p>&lt;10% increase in cost of services in near-zero atmospheric emission advanced gasification plants integrated with carbon sequestration<sup>3</sup></p>	<ul style="list-style-type: none"> <li>• Advances for low costs gasifiers by 2007 (e.g. coal feed, char recycle, ash removal systems)</li> <li>• Pilot plant tests on gas cleanup technology that contributes to increased efficiency and reduced capital cost by 2007</li> <li>• Pilot scale advanced air separation systems that contributes increased efficiency and reduced costs by 2009</li> <li>• Test of advanced syngas-fueled turbine combustors that increase efficiency by 2010</li> <li>• Pilot scale tests of advanced fuel-flexible, high-throughput gasifiers that contribute to higher efficiency and lower cost by 2010</li> </ul>

<sup>1</sup> All dates are meant to indicate completion dates for ongoing research. The referenced technologies will still have to be commercially demonstrated before they are ready or available for commercial deployment.

<sup>2</sup> Carbon capture is not included in these goals. Carbon capture can be incorporated in systems co-producing electricity and fuels and the degree of carbon capture depends on the plant electricity to fuel production design.

<sup>3</sup> Near-zero emissions goals for an advanced gasification plant integrated with carbon sequestration are identified in FutrueGen Report to Congress dated 2004.

**Table 3**  
**Program Activity: Carbon Sequestration**

Performance Goals <sup>1</sup>		Cost Goals <sup>1</sup>	Technical Milestones
Efficiency	Environmental		
Efficiency consistent with cost of electricity target	2012 Goal: 90% CO <sub>2</sub> capture and sequestration	2012 Goal: <10% increase in cost of electricity services to separate, capture, transport, and sequester carbon using either direct or indirect systems	<ul style="list-style-type: none"> <li>• Pilot tests that show potential for lower cost CO<sub>2</sub> capture by 2007</li> <li>• Field tests to show CO<sub>2</sub> storage in unmineable coal seams by 2007</li> <li>• Begin one large-scale demonstration of CO<sub>2</sub> storage in geologic formation by 2009</li> <li>• Develop instrumentation and protocols to accurately monitor carbon storage by 2010</li> <li>• Validate geologic CO<sub>2</sub> storage by 2012</li> </ul>

<sup>1</sup> All dates shown are meant to indicate the completion dates for ongoing research. The reference technologies will still have to be commercially demonstrated before they are ready or available for commercial deployment.

**Table 4**  
**Program Activity: Hydrogen and Fuels**

Performance Goals <sup>1</sup>		Cost Goals <sup>1</sup>	Technical Milestones
Efficiency	Environmental		
Efficiency consistent with advanced power system goals <sup>2</sup>	Emissions consistent with advanced power systems <sup>3</sup>	<u>2015 Goal:</u> Hydrogen at \$2.00/gallon gasoline equivalent (gge) delivered <sup>4</sup> to the retail consumer or less with no incentives or tax credits when integrated with advanced coal power systems	<ul style="list-style-type: none"> <li>• Conduct initial bench-scale tests of hydrogen separation technology by 2006</li> <li>• Demonstrate hydrogen separation modules for coal gasification combined-cycle co-production plants by 2010</li> </ul>

<sup>1</sup> All dates shown are meant to indicate the completion dates for ongoing research. The reference technologies will still have to be commercially demonstrated before they are ready or available for commercial deployment.

<sup>2</sup> Carbon capture is not included in these goals. Carbon capture can be incorporated in systems co-producing electricity and fuels and the degree of carbon capture depends on the plant electricity to fuel production design.

<sup>3</sup> There is no 90% carbon capture and sequestration for hydrogen and fuels.

<sup>4</sup> Fuel delivery cost of \$1.00/gge of hydrogen assumed based on DOE Hydrogen Posture Plan dated February 2004.

Table 5  
Program Activity: Fuel Cell Systems

Performance Goals <sup>1</sup>		Cost Goals <sup>1</sup>	Technical Milestones
Efficiency	Environmental		
<p><u>2010 Goal:</u> 40% for kilowatt size fuel cell modules</p> <p><u>2015 Goal:</u> 60% for megawatt class hybrid systems integrated with coal gasification</p>	<p>Emissions consistent with advanced power systems</p>	<p><u>2010 Goal:</u> Produce 3 – 10 kilowatt solid oxide fuel cell modules having a capital cost <math>\leq</math>\$400/kW</p> <p><u>2015 Goal:</u> Modules adaptable to coal based megawatt class hybrid systems having a fuel cell module capital cost <math>\leq</math>\$400/kW</p>	<p>The Solid State Energy Conversion Alliance (SECA) project is structured in three phases over ten years with the following technology requirements for a 3-10 kW module:</p> <ul style="list-style-type: none"> <li>• Phase I (2005 for one or more industry teams): 25% efficiency at <math>\leq</math>800/KW</li> <li>• <math>\leq</math>Phase II (2008 for one or more industry teams): 40% efficiency at \$600/kW</li> <li>• Phase III (2010): 40% efficiency at <math>\leq</math>\$400/kw</li> </ul> <p>The 60% system efficiency is obtained by a fuel cell / turbine hybrid energy system.</p>

<sup>1</sup> All dates shown are meant to indicate the completion dates for ongoing research. The reference technologies will still have to be commercially demonstrated before they are ready or available for commercial deployment.