

# Executive Summary

# THE CURC-EPRI ADVANCED COAL TECHNOLOGY ROADMAP

*July 2015  
UPDATE*

Prepared by the Coal Utilization Research Council  
and the Electric Power Research Institute

## EXECUTIVE SUMMARY

### The CURC-EPRI 2015 Advanced Coal Technology Roadmap Update

#### Background

Coal is a key element of the U.S. economy and provided the fuel for 18.5% of total U.S. energy consumption, and 43% of U.S. electric power generation in 2013. This energy resource plays a similar role in the global energy economy. Between 2002 and 2010, world coal consumption grew at nearly twice the rate of growth of all other fuels. Coal's wide use derives from its abundance, accessibility, transportability/storability and stable low cost compared to other fuels.

Despite these attributes, coal faces strong regulatory and economic challenges in today's marketplace. Compliance with recent environmental regulations has driven up the cost of coal-based power generation in the United States, and future regulations may increase costs further. These regulations are a key factor in early coal plant retirements, cancellations of planned new coal units and the drive to increase coal plant efficiency. Reduced demand for electricity due to the lingering effects of the 2008 recession and competition from natural gas-fueled generation also have limited the demand for new coal-based power plants.

Technology has enabled the historical environmental and economic challenges of coal use to be overcome in the past. The formula for successful technology development continues to rely on collaboration between the government and the private sector to cost-share in research, development, and demonstration (RD&D). These public and private sector RD&D collaborations have yielded a return of \$13 for every dollar of federal funding spent for coal RD&D (per DOE calculations; see footnote 13).

This report identifies key research, development, and demonstration (RD&D) priorities for developing cost-effective, efficient, and environmentally compliant technologies that convert coal to electricity and other useful forms of energy and manufacturing feedstocks. This "Roadmap" is a joint effort between the Coal Utilization Research Council ("CURC", [www.coal.org](http://www.coal.org)) and the Electric Power Research Institute ("EPRI", [www.epri.com](http://www.epri.com)). Earlier Roadmaps were published by CURC and EPRI in 2003, 2008, and 2012. CURC led the development and publication of this report; recommendations and opinions regarding existing or future policies and regulations are solely those of CURC. EPRI provided detailed technical input and review relative to characteristics, capabilities and RD&D needs for existing, emerging, and potential technologies.

#### The 2015 Update

The 2015 Roadmap Update was undertaken amid several new market conditions that required a re-examination of the technology development needs for the new and existing fleet of coal plants. This re-examination took into account several factors, including fluctuations in the market for coal use in the United States today; the impact of recently proposed regulations to limit emissions of greenhouse gas (GHG) emissions from fossil-fueled power plants; the availability and growth of low-cost, domestic supplies of natural gas being used in both new and existing power generation, increasing levels of renewable electricity generation; and an electric power

market that is experiencing and projecting low or no load growth over the next decade. Additionally, since 2012, two carbon capture utilization and storage (CCUS) projects have been completed or nearly completed their construction phase, which has provided a better understanding of the costs of carbon capture and storage (CCS)/CCUS. Lastly, amid growing concerns associated with an aging, existing coal fleet and anticipated coal fleet retirements, the 2015 Roadmap Update also examines the ability to accelerate the development of transformational technologies so that viable new coal-based technology options will exist in the 2025-2030 timeframe to replace retiring coal capacity. However, the availability of these transformational options will be strongly dependent on the level of federal funding available to implement the technology development recommendations included in this report.

The 2015 Roadmap Update examines three new technology development pathways:

- (1) A new program that considers the value of the existing coal fleet, and describes a technology program necessary to support the existing coal fleet as it takes on new challenges in responding to new regulatory and dispatch requirements;
- (2) A new “transformational” technology program that defines development needs for new technologies that will deliver significantly higher value in terms of cost, efficiency, flexibility and environmental performance relative to current coal-based electricity generation; and
- (3) A new large-scale pilot program that anticipates federal support of evaluating new technologies under real operating conditions at a scale beyond laboratory and bench-scale and before testing technologies in a commercial-scale demonstration.

The 2015 Roadmap Update also reflects changes to the Gasification RD&D program, which identifies promising new technologies that offer lower cost and better performing gasification-based power systems in the future, and a more defined Advanced Combustion program that includes pathways for next generation and transformational carbon dioxide (CO<sub>2</sub>) capture technologies.

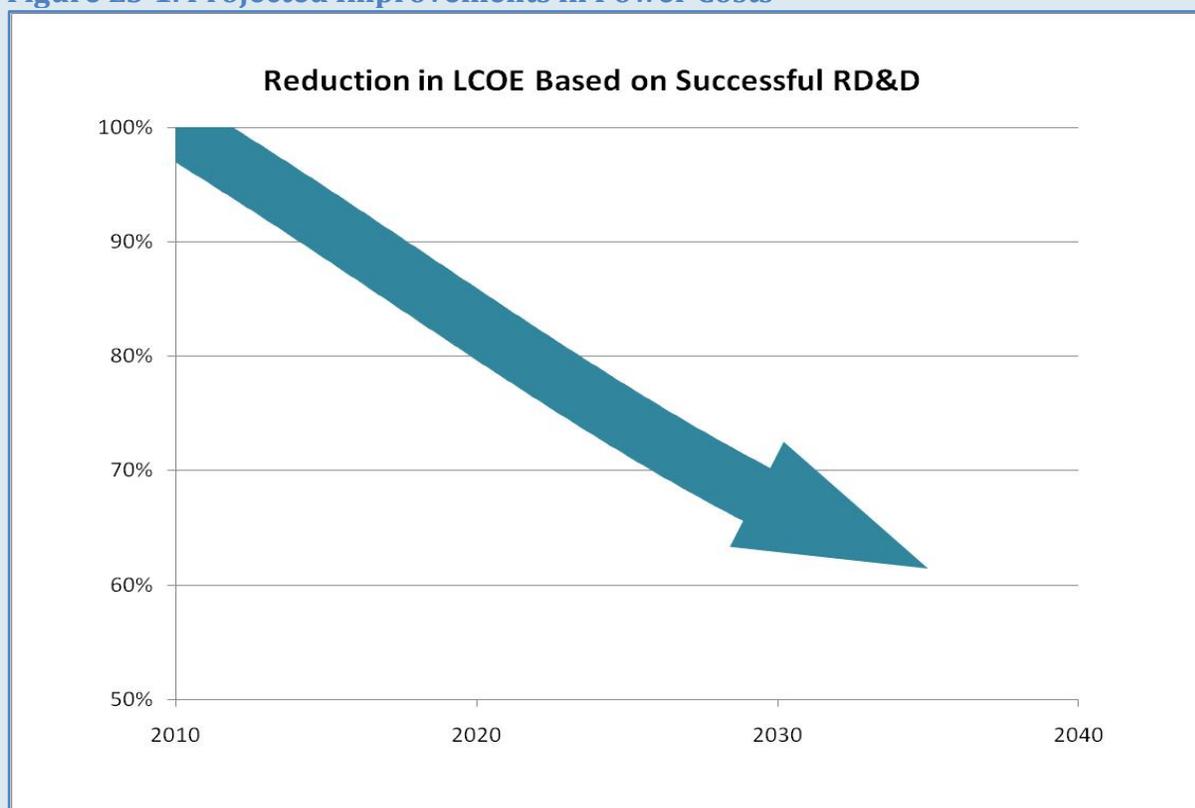
Other changes include updated descriptive statistical data on coal-based power – both the technology RD&D pathways and funding profiles – as a result of new and changed development activities in each program area, and a new cost-of-electricity analysis that reflects the benefits and impacts of the Roadmap development efforts if fully funded and successfully implemented by the private sector in partnership with the federal government.

## **Projected Benefits of Technology Development**

The technology development plan outlined in this Roadmap offers the potential to deliver first-of-a-kind (FOAK), low-carbon coal technology options by the 2025-2030 timeframe, including small-scale transformational systems which would be compatible in size with capacity needs of the United States power market at that time. If proposals to regulate GHGs are promulgated in their proposed form, additional funding to support accelerated RD&D will be necessary to enable the availability of a coal technology option based on the proposed regulatory timeline.

Attachment 2 to this report identifies a significant number of commercial-scale demonstration projects that are currently in planning or underway. The majority of these projects will be fueled by coal and incorporate CO<sub>2</sub> capture and storage. They have received partial funding from the federal government through demonstration grants or other financial incentives. They are “first-generation” projects utilizing technologies developed through public and private cost-share programs. Continued, well-funded and successfully executed RD&D can reduce costs further and could produce the next generation of technologies in new demonstration plants. Figure ES-1 shows how the cost of electricity (relative to today’s levels) from coal-based power plants equipped with CCS can be reduced through RD&D. Levelized costs of electricity (LCOE) could potentially be reduced by another 10-15% (absolute)<sup>1</sup> in 2025-2035 if the captured CO<sub>2</sub> is sold for use in Enhanced Oil and Gas Recovery (EOR).

**Figure ES-1. Projected Improvements in Power Costs**



These reductions can be achieved while further reducing the already well-controlled emissions of traditional pollutants. Figure ES-2 depicts the reductions of sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>x</sub>) and other traditional pollutants compared to a new coal-fueled power plant built with 2010 technology.

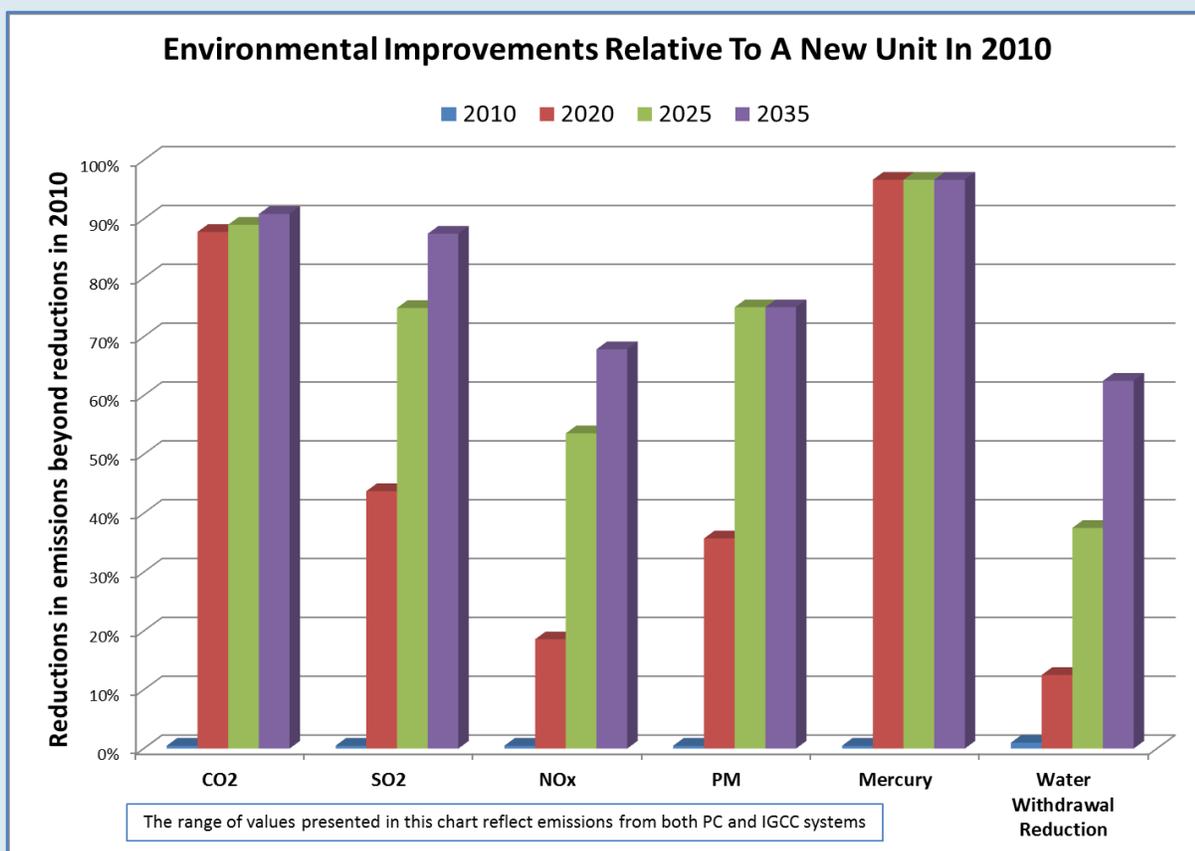
<sup>1</sup> For example, if saline storage-based LCOE has decreased by 35% in 2030, the decrease for an EOR-based power system could decrease by an additional 10-15%, or an overall decrease of 45-50%. The value of EOR revenues is uncertain because they vary regionally, and with the future price of crude oil.

In addition to these economic and environmental benefits, improved coal technologies can enhance the nation’s energy security by reducing imports of crude oil through capturing CO<sub>2</sub> for use in producing domestic oil via EOR; converting coal to transportation fuels or coproducing both electricity and liquid fuels or chemicals; reducing exposure to increasing electricity costs through a diverse generation technology portfolio; and lowering the cost of electricity to facilitate greater market penetration by electric vehicles, thereby lowering the numbers of fossil fueled vehicles.

### The Cost of the RD&D Effort

The RD&D and large-scale pilot efforts required to achieve these results are estimated to cost, on average, approximately \$650 to \$1,420 million per year in the early years of the program, and average \$850 million per year through 2035 (see Table ES-1). The federal share of these requirements are estimated to average approximately \$570 to \$940 million per year in the early years, and \$495 million per year from 2026-2035.

Figure ES-2. Projected Reductions in Air Emissions and Water Use from Coal RD&D



Notes to Figure ES-2: Percentages are relative to levels of reduction achieved as of 2010 for U.S. fossil fleet (NO<sub>x</sub> and SO<sub>2</sub> = 90 - 99% reduction; Particulate Matter (PM) = 99.6% reduction; Mercury (Hg) = 90% reduction; and water withdrawal reduction (as a result of cooling towers) = 98%). For CO<sub>2</sub>, percentages are relative to capture levels of 0%, as carbon controls were not required in 2010.

**Table ES-1. Projected Cost of Recommended RD&D Effort**

Funding (\$M/year)		2016-2020	2021-2025	2026-2035
RD&D	Total (Industry and Federal)	346	241	97
	Federal (80%)	277	192	77
Pilots	Total (Industry and Federal)	279	322	89
	Federal	279	322	89
Demos	Total (Industry and Federal)	28	854	654
	Federal (50%)	14	427	327
<b>Total (Public/Private) Annual Funding</b>		<b>653</b>	<b>1,416</b>	<b>850</b>
<b>Annual Federal Budget</b>		<b>570</b>	<b>941</b>	<b>493</b>

Details on the specific types of technologies needed, and cost of RD&D over time, by major technology category, are included in the body of this report.