ORAL ARGUMENT SCHEDULED FOR APRIL 17, 2017
No. 15-01381 (and consolidated cases)

IN THE UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

STATE OF NORTH DAKOTA, ET AL.,

Petitioners,

v.

U.S. ENVIRONMENTAL PROTECTION AGENCY, ET AL.,

Respondents.

On Petitions for Review of a Final Action of the
United States Environmental Protection Agency

BRIEF OF *AMICI CURIAE* TECHNOLOGICAL INNOVATION EXPERTS NICHOLAS ASHFORD, M. GRANGER MORGAN, EDWARD RUBIN, AND MARGARET TAYLOR IN SUPPORT OF RESPONDENTS

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December 21, 2016

CERTIFICATE AS TO PARTIES, RULINGS, AND RELATED CASES

a. Parties and *Amici*

Except for the following, all parties, intervenors, and *amici* appearing in this court are, to the best of my knowledge, listed in the Certificate as to Parties, Rulings, and Related Cases filed by counsel for the State of North Dakota on October 13, 2016:

Amicus Curiae for Respondent: Institute for Policy Integrity at New York University School of Law; and

Movant-Amicus Curiae for Respondent: Carbon Capture and Storage Scientists Roger Aines, Sally Benson, S. Julio Friedmann, Jon Gibbins, Raghubir Gupta, Howard Herzog, Susan Hovorka, Meagan Mauter, Ah-Hyung (Alissa) Park, Gary Rochelle, and Jennifer Wilcox.

b. Rulings Under Review

References to the rulings at issue appear in the Respondent EPA's Initial Brief filed December 14, 2016.

c. Related Cases

References to related cases appear in the Respondent EPA's Initial Brief filed December 14, 2016.

_/s/ Sean B. Hecht_________
Sean B. Hecht

RULE 29 STATEMENTS

The following parties have indicated their consent to the filing of this brief:

U.S. Environmental Protection Agency; Calpine Corporation, the City of Austin d/b/a Austin Energy; the City of Los Angeles, by and through its Department of Water and Power; the City of Seattle, by and through its City Light Department; National Grid Generation, LLC; New York Power Authority; Pacific Gas and Electric Company; Sacramento Municipal Utility District; NextEra Energy, Inc.; Environmental and Health Non-Governmental Organizations; and State of Missouri.

All remaining parties do not oppose or take no position on the filing of this brief.

Pursuant to Fed. R. App. P. 29(c)(5), *amici* state that no party or party's counsel authored this brief in whole or in part, and that no other person besides *amici* or their counsel contributed money that was intended to fund preparing or submitting the brief.

Pursuant to D.C. Cir. R. 29(d), *amici* state that a separate brief is necessary for their presentation to this court due to their distinct expertise and interests. *Amici* are Nicholas Ashford, Edward S. Rubin, M. Granger Morgan, and Margaret Taylor. They have a unique capacity to aid the court in understanding the dynamics of developing and commercializing a technology. No other *amici* of which we are aware share this perspective, or address these specific issues. Accordingly, the *amici*, through counsel, certify that filing a joint brief would not be practicable.

_/s/ Sean B. Hecht_________
Sean B. Hecht

Counsel for Nicholas Ashford, M. Granger Morgan, Edward Rubin, and Margaret Taylor

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GLOSSARY OF ABBREVIATIONS

CAA	Clean Air Act
CCS	Carbon Capture and Storage (or Sequestration)
CO_2	Carbon Dioxide
EPA	U.S. Environmental Protection Agency
JA	Joint Appendix
NO_x	Nitrogen Oxides
SO_2	Sulfur Dioxide

INTEREST OF *AMICI CURIAE*

The four *amici curiae* technology experts are all highly-respected and recognized academics from top American universities whose work is focused on technology innovation and diffusion. The previously-filed Motion for Leave to File Amicus Curiae Brief in Support of Respondents (Nov. 16, 2016) provides more detail on the qualifications and background of *amici*, summarized briefly here.

Nicholas Ashford is Professor of Technology and Policy at the Massachusetts Institute of Technology. Among other titles, he is Director of the Technology and Law Program there. Since the 1970s, Dr. Ashford's pioneering and continuing research on regulation-induced innovation has been influential in shaping academic thought on the subject and informing policy actions by governmental agencies.

M. Granger Morgan is the Hamerschlag University Professor of Engineering in the Department of Engineering and Public Policy at Carnegie Mellon University. His publications have included work relating to the future performance and costs of, and the impact of regulation on, implementation of carbon capture and sequestration technology.

Edward S. Rubin is a Professor of Engineering and Public Policy and of Mechanical Engineering in the Department of Engineering and Public Policy at Carnegie Mellon University. His work has generated a widely-used model for designing and evaluating cost-effective emission control systems for fossil-fuel power plants, as well as insights used to estimate the future cost trends of advanced power systems. Dr. Rubin's research has focused on technological innovation and diffusion in the context of pollution reduction technology, how innovation and associated "learning curves" reduce costs of technology implementation, and the application of these principles to the case of carbon capture and sequestration.

Margaret Taylor is a Project Scientist at Lawrence Berkeley National Laboratory (LBNL) and an Engineering Research Associate in Stanford University's Precourt Energy Efficiency Center. Her research explores questions at the nexus of innovation and energy/environmental policy. Dr. Taylor's research has shed light on policy-induced innovation, technological development and diffusion, and the cost reductions achievable as technology diffusion increases. In its preamble to the Rule, U.S. EPA references Dr. Taylor's published research on these topics. 80 Fed. Reg. 64,509, 64,575 (October 23, 2015).

The technology innovation experts have a significant interest in the outcome of the present case, which is directly relevant to their professional expertise; their perspective will assist the court in evaluating the claims of the parties.

INTRODUCTION

On October 23, 2015, the United States Environmental Protection Agency ("EPA") finalized emission standards for new coal-fired power plants under Section 111(b) of the Clean Air Act ("CAA" or "the Act"), 42 U.S.C. § 7411(b), within the final rule entitled "Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources – Electric Utility Generating Units" ("the Rule"). 80 Fed. Reg. 64,509 (October 23, 2015). The Rule, like many before it, is intended to achieve reductions in pollution by setting emissions standards based on the level of emissions achievable by the best system of emission reduction. These standards promote cost-effective pollution control by stimulating demand for pollution control technology and creating incentives to innovate. EPA has based its standards for new coal-fired power plants on a demonstrated, cost-effective system of reduction, partial carbon capture and storage (CCS). The selection of partial CCS as the best system of emission reduction is consistent with the technology-forcing purpose and historic application of Section 111. This technology will only become more cost-effective as experience with CCS grows throughout the world. *Amici curiae* are widely recognized experts in the innovation and diffusion of pollution control technology through the adoption of technology-forcing regulation. They file this brief in support of the Rule and to provide insight into the technological, economic, and regulatory context for this rulemaking, and the theory and history of technology-forcing in Clean Air Act regulation, to the Court.

SUMMARY OF ARGUMENT

EPA's final rule establishing New Source Performance Standards for carbon pollution from fossil-fuel fired power plants properly determines that partial CCS is the best system of emission reduction, both because it is a demonstrated technology and because the costs are reasonable. CCS is presently used in multiple sectors, and has been fully demonstrated in commercial electric power applications. The Rule sets a numerical performance standard based on the level of emission reduction achievable with the application of partial CCS. The Rule creates incentives to advance and diffuse CCS technology, and to innovate by developing and applying other technologies that can achieve the same or deeper carbon dioxide emission reductions. EPA found that CCS has been adequately demonstrated. The agency also found it to be cost-effective, based on analysis of the projected costs of deployment of the technology.

Amici conclude that EPA's analysis is not only reasonable, but is conservative since it does not fully take into account the expected decline in future cost to implement the technology. In addition to reducing pollution directly, stimulating increased adoption of CCS will lead to a decline in capital and operational costs associated with the technology, similar to declines *amici* have documented in the cost of other pollution control technologies fostered by previous EPA regulations.

The development and implementation of technology is an iterative process that has multiple stages and depends on various conditions. *Amici curiae* have studied that process in the pollution control context. They and others in their field have observed that pollution regulation stimulates innovation and deployment of technology to meet that standard, which leads to design and operating improvements, which in turn reduce costs further. Regulators and policy experts often rely on the cost reduction trajectories, or "learning curves," documented from comparable technologies when assessing the possible future cost trajectory of a technology. Here, EPA found that both capital costs and the levelized costs of electricity were not exorbitant, based on a sound analysis of the costs for the next commercial application of CCS technology. Based on our analysis of the history of pollution control technology diffusion and related regulation and cost dynamics, we believe costs are likely to decline substantially further over time.

Congress intended that Section 111 standards reduce emissions to the maximum practicable degree and reflect the latest available pollution control methods. This Court has upheld such standards before. Technology need not have actually been adopted by sources prior to a standard's enactment so long as it will be available to new sources. Here, EPA's standard, based on adoption of partial CCS, is consistent with that statutory purpose and legal precedent. CCS has been adopted by existing sources, and it is also available to new sources.

ARGUMENT

I. THE RULE WILL INCREASE DIFFUSION OF CARBON CAPTURE AND STORAGE, AN ADEQUATELY DEMONSTRATED TECHNOLOGY, AND WILL CREATE COST DECLINES CONSISTENT WITH PAST EXPERIENCE.

CCS technology is both adequately demonstrated and commercially available for use in coal-fired power plants. The technology of CO_2 capture has been demonstrated in industrial applications for several decades, and is in use in multiple industries, including applications in power-generating facilities. *See* 80 Fed. Reg. at 64,548-50. Based on the state of the technology and their expertise in the dynamics of technological advancement, *amici* have concluded that, under the Rule, CCS technology will follow a learning curve similar to that observed in other pollution control technologies, such as sulfur dioxide (SO_2) capture systems. *See* Section I.a.ii, *infra*. Those learning curves exhibit an inverse relationship between levels of diffusion and cost; as adoption of the technology becomes more widespread throughout the global market, the capital and operating costs of that technology decrease. By basing the NSPS on the emission reduction achievable through partial carbon capture and storage, the Rule encourages further deployment of CCS technology.

EPA has concluded that the cost of implementing the Rule is not exorbitant – the applicable legal standard – even without including the projected future cost declines discussed in this brief. *See, e.g.*, 80 Fed. Reg. at 64,538-39, 64,558. While EPA did not base its cost determination on future declining costs, it nonetheless recognized that costs are likely to decrease over time, relying on the research of amicus Margaret Taylor. 80 Fed. Reg. at 64,575. *Amici* conclude that costs will be at least as low as those projected by EPA in its regulatory analysis of the Rule, and almost certainly lower. In the preamble to the Rule, EPA "concludes that the costs associated with the final standard are reasonable." 80 Fed. Reg. at 64,558. Its cost estimates rely on "up-to-date cost and performance information from recent vendor quotes," 80 Fed. Reg. at 64,560, and thus reflect the cost of the next commercial application of CCS technology at its current level of deployment. As explained below, while the standard is achievable now and EPA's determination is sound, EPA's cost estimation is conservative; new coal-fired power plants covered by the Rule will experience declining costs with increasing levels of deployment. Costs will decline based on deployment not only domestically in power sector applications, but worldwide in multiple industries.

a. Pollution control technologies tend to decrease in cost as adoption increases, and technology-based performance standards stimulate adoption.

Previous experience with emissions standards based on advanced technologies, such as the 1971 and 1979 New Source Performance Standards for sulfur dioxide emissions from power plants, demonstrates that such regulations lead to significant emission reductions, as well as enhanced deployment of the technology that results in dramatic cost declines. *Amici* have studied the trajectory and causes of technological advancement for decades. Their research has shown that environmental regulation creates demand for pollution control technology, which in turn stimulates diffusion of that technology throughout the market. Increased experience with the technology leads to innovation, operational improvements, and cost reductions.

i. Technology-forcing regulation under the Clean Air Act has successfully prompted the deployment of crucial pollution control technology.

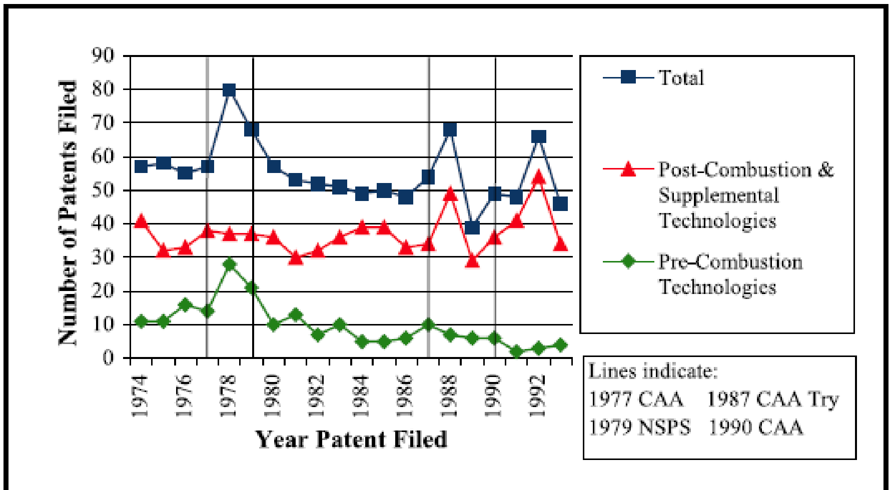
Technology-forcing policies have successfully achieved substantial reductions in emissions of harmful pollutants where other policies have failed. The successful regulatory effort under the Clean Air Act to reduce emissions of sulfur dioxide – the primary pollutant responsible for “acid rain” that significantly harmed ecosystems in the U.S. for decades – illustrates the efficacy of these policies. EPA regulation, including the New Source Performance Standard adopted in 1971 and revised in 1979, has resulted in widespread adoption of technology that captures sulfur dioxide from stationary sources of pollution, significantly reducing sulfur dioxide emissions.

Congress chose to enact mandatory standards for pollution from stationary sources, including power plants, only after other policies had failed to address the issue. During the 1950s and 1960s, the federal government developed grants and other funding for research and demonstration projects to encourage the development of pollution control technology. Margaret Taylor, Edward S. Rubin, & David A. Hounshell, *Regulation as the Mother of Innovation: The Case of SO_2 Control*, 27 L. & POLICY 349, 357 (2005) (cited in EPA-HQ-OAR-2013-0495-11005 at 23, JA__). Although these efforts led to the invention of several technologies for capturing sulfur dioxide from power plants and other industrial sources, the technologies did not fully commercialize because there was no market demand. *Id.* at 371. It was not until Congress required sector-wide pollution reduction on a specific timetable that the deployment of these technologies grew. The 1970 Act drove the necessary market demand by creating national air quality standards for multiple pollutants, including sulfur dioxide, and the 1979 standard further stimulated demand by imposing an even stricter sulfur dioxide reduction requirement (70-90%) on new sources. *See id.* at tbl. 1, 365.

The success of technology-forcing regulatory policy in stimulating the adoption of sulfur dioxide control technology is apparent in the market changes in the 1970s. Flue gas desulfurization has long been the most effective commercially-available technology for sulfur dioxide emissions control. At the time the first sulfur dioxide performance standard was established in 1971, there were only three flue gas desulfurization units in operation and only one vendor for the technology. *See* Larry Parker & James E. McCarthy, CONG. RESEARCH SERV., R40585, CLIMATE CHANGE: POTENTIAL REGULATION OF STATIONARY GREENHOUSE GAS SOURCES UNDER THE CLEAN AIR ACT 18 (2009). After the regulation was in place, deployment rapidly increased: the number of commercial vendors of went from one to sixteen by the end of the 1970s. Taylor et al., *Mother of Innovation*, *supra*, at 356. These post-combustion control devices, commonly known as "scrubbers," became the industry standard. *Id.* at 355-56.

The 1979 standard imposed a stringent emission limit on sulfur dioxide. This standard, together with Section 111's flexibility to use any available technology to comply, was particularly conducive to the growth of the market for "wet" flue gas desulfurization systems. *Id.* at 357. Flue gas desulfurization systems are subdivided into "wet" and "dry" systems. Although the "wet" systems were more expensive at the outset, they captured more sulfur dioxide pollution than dry systems. Due to the stringent 1979 NSPS standard, the more effective "wet" systems began to dominate the commercial market in the 1970s. *Id.* at 355.

Patent records provide further evidence of the impact of regulatory strategy on the development and commercialization of sulfur dioxide scrubbers. Patents require showing that a technology is novel and useful, and thus are considered representative of innovation aimed at commercialization. *Id.* at 361. The number of patents for technologies related to sulfur dioxide control jumped in 1970, the year Congress established mandatory air quality standards, and continued to rise. *Id.* at Fig. 6. Multiple regression analyses of the relationship between patent filing data and both government research and development funding and regulatory events found that research and development funding explained as little as 4% of the variance in the number of patents, whereas regulatory events explained 39-73% of the variance. *Id.* at 365-66. Furthermore, each of the three spikes in patent filings between 1974 and 1994 occurred just before or after a regulatory event. *Id.* at Fig. 7; *see also* Margaret Taylor et al., *Control of SO_2 Emissions from Power Plants: A Case of Induced Technological Innovation in the U.S.*, 72 TECH. FORECASTING & SOCIAL CHANGE 697, 710 (2005) (cited in EPA-HQ-OAR-2013-0495-10969, JA__).



Technology	% of Patents	Organization	% of Patents
Post-Combustion Treatment	53%	Firm	76%
Pre-Combustion Treatment	17%	Individual	14%
Gassification	12%	Government	6%
Sorbent/additive development	5%	University	4%
By-product modification	5%	Consortium	3%
During-Combustion Treatment	4%		
Fluidized Bed Combustion	4%		
Measurement Technology	1%		

Figure A (From Taylor et al. *Mother of Innovation*, *supra*, at 364, fig. 7).

As illustrated in Figure A, there was one spike in 1978 just after the 1977 CAA amendments and just before the 1979 New Source Performance Standard, one in 1988 just after the 1987 proposed CAA amendments almost passed (reflecting the influence of anticipation of more regulation), and a third in 1992 just after the 1990 CAA amendments. Taylor et al., *Mother of Innovation*, *supra*, at 365-66.

Overall, through the increased deployment of scrubbers caused by the sulfur dioxide emissions standard and the experience and learning it produced, vendors were able to cut the capital cost of scrubber systems, in constant dollars, in half over twenty years. *Id.* at 369. This evidence supports *amici*'s conclusion that CCS in power plants will respond positively to a technology-forcing regulation and will produce further diffusion and cost declines. While EPA predicts that few coal power plants will be built under current market conditions, regulation will facilitate widespread deployment should market conditions change; moreover, costs of the technology will decrease with deployment.

ii. The study of technological development has documented learning curves that link the increasing diffusion of a technology with decreasing costs over time.

Researchers have identified four major phases of technological development: invention, innovation, adoption, and diffusion.[2] Edward S. Rubin et al., *The Outlook for Improved Carbon Capture Technology*, 2012 PROGRESS IN ENERGY AND COMBUSTION SCIENCE 1, 9, cited in EPA-HQ-OAR-2013-0495-10108, JA__; Nicholas A. Ashford & Ralph P. Hall, *The Importance of Regulation-induced Innovation for Sustainable Development*, 3 SUSTAINABILITY 270 (2011). Invention is the discovery or creation of a new technique or idea; innovation is the transformation of that idea into a commercial product or process; adoption is the initial use of the new technology; and diffusion is the proliferation of the technology throughout the market. Rubin et al., *Outlook*, *supra*, at 9; *see*

[2] Researchers sometimes use different names for the phases, or split the development curve into more or fewer phases, but all maintain the same pattern of development and identify at least three distinct phases.

also Nicholas A. Ashford, *Understanding Technological Responses of Industrial Firms to Environmental Problems: Implications for Government Policy*, ENVIRONMENTAL STRATEGIES FOR INDUSTRY 277-78 (K. Fischer & J. Schot, eds., 1993). These stages, illustrated by Figure B below, are interactive and iterative; technological development builds on "the experience of early adopters, plus added knowledge gained as a technology diffuses more widely into the marketplace." Rubin et al., *Outlook*, *supra*, at 9.

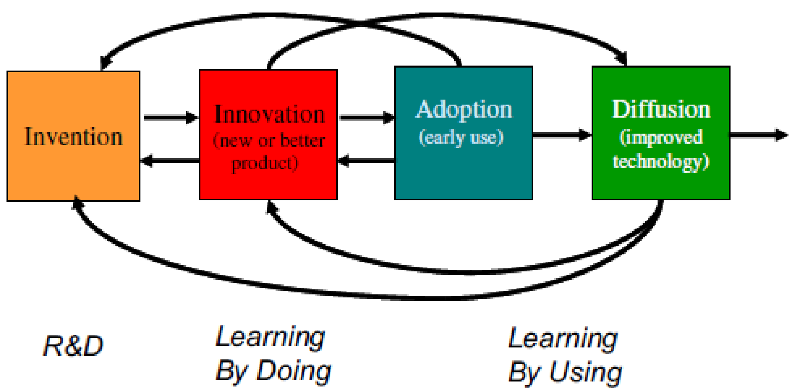


Figure B (From Rubin et al., *Outlook*, *supra*, at fig. 10).

The relationship between the movement through these stages and the decrease in the cost of technology implementation is known as a "learning curve" or "experience curve." *See, e.g.*, Linda Argote & Dennis Epple, *Learning Curves in Manufacturing*, 247 SCIENCE 920, 920 (1990). The learning curve reflects "the combined impacts of sustained R&D [research and development] plus the benefits derived from 'learning by doing' (economies in the manufacture of a product) and 'learning by using' (economies in the operating costs of a product)." Rubin et al., *Outlook*, *supra*, at 9. Economists apply the "learning curves derived from past experience with similar technologies to estimate the future cost of a new technology based on its projected installed capacity at some future time." *Id.* at 27. Figure C is an idealized illustration of such a "learning curve."

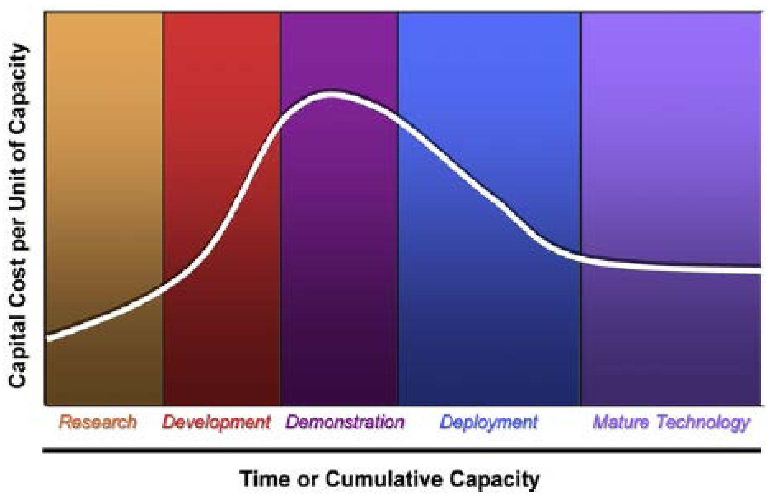


Figure C (From Rubin et al., *Outlook*, *supra*, at fig. 27).

Multiple factors, including government policies, influence whether, and how rapidly, a technology advances along the learning curve and spreads throughout the market. *See generally* Nicholas A. Ashford, Christine Ayers, & Robert F. Stone, *Using Regulation to Change the Market for Innovation*, 9 HARV. ENVTL. L. REV. 419 (1985), JA__. Governments often influence the market for a technology through two general strategies: reduce the cost of production of the technology through subsidies, research and development funding, and technology demonstrations (also called "technology-push" policies); or increase demand through regulation that requires performance at a level attainable through use of technology (also called "demand-pull" policies). *See, e.g.*, Edward Rubin, *Climate Change*, *Technology Innovation, and the Future of Coal*, 1 CORNERSTONE 37, 39-40 (2013); *see also* John A. Alic, David C. Mowery, & Edward S. Rubin, U.S. TECHNOLOGY AND INNOVATION POLICIES: LESSONS FOR CLIMATE CHANGE, 15-33 (November 2003), *available at* http://www.c2es.org/publications/us-technology-and-innovation-policies-lessons-climate-change.

"Demand-pull" regulation is particularly important to incentivize the use of pollution-control technology. Pollution costs are ordinarily externalized onto the public, since the market does not require polluting businesses to price into their products and services the costs of the resulting pollution. Thus, polluting businesses have little or no incentive to install pollution control technologies; firms incur all of the cost of installing the control technology, while the benefits of environmental protection flow to the public.

Amici's research confirms that technology-forcing demand-pull regulation addresses this incentive gap by requiring a level of performance achievable through using the most effective technology, and enforcing that performance standard. *See*, *e.g.*, Ashford & Hall, *supra*, at 279. Evidence shows that these types of health, safety, and environmental regulations generally incentivize innovation. *Id.* A study by Massachusetts Institute of Technology researchers, including one of the *amici* here, of various types of industrial policies in five countries found that regulations to protect health, safety, and the environment – unlike other regulations – affected innovation, and that the effect was positive. *Id.* This finding supports the assertion that firms do not have market-based incentives to adopt innovative technologies in these areas. Furthermore, more stringent regulations can even "stimulate new entrants to introduce entirely new products and processes into the market" by requiring levels of performance that can be achieved only through development and adoption of new technology. *Id.* (emphasis omitted).

The cost of applying a given technology will depend on where on the learning curve the technology sits at the time of application. The first adoptions of a technology in a commercial context are assumed to incur "first-of-a-kind" costs, which are represented on the far left-hand side of that technology's learning curve. Beyond the first deployment, costs will begin to reflect the lessons from experience and shift to "next-of-a-kind" and more mature "N^{th}-of-a-kind" (future iterations of) plant designs and costs. *See* Edward S. Rubin et al., *The Cost of CO_2 Capture and Storage*, 40 INT'L J. GREENHOUSE GAS CONTROL 378, 379 (2015). As illustrated by Figure C, *supra*, learning curves thus feature a peak, after which costs begin to decline significantly. As a technology moves along the learning curve from adoption to diffusion, gaining efficiency and mitigating stumbling blocks, the cost of implementation will continue to decline. Edward S. Rubin et al., *Experience*

Curves for Power Plant Emission Control Technologies, 2 INT'L J. ENERGY TECH. & POL'Y 52, 60 (2004); Edward S. Rubin et al., *Use of Experience Curves to Estimate Future Cost of Power Plants with CO_2 Capture*, 1 INT'L J. GREENHOUSE GAS CONTROL 188, 190 (2007) (cited in EPA-HQ-OAR-2013-0495-10108 at 23, JA__).

b. CCS technology is already in use, so plants covered by the Rule will be "next-of-a-kind" and costs will continue to decline as adoption expands.

While a technology need not be commercially available at the time an emission standard is adopted to be "adequately demonstrated" for the purposes of Section 111, CCS technology is already commercially available and its use is expanding in a global market. *Amici* conclude that CCS technology is advanced enough that costs of implementation in power plant contexts are declining with each successive deployment.

Carbon capture technology has been used for decades in the industrial sector, including at power generation facilities burning coal or natural gas. Technology deployment at facilities of any scale is relevant to the experience curve. Nonetheless, there are fifteen large-scale CCS applications currently in operation around the world, and several under construction. *See* "Large Scale CCS Projects," Global CCS Institute, http://www.globalccsinstitute.com/projects/large-scale-ccs-projects (last visited December 15, 2016). Several vendors now offer commercial guarantees for full-scale CCS systems installed at power plants, including vendors for CO_2 capture systems, pipeline transport, and geological storage site operations. 80 Fed. Reg. at 64,555; *see*, *e.g.*, "Cansolv Carbon Dioxide (CO2) Capture System," http://tinyurl.com/zlc5tuk (last visited Sept. 22, 2016) ("This patented technology is designed and guaranteed for bulk CO_2 removal up to 90%."); "Carbon Capture Recovery Technologies for Flue Gas Streams Reduce Greenhouse Gas Emissions," http://tinyurl.com/jtkcn7p (last visited Sept. 22, 2016) (cited in EPA-HQ-OAR-2013-0495-11773 at 51, JA__).[3] The technology has moved well beyond the first commercial adoptions, and thus it is reasonable to use cost projections for next-of-a-kind facilities.

Thus, the iterative learning-by-doing and learning-by-using processes that have led to cost reductions in numerous other technological contexts are already underway. For example, SaskPower expects its next CCS project – in development now – to cost 30% less than the final cost of the currently operational Boundary Dam project. 80 Fed. Reg. at 64,565; Edward S. Rubin, Op-Ed, *Will Cutting Carbon Kill Coal?: Only If the Industry Fails to Adapt, Explains CMU Engineering Professor Edward S. Rubin*, PITTSBURGH POST-GAZETTE, Nov. 23, 2014, at E1, 2014 WLNR 32977019. This commitment to future projects and the

[3] For more information on the state of CCS technology, *see* Brief for Amici Curiae Carbon Capture and Storage Experts in Support of Respondents.

expected cost decrease show that industry participants consider CCS a commercially viable technology and signal a growing global adoption of CCS. EPA's conclusion that the costs were reasonable was conservative.

Amici expect that the cost of CCS will significantly decline for all levels of carbon capture. However, the final Rule establishes a standard based on only *partial* CCS. By rejecting full CCS and selecting partial CCS as the best system of emission reduction, EPA has further reduced the economic impact of the Rule. Based on their assessment of the state of the technology and the predicted costs, *amici* believe that the Rule would have resulted in reasonable costs even as originally proposed, and thus conclude that the final Rule is exceptionally reasonable.

c. Capital costs for CCS at new coal-fired power plants will be at least as low as those projected by EPA, and likely substantially lower, based on experience with other pollution control technologies.

The learning curve for CCS at new coal-fired power plants is similar to that of other pollution control technologies where emission standards have created demand. Studies show that pollution control technologies, particularly those applied to power plants, experience declining costs as the number of installations increases. The learning curves of post-combustion sulfur dioxide and nitrogen oxides (NO_x) control technology provide particularly useful insight into how the cost of CCS may change with growing deployment because those technologies experienced similar market conditions prior to regulation, and because sulfur dioxide removal systems also have technical similarities to current post-combustion CO_2 removal systems.

The learning curves for both wet flue gas desulfurization and the nitrogen oxides control process known as selective catalytic reduction have reflected an overall decline in costs over time. Over the course of two decades of deployment at coal-fired power plants in the U.S. and globally, the cost of these systems declined by at least fifty percent. Rubin et al., *Outlook*, *supra*, at 39; Rubin et al., *Experience Curves for Power Plan Emission Control Technologies*, *supra*, at 59, 63. As discussed in Sec. I.a.i, *supra*, the imposition of the Clean Air Act standard prompted this steep cost decrease as market demand grew, resulting in an increase from one to sixteen vendors competing in the marketplace by the end of the 1970s. Taylor et al., *Mother of Innovation*, *supra*, at 356. Carbon capture technology for power plants is already offered by several vendors, and there are more vendors than there were of sulfur dioxide scrubbers when those regulations were enacted. Thus, it is even more commercially advanced than scrubbers were. It is reasonable to expect future CO_2 capture costs to experience a comparable decrease, making costs lower than those predicted by EPA.

The experience so far with the cost of power plants with CCS is also consistent with expected lower costs as the technology is more widely adopted. Increases in capital costs of coal power with CCS largely result from increases in the capital cost of new coal-fired power plants generally. Edward S. Rubin, John E. Davison, & Howard J. Herzog, *The Cost of CO_2 Capture and Storage*, 40 INT'L J. GREENHOUSE GAS CONTROL 378, 392 (2015). Moreover, as discussed earlier, the control technologies applied to both sulfur dioxide and nitrogen oxides emissions experienced increases in capital costs during the first generation of adoption, and exhibited significant cost declines with each generation of deployment, reflecting the expected experience curve dynamic.

Another important sign that CCS technology is poised for increased deployment and cost declines is that several reputable vendors offer commercial guarantees for full-scale CCS systems on power plants. *See* Section I.b, *supra*. These guarantees signal the producers' confidence that the technology is ready for widespread diffusion, providing further evidence that costs are decreasing with international as well as domestic deployment of the technology. CCS retrofits are already occurring at existing plants and CCS projects at both new and existing units are occurring in other countries. Therefore, regardless of the level of deployment in the U.S., CCS deployment will increase as a result of global trends, and will drive down costs for new coal plant operators installing CCS systems in the U.S. going forward. As projections based on the "first-of-a-kind" experience at Boundary Dam show, even the development of a single project can have important cost-saving benefits for subsequent plants. The Rule will help to continue that diffusion.

II. CONGRESS AND THIS COURT HAVE CONSISTENTLY UNDERSTOOD SECTION 111 AS A TECHNOLOGY-FORCING STATUTE, AND EPA'S ACTION HERE IS CONSISTENT WITH THAT UNDERSTANDING.

The Clean Air Act is intended to limit emissions of harmful pollutants. Section 111 authorizes EPA to look beyond typical industry practice in setting emissions standards for major new sources of air pollution, in order to reduce pollution to levels necessary to avoid endangering public health and welfare. By prioritizing public and environmental health and requiring regulated firms to use the most advanced technology, the Act incrementally and continuously improves the performance of the industry as a whole. As detailed in Section I, *supra*, regulation under the CAA has succeeded in making the most effective pollution control methods – such as sulfur dioxide "scrubbers" at coal-fired power plants – the industry standard. Congress intended Section 111 to push industry and businesses beyond what they would do otherwise, and this court has repeatedly recognized the effectiveness of technology-forcing regulations in achieving the pollution reduction goals of the CAA. EPA's Rule continues this strategy.

a. Congress intended Section 111 to allow EPA to achieve pollution reduction by creating demand for innovative pollution control technology.

The Clean Air Act of 1970 is one of the most comprehensive and ambitious pieces of legislation in U.S. history. Congress intended that the Act clean up our air to levels protective of public health through requiring polluters to internalize the costs imposed on society by their pollution. At the same time, it recognized that in order to accomplish its goal, the Act would need to spur the development and diffusion of advanced pollution control technology. Existing technology in 1970 was inadequate to protect public health, and experience showed that market forces and financial incentives alone would not suffice to prompt polluters to adopt pollution control technology.

When Congress enacted the Clean Air Act, the country was suffering from dangerous levels of air pollution. 42 U.S.C. § 7401(a). Previous attempts to control pollution through technology-push policies had failed to create the large-scale changes needed, and Congress concluded that achieving meaningful improvements in air quality would "require major action throughout the Nation." S. Rep. No. 91-1196, at 2 (1970). Congress did not expect or want that action to involve a significant decrease in economic activity. Instead, Congress intended the Clean Air Act, and Section 111 specifically, to allow EPA to reduce pollution by requiring industrial sources to internalize the costs of pollution, thus creating demand for innovative pollution control technology. Congress thus put its faith in the ingenuity of American engineers, scientists, and businesses, noting that the new law would "require major investments in new technology and new processes." *Id.*

In service of this goal, Section 111 allowed EPA to require improvements in pollution control technology. Standards of performance under Section 111 must reflect "the degree of emission limitation achievable through the application of the best system of emission reduction which … the Administrator determines has been adequately demonstrated." 42 U.S.C. § 7411(a)(1). In requiring new sources to reduce emissions to the level achievable by the "best" system of emission reduction that has been "adequately demonstrated," Congress intended to proactively prevent future pollution as the economy grew. S. Rep. No. 91-1196, at 16 (1970) ("The overriding purpose of [the NSPS] would be to prevent new air pollution problems"). Congress understood that it is less costly to incorporate new technologies into a design from the beginning than to add them on to an existing plant. It thus concluded that achieving the "maximum feasible control of new sources at the time of their construction is … the most effective, and, in the long run, the least expensive approach." *Id.* The fact that Congress adopted a strategy with a long-term economic justification shows that it anticipated future standards to be more stringent and technology to continue to improve.

Congress intended to authorize performance standards based on expected technological innovation and diffusion of new technology. For years prior to enacting the 1970 CAA Amendments, the federal government had sought to generate advances in pollution control technology through grants, research and development programs, and demonstration projects, in the hope that the market would independently recognize the technologies' benefits and adopt them. Taylor et al., *Mother of Innovation*, *supra*, at 360 tbl. 2. When that transition did not occur, Congress realized that merely improving the technology was not going to incentivize companies to invest in a costly new system. *See* 113 Cong. Rec. 19171 (1967) ("[T]o date, public and private efforts to accomplish air quality objectives have been inadequate."). The 1970 Act was a product of experience and necessity.

The Clean Air Act Amendments of 1977 continued this effort by directing EPA to implement a more stringent new source performance standard for some pollutants. Congress confirmed in its analyses of these amendments that Section 111 authorized EPA to spur the development and diffusion of innovative pollution control technology. For example, the Senate Committee Report for the 1977 amendments noted that in enacting Section 111, Congress sought "to assure the use of available technology and to stimulate the development of new technology." S. Rep. No. 95-127, at 171 (1977). As noted in the House report on the amendments, the Act was intended to "require achievement of the maximum degree of emission reduction from new sources, while encouraging the development of innovative technological means of achieving equal or better degrees of control." H.R. Rep. No. 95-294 at 189 (1977).

b. Courts have consistently affirmed EPA's authority to issue technology-forcing emission standards under Section 111.

As demonstrated above, technology-forcing emission standards under the Act have successfully reduced emissions to protect public health and the environment. In the face of challenges to that regulatory choice, courts have confirmed EPA's authority to issue emission standards that encourage technological development. Relying on both the language of the Act and the intent of Congress, this Court has properly recognized the technology-forcing nature of the Act.

EPA's authority to set standards at a level that stimulates the development and diffusion of pollution-control technology is accordingly broad. In *Sierra Club v. Costle*, 657 F.2d 298 (D.C. Cir. 1981), environmental organizations and regulated parties challenged EPA's 1979 performance standard for sulfur dioxide (the same rule discussed in the previous section). In the preamble to the sulfur dioxide rule, EPA stated that "the Administrator sought a percentage reduction requirement that would provide an opportunity for dry sulfur dioxide technology to be developed … yet would be sufficiently stringent to assure that the technology was developed to its fullest potential." 44 Fed. Reg. 33,580, 33,583 (June 11, 1979).

In *Costle*, this Court concluded that EPA appropriately considered how the sulfur dioxide rule might affect the development and diffusion of technology, including reductions in cost associated with diffusion. It held that the balancing required under Section 111(a) of the CAA "embraces consideration of technological innovation as part of that balance." 657 F.2d at 346. That provision requires that EPA "tak[e] into account the cost of achieving such reduction and any nonair quality health and environmental impact and energy requirements" in setting an emission performance standard. 42 U.S.C. § 7411(a)(1). The "cost of achieving such reduction" would inevitably depend upon the technology available at the time of implementation, including any predicted advances in technology and related reductions in cost.

Importantly, the Court elaborated that EPA should view technological development and diffusion from a long-term perspective. It held that as "long as EPA considers innovative technologies in terms of their *prospective* economic, energy, nonair health and environmental impacts the agency is within the scope of its authorized analysis." *Costle*, 657 F.2d at 346 (emphasis added). Ultimately, the *Costle* court held that EPA has even more authority to stimulate technology adoption and diffusion than it is using in the present Rule. It decided that a NSPS may be set at a level that would require more effective application of control technology than had previously been demonstrated:

> Recognizing that the Clean Air Act is a technology-forcing statute, we believe EPA does have authority to hold the industry to a standard of improved design and operational advances, so long as there is substantial evidence that such improvements are feasible and will produce the improved performance necessary to meet the standard. … [W]e uphold EPA's judgment that the standard can be set at a level that is higher than has been actually demonstrated over the long term by currently operating lime scrubbers at plants burning high sulfur coal.

657 F.2d at 347. In so holding, this Court followed its prior holding in *Portland Cement Ass'n v. Ruckelshaus,* where it concluded that "Section 111 looks toward what may fairly be projected for the regulated future, rather than the state of the art at present, since it is addressed to standards for new plants…. The essential question was … whether the technology would be available for installation in new plants." *Portland Cement Ass'n v. Ruckelshaus*, 486 F.2d 375, 391 (D.C. Cir. 1973), cert. denied, 423 U.S. 1025, 96 S. Ct. 469, 46 L. Ed. 2d 399 (1975).

This Court has approved EPA's determinations of the best system of emission reduction even where the evidence for the effectiveness of the system is derived from different applications of the technology. For example, this court upheld EPA's New Source Performance Standard for nitrogen oxides from coal-fired boilers despite the absence of emissions data for the use of the technology on coal-fired boilers. *Lignite Energy Council v. EPA*, 198 F.3d 930, 933 (D.C. Cir.

1999). The Court recognized that "EPA may compensate for a shortage of data through … the reasonable extrapolation of a technology's performance in other industries." *Id.* at 933-34. Although this precedent makes clear that evidence from other industries alone is sufficient, in this instance evidence from both the power sector and other industries supports EPA's determination that CCS is adequately demonstrated. On this record, EPA could not justify a contrary determination.

This Court has also deferred to EPA's judgment that a technology is available in cases involving other provisions of the Act. In 1973, the Court rejected the arguments that EPA's determination of whether a technology was "available" within the meaning of the Act must be based "solely on technology in being as of the time of the application" and that the Act prohibits considering how technology is likely to develop. *Int'l Harvester Co. v. Ruckelshaus*, 478 F.2d 615, 628 (D.C. Cir. 1973). Almost a decade later, this Court reiterated this understanding of Congress' reliance on EPA expertise, noting that the "legislative history of both the 1970 and 1977 amendments [to the Act] demonstrates that Congress intended the agency to project future advances in pollution control capability … [and to] press for the development and application of improved technology rather than be limited by what exists" at the time of regulation. *Natural Res. Defense Council v. EPA,* 655 F.2d 318, 328 (D.C. Cir. 1981) (quoting S. Rep. No. 91-1196, at 24 (1970)) (internal quotation marks omitted).

Providing flexibility in the types of technologies that may comply with a standard is a key component of crafting a regulation that effectively reduces pollution at the lowest cost. The exact path of a particular technology's development and diffusion may not be linear or there may be new entrants to the market that were unforeseen. Understanding this, courts have declined to require that EPA "provide detailed solutions to every engineering problem posed," or "rebut all speculation that unspecified factors may hinder 'real world' emission control." *Natural Res. Defense Council v. EPA*, 655 F.2d at 333. *See also Husqvarna AB v. EPA*, 254 F.3d 195, 201 (D.C. Cir. 2001); *Natural Res. Defense Council v. Thomas*, 805 F.2d 410, 434 (1986).

c. EPA's determination that the technology is adequately demonstrated was well within its authority.

EPA has more than established the fact that CCS technology is adequately demonstrated; it has shown CCS to be in use across industries, including the power sector. This court has repeatedly affirmed EPA's authority under Section 111 to set emission standards based on technology that, though technically demonstrated, is not in widespread commercial use. Given this precedent, basing a performance standard on partial CCS, a technology that is not only demonstrated but also commercially available at the time EPA issued the Rule, with the likely costs of adoption substantially lower than those estimated by EPA, is well within this

Court's understanding of EPA's authority under Section 111(b). It would be unreasonable for EPA to conclude otherwise.

CONCLUSION

Amici conclude that partial CCS for coal-fired power plants is adequately demonstrated, and that costs are reasonable and will decline with more widespread adoption. The Rule falls squarely within EPA's authority as articulated in the statute, as interpreted by this Court in similar contexts. For all the reasons above, we support EPA's determination that the best system of emission reduction for new coal-fired power plants may be based on adoption of partial CCS.

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December 21, 2016

CERTIFICATE OF COMPLIANCE

I hereby certify that the foregoing brief complies with the type-volume limitations set forth in D.C. Cir. R. 32(e)(3) and Fed. R. App. P. 29(d) because this brief contains 6,694 words, excluding the parts of the brief exempted by Fed. R. App. P. 32(a)(7)(B)(iii) and D.C. Cir. R. 32(e)(1). The foregoing brief complies with the typeface requirements of Fed. R. App. P. 32(a)(5) and the type style requirements of Fed. R. App. P. 32(a)(6) because this brief has been prepared in a proportionally spaced typeface using Microsoft Office Word 2010 in 14-point Times New Roman font.

Respectfully submitted,

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December 21, 2016

CERTIFICATE OF SERVICE

I hereby certify that, on this 21st day of December 2016, I electronically filed the foregoing with the Clerk of the Court for the United States Court of Appeals for the District of Columbia Circuit using the Court's CM/ECF system, which will send notice of such filing to all counsel who are CM/ECF registered users. I also caused the foregoing to be served via first-class mail on counsel for the following parties at the following addresses:

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