Regulatory Promotion of Emergent CCS Technology

Topical Report

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Abstract

Despite the growing inevitability of climate change and the attendant need for mitigation strategies, carbon capture and sequestration (CCS) has yet to gain much traction in the United States. Recent regulatory proposals by the U.S. Environmental Protection Agency (EPA), limited in scope to new-build power plants, represent the only significant policy initiative intended to mandate diffusion of CCS technology. Phase I of this Project assessed barriers to CCS deployment as prioritized by the CCS community. That research concluded that there were four primary barriers: (1) cost, (2) lack of a carbon price, (3) liability, and (4) lack of a comprehensive regulatory regime. Phase II of this Project, as presented in this Report, assesses potential regulatory models for CCS and examines where those models address the hurdles to diffusing CCS technology identified in Phase I. It concludes (1) that a CCS-specific but flexible standard, such as a technology performance standard or a very particular type of market-based regulation, likely will promote CCS diffusion, and (2) that these policies cannot work alone, but rather, should be combined with other measures, such as liability limits and a comprehensive CCS regulatory regime.

Executive Summary

This Report examines potential regulatory models for promoting CCS and seeks to assess where those regulatory regimes address or fail to address the impediments to commercial-scale CCS deployment identified in Phase I of this Project. Notwithstanding sustained government efforts to advance CCS—and ongoing industry utilization of many of the technologies comprising CCS in enhanced oil recovery (EOR) efforts— CCS technology remains primarily an R&D rather than a commercial technology. Given the extent of domestic dependence on coal-fired power plants for baseload electricity production, and the increasingly ominous specter of unavoidable climate change, CCS would seem to be a potentially critical tool in mitigating the rise of global warming.

Numerous analyses, including the Phase I Report, have identified and assessed the various barriers to effective CCS technology diffusion. The Phase I research utilized an opinion survey issued and completed in the first quarter of 2011 by 229 members of the CCS community.[1] Phase I examined three questions: What are the most significant obstacles to broad-scale CCS use? What incentives might best overcome those obstacles? How should CCS regulation be shaped to close the gap between the state of the CCS industry today and its realization as a full-fledged climate change solution?

The Phase I survey data showed that the CCS community believes that, given the high costs associated with CCS adoption, the primary barrier to CCS deployment is the lack of a carbon price. This finding confirmed previous CCS studies' conclusion that definitive governmental action on climate change is crucial to domestic commercialization of CCS technology. The Phase I research further found that liability concerns were a prominent barrier to CCS deployment, as was the lack of a

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[1] The CCS community surveyed in Phase I included CCS operators working directly in the industry, consultants providing professional services to the CCS industry, CO_2 emitters, CCS technology and policy researchers, non-profit advocacy organizations involved with CCS, and government regulators.

comprehensive CCS regulatory regime. Finally, the Phase I survey data reflected the CCS community's distinct preference that a comprehensive CCS regulatory regime be initiated at the federal level, and incorporate federal authority over liability and CO_2 transport, while retaining traditional state primacy over relevant property rights issues (*e.g.*, pore space ownership, reservoir unitization, rights-of-way, and easements).

Phase II of this Project seeks to take the impediments to CCS commercialization that were identified in Phase I and consider them in the context of potential models for CCS regulation and promotion. Various regulatory models could be applied to incent CCS technology diffusion, including design standards, performance standards, and market-based regulatory mechanisms. These regulatory models are discussed in greater detail in the body of the Report. Summarized briefly, however, design standards mandate the use of a particular technology, whereas performance standards utilize a numerical limit to set a pollution limit that is equivalent to the pollution reduction capacity of a given technology. Market-based regulatory regimes attempt to harness economic forces to reach a given regulatory result; those potentially applicable to CCS include a carbon tax, a cap and trade system, and subsidies. For purposes of illustration, historical case studies of these regulatory approaches are presented in the body of the report to highlight each policy's comparative advantages and disadvantages. These case studies include California's efforts to ban perchloroethylene in the dry cleaning industry, EPA's regulation of tailpipe emissions, and EPA's efforts to reduce SO_2 and NO_x emissions.

The Phase I data, plus recent assessments both by DOE and the EPA, make clear that CCS is sufficiently far along the development spectrum as to be deployment ready. Despite this technology readiness, deficiencies in the CCS market remain. Thus, in order to effectively diffuse CCS technology, policymakers should identify policies that will create greater market demand for CCS technology. Ideally such policies would be CCS-specific, rather than broadly focused on general climate mitigation technologies, but sufficiently flexible to spur continued CCS innovation. Based on the research completed in Phase I and Phase II of this Project, technology performance standards and CCS-specific market-based regime appear to hold the greatest regulatory promise for accelerating CCS diffusion.

Whichever policy approach is pursued, that policy will need to be supported by coordinated governmental incentives. Phase I found that the CCS community believed carbon pricing, caps on liability arising from CCS, economic incentives for CCS deployment, and a comprehensive CCS regulatory scheme to be the most effective CCS diffusion incentives. To afford CCS diffusion the best possible chance at success, CCS policy and incentives will need to be integral elements of a high-level political and legislative commitment to developing and implementing a long-term national climate policy. Hopefully the Phase II research presented in this Report will aid policymakers in efficaciously evaluating the regulatory gaps that impede widespread diffusion of CCS technology, as well as the critical political and legislative commitments needed to incent CCS commercialization.

Table of Contents

List of Acronyms

AQMD	South Coast Air Quality Management District
CAA	Clean Air Act
CCAP	Climate Change Adaptation Plan
CCS	Carbon Capture and Sequestration
CO_2	Carbon Dioxide
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
EOR	Enhanced Oil Recovery
IGCC	Integrated Gasification Combined Cycle
IRGC	International Risk Governance Council
IPCC	Intergovernmental Panel on Climate Change
KWh	Kilowatt Hour
MTBE	Methyl Tertiary-Butyl Ether
MWh	Megawatt Hour
NO_x	Nitrogen Oxide
NSPS	New Source Performance Standards
NSR	New Source Review
PCE	Perchloroethylene
R&D	Research & Development
SO_2	Sulfur Dioxide

I. Introduction

On May 9, 2013, the atmospheric concentration of CO_2 briefly surpassed 400 parts per million for the first time on record.[1] Today, CO_2 emissions are expected to continue rising, with 2013 emissions projected to total 36 billion metric tons, or a 2.1 percent increase from 2012.[2] As greenhouse gas emissions continue to rise, so too do the activities that contribute to these emissions. The Energy Information Administration (EIA) predicts that domestic power demand will increase 28 percent between 2012 and 2040, and that domestic coal production will increase at an average rate of 0.3 percent annually between 2012 and 2040.[3] Against this backdrop, the United Nations' November 2013 climate talks in Warsaw failed to reach consensus on the details of efforts to address climate change, with the convening nations instead opting to defer the specifics of international commitments to reduce global CO_2 emissions until 2015.[4] Meanwhile, in the United States, federal agencies submitted their inaugural Climate Change Adaptation Plans (CCAPs), addressing climate change in the context of their required annual Strategic Sustainability Performance Plans.[5]

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[1] U.S. Dep't of Commerce, National Oceanic & Atmospheric Administration, *CO_2 at NOAA's Mauna Loa*

[2] Global Carbon Project, *Carbon Budget 2013*, Nov. 19, 2013, http://www.globalcarbonproject.org/carbonbudget/13/hl-full.htm. EIA anticipates decreases in domestic coal utilization for power generation being offset by global imports of U.S. coal.

[3] U.S. Dep't of Energy, Energy Information Administration, *Annual Energy Outlook 2014 Early Release*, http://www.eia.gov/forecasts/aeo/er/index.cfm.

[4] Andrew Restuccia, *Warsaw Climate Change Talks End on a Blurry Note*, POLITICO PRO, Nov. 25, 2103, http://www.politico.com/story/2013/11/warsaw-climate-change-talks-end-on-a-blurry-note-100317.html; Fiona Harvey, *Warsaw Climate Talks Set 2015 Target for Plans to Curb Emissions*, THE GUARDIAN, Nov. 24, 2013, http://www.theguardian.com/environment/2013/nov/24/warsaw-climate-talks-greenhouse-gas-emissions; David Jolly, *Deals at Climate Meeting Advance Global Effort*, N.Y. TIMES, Nov. 23, 2013, http://www.nytimes.com/2013/11/24/world/deals-at-climate-meeting-advance-global-effort.html.

[5] The federal agencies' CCAPs were prepared as part of their annual Strategic Sustainability Performance Plan reporting in accordance with Executive Order 13514, issued by President Obama on October 5, 2009. CCAPs require that agencies identify and analyze their respective susceptibilities to risks and challenges specifically occasioned by climate change

This microcosm of governmental efforts to address climate change—simultaneous action but delay, stops and starts and uncertainty all at once—is also reflected in the way the United States has treated many of the potential climate mitigation tools at its disposal. Given the continued rise of greenhouse gases, the consequent inevitability of at least some measure of climate change, and growing demand for fossil fuels, including coal,[6] one might expect that the United States government would avidly pursue carbon capture and sequestration (CCS), with the technology well on track to be widely implemented.

Indeed, CCS holds a number of advantages that other climate mitigation tools do not. Not only has CCS repeatedly been identified as a potentially significant tool for addressing climate change, it would also facilitate continued domestic coal utilization, and thus bolster domestic energy security,[7] as the United States possesses greater coal reserves than any other nation in the world.[8] Retrofitting existing coal-fired power plants with CCS technology also could extend the useful life of those resources, possibly deflecting capital costs that might be invested elsewhere.[9] CCS, in short, holds the potential to help allow the United States to rely on proven, conventional baseload electricity generation facilities that run on domestic fuel—a unique combination most other climate mitigation tools cannot match.

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[6] *See, e,g.* Anders Leverman et al., *The Multimillenial Sea-level Commitment of Global Warming*, PNAS 2013, doi:10.1073/pnas.1219414110; National Center for Atmospheric Research, *Climate Change Inevitable in 21st Century, Sea Level Rise to Outpace Temperature Increase*, http://www.ucar.edu/news/releases/2005/change.shtml.

[7] *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS (2013); U.S. DEP'T OF ENERGY, CCS TASK FORCE REPORT (2010); Larry PARKER ET AL., CONG. RESEARCH SERV., CAPTURING CO_2 FROM COAL-FIRED POWER PLANTS: CHALLENGES FOR A COMPREHENSIVE STRATEGY (2009); INT'L RISK GOVERNANCE COUNCIL (IRGC), REGULATION OF CARBON CAPTURE AND STORAGE 4 (2008) (citing IPCC, 4TH ASSESSMENT REPORT (2007)).

[8] U.S. Dep't of Energy, Energy Information Administration, *Today in Energy: United States Leads World in Coal Reserves*, http://www.eia.gov/todayinenergy/detail.cfm?id=2930.

[9] Steven Specker et al. Electric Power Research Institute, *The Potential Growing Role of Post-Combustion CO_2 Capture Retrofits in Early Commercial Application of CCS to Coal-Fired Power Plants*, MIT Coal Retrofit Symposium (Mar. 23, 2009).

U.S. Secretary of Energy Ernest Moniz has stated that while the Department of Energy (DOE) "perhaps could do more" to advance CCS, the "technology is nonetheless ready" for deployment.[10] Similarly, the U.S. Environmental Protection Agency (EPA) recently agreed with Secretary Moniz' assessment that there is no technical or feasibility reason precluding the use of CCS on a commercial basis. In its proposed New Source Performance Standards (NSPS), which would effectively mandate use of partial CCS for new coal-fired power plants,[11] the agency pointed to Southern Company's integrated gasification combined cycle (IGCC) power plant in Kemper, Mississippi; the Boundary Dam power plant being retrofitted by SaskPower in Saskatchewan, Canada; and over a decade of enhanced oil recovery (EOR) activities in North Dakota all as evidence that CCS is ready for commercial use.[12] Yet, despite the availability of CCS technology, and the increasingly urgent need for effective climate mitigation strategies, efforts to speed deployment of CCS in the domestic electricity sector have failed to gain traction.

The impediments to advancing CCS have been the subject of much analysis in the CCS literature, including the research presented in the first phase of this project. Our research conducted in Phase I highlighted the key hurdles to broadscale CCS commercialization. The overwhelming consensus is that, due to the costs of CCS adoption, carbon pricing or some other clear financial signal is an essential first step to

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[10] Christa Marshall, *DOE Secretary Says Carbon Capture and Storage Is 'Ready' at World Meeting*, CLIMATEWIRE, Nov. 8, 2013, http://www.eenews.net/stories/1059990199; *see also* Karen Frantz, *Moniz on CCS: 'The Technology is Ready,'* GHG MONITOR, Nov. 8, 2013, http://ghgnews.com/PDFs/vol-8-issue-48.pdf.

[11] *Standards of Performance for Greenhouse Gas Emissions From New Stationary Sources: Electric Utility Generating Units: Proposed Rule*, 79 Fed. Reg. 1429 (Jan. 8, 2014). Partial CCS refers to CCS with a CO_2 capture rate of less than 90 percent. *Id.* at 1470.

[12] *Id.* at 1450-51.

commercializing CCS.[13] Other hurdles include risk of long-term liability and lack of a comprehensive regulatory regime.[14] Using an extensive opinion survey of CCS industry representatives and experts, the Phase I research empirically confirmed technology cost, lack of a carbon signal, and liability risks as key CCS impediments. It also identified the absence of a comprehensive regulatory regime as a significant hurdle to CCS commercialization—a hurdle often overlooked in the literature.

In identifying these concerns as the four primary obstacles to CCS deployment, the Phase I research also revealed another important insight about CCS policy. While much effort has focused on CCS innovation and demonstration, none of the four primary obstacles fall into those categories. Rather, each of these obstacles relates to CCS deployment. Thus, an open and important question in CCS policy is what devices might best encourage the diffusion of CCS technology in the marketplace, rather than merely the refinement or demonstration of the technology. This question is an understudied one in the literature, and it is the focus of this Report, which concludes Phase II of our CCS regulatory gap assessment. The question addressed is: Which regulatory regime will most expeditiously incent CCS adoption and diffuse CCS technology?

The aim of this Report is to build upon Phase I of this project by discussing available regulatory frameworks for CCS in the context of the CCS deployment challenges identified in the Phase I Report. This Report proceeds in four parts. Section

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[13] LINCOLN DAVIES, KIRSTEN UCHITEL AND JOHN RUPLE, CARBON CAPTURE AND SEQUESTRATION: A REGULATORY GAP ASSESSMENT, TOPICAL REPORT, 41-43 (2012) (Phase I Report); *see also* PETER FOLGER, CONG. RESEARCH SERV., CARBON CAPTURE AND SEQUESTRATION (CCS) 25, (2009); L. STEPHEN MELZER, PEW CENTER ON GLOBAL CLIMATE CHANGE, CONGRESSIONAL POLICY BRIEF 7 (2008); GAO, REPORT TO THE CHAIRMAN OF THE SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING, HOUSE OF REPRESENTATIVES, FEDERAL ACTIONS WILL GREATLY AFFECT THE VIABILITY OF CARBON CAPTURE AND STORAGE AS A KEY MITIGATION OPTION 2 (2008).

[14] Lincoln Davies, Kirsten Uchitel and John Ruple, *Understanding Barriers to Commercial-Scale Carbon Capture and Sequestration in the United States*, 59 ENERGY POLICY 745 (2013).

II begins with a brief overview of the most prominent hurdles for commercializing CCS technology, as indicated by the research presented in the Phase I Report. Section III follows with a summary of available regulatory approaches intended to speed technology diffusion, specifically performance standards, design standards, and market-based regulatory mechanisms. Section III further presents case studies of how those regulatory options have been used to promote specific technologies in the past. Section IV discusses technology diffusion policy as applied to CCS, and Section V presents conclusions based on the research completed in Phase I and Phase II as to what policy regime is likely to effectively speed utilization of CCS technology.

II. Hurdles to CCS Commercialization

More than half a decade ago, the IPCC commented that the global rate of fossil fuel production would become environmentally unsustainable unless CCS became widely deployed.[15] In 2010, the DOE CCS Task Force determined that "there are no insurmountable technological, legal, institutional, regulatory or other barriers that prevent CCS."[16] Even though CCS is comprised of proven technologies,[17] not much has occurred between 2010 and the present on either the policymaking or industry front to alter the practical realities of the CCS status quo. That status quo is that CCS is available as a climate mitigation tool, but it is not being used on a broad scale in commercial electricity generation plants. The only recent policy initiative intended to directly spur domestic CCS deployment is EPA's proposed NSPS rules for CO_2 emissions from coal-fired utility

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[15] IRCG, *supra* note 7, at 4 (citing IPCC, 4th Assessment Report (2007)); *see also* IEA, CLEAN ENERGY PROGRESS REPORT 31-32 (2011) ("[R]aising the efficiency of existing and new coal-fired plants is important. Switching to less carbon-intensive fuels (*e.g.* from coal to natural gas) and improving the efficiency of coal plants will achieve significant reductions in CO_2 and should be a top priority. However, improving efficiency alone will not meet the reductions needed . . . . For deep cuts in emissions at lowest overall cost, CCS must be deployed.").

[16] *Id* at 7.

[17] CCS TASK FORCE REPORT, *supra* note 7, at 9.

boilers and IGCC electric generating units.[18] Those proposed rules would set an emissions limit of 1,100 pounds of CO_2 per megawatt hour for newly constructed coal fired power plants, effectively mandating integration of partial CCS technology.[19] Yet immediately following their release, these proposed rules promptly came under political attack and threats of judicial challenge.[20] Such a display of resistance is indicative of the barriers CCS commercialization long has faced. Those barriers persist today.

Indeed, the hotly contested debate over the appropriateness of EPA's proposed NSPS rules illuminates the essential issues informing the question of why CCS has not proceeded further down the road to commercialization. Continued reliance on coal-generated electricity undeniably will negatively impact the climate. At the same time, reliable electricity is a domestic necessity. As CCS technology is, in the view of both DOE and the EPA, proven and available, imposing an emissions standard that essentially requires CCS utilization is, quite arguably, nothing more than "taking commonsense action to limit carbon pollution from new power plants . . . spark[ing] the innovation we need to build the next generation of power plants, [and] helping grow a more sustainable clean energy economy."[21] For opponents of these proposed rules, however, EPA is conducting an economically unsound experiment with an unproven technology—an

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[18] 79 Fed. Reg. 1429.

[19] *Id.* at 1447.

[20] *See* Jean Chemick, *Whitfield Drops Bill Taking Aim at EPA Carbon Rules*, E&E NEWS PM, Jan. 9, 2014, http://www.eenews.net/eenewspm/2014/01/09/stories/1059992665; Jean Chemick, *Hill Republicans Weigh in Ahead of Supreme Court challenge over CO_2 Regs*, E&E DAILY, Dec. 19, 2013, www.eenews.net/eedaily/2013/12/19/stories/1059992108; *For Now, EPA Appears to Stave Off Legal, Political Attacks on Climate NSPS*, INSIDEEPA.COM, Dec. 10, 2013, http://environmentalnewsstand.com/Shared-Newsletter-Stories/Climate-Policy-Watch-Analysis/menu-id-1081.html; *EPA Faces Early Test on Power Plant GHG Rules, Rule Agenda Sparks Criticism of EPA*, INSIDEEPA.COM, Dec. 2, 2013, http://environmentalnewsstand.com/EPA-Daily-News/The-Week-Ahead/menu-id-992.html.

[21] U.S. Environmental Protection Agency, *News Release*: *EPA Proposes Carbon Pollution Standards for New Power Plants* (Sept. 20, 2103), http://yosemite.epa.gov/opa/admpress.nsf/0/da9640577ceacd9f85257beb006cb2b6!OpenDocument..

unfounded attempt, they assert, at forcing an immature and costly technology onto the electricity sector.[22] Therein lies the dilemma: At what point and based on what criteria is it fair to expect organic commercialization of CCS? In the absence of a policy mandate, will CCS surmount its impediments with enough rapidity that it can be utilized to mitigate climate change?[23]

A growing body of academic and policy literature has identified the impediments to CCS commercialization, and assessed why the technology has not been widely deployed.[24] The research completed in Phase I of this project both confirmed prior works' evaluation of the key impediments to CCS, and identified other barriers previously ignored. The Phase I research was notable because unlike much of the other CCS literature, which often has not been empirical nor has focused on public opinion surveys, the Phase I research sought to identify what members of the CCS community believed to be impeding CCS diffusion.

There is effectively universal agreement among CCS analysts and proponents that the lack of carbon pricing (or some other clear financial signal) is the threshold impediment to commercial-scale CCS deployment,[25] a view supported by our Phase I research. As we concluded there, "A financial incentive that will send an appropriately

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[22] Opponents contend that CCS is not a "pull me" technology, *i.e.* a technology that will be developed and implemented if use of the technology is mandated. For an brief explication of the position that CCS is not sufficiently developed in this way, *see, e.g.*, McGuireWoods, Legal Alert, *EPA's CO_2 NSPS for New Power Plants: A Controversial Rule About Nothing*, Oct. 9, 2013, http://www.mcguirewoods.com/Client-Resources/Alerts/2013/10/EPA-CO2-NSPS-for-New-Power-Plants.aspx.

[23] For a discussion of domestic technology policy tools that have fostered innovation, and the possible implications of those tools for climate change, *see* JOHN A. ALIC ET AL. U.S. TECHNOLOGY AND INNOVATION POLICIES, PEW CENTER ON GLOBAL CLIMATE CHANGE (2003).

[24] *See, e.g.*, Phase I Report; CCS TASK FORCE REPORT, *supra* note 7, at 28; DEPARTMENT OF ENGINEERING AND PUBLIC POLICY, CARNEGIE MELLON UNIVERSITY, CARBON CAPTURE AND SEQUESTRATION: FRAMING THE ISSUES FOR REGULATION, AN INTERIM REPORT FROM THE CCSREG PROJECT (2009); REPORT TO THE CHAIRMAN OF THE SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING, *supra* note 13; IRCG, *supra* note 7, at 18 (2008); IPCC *supra* note 7, at 3.

[25] *See supra* note 13.

strong signal is imperative if CCS is to be deployed on a commercial scale. Most likely, this should be a carbon price. . . . If CCS is to move to broad-scale use, governmental action on climate change, with a meaningful economic component, is not negotiable."[26]

Data from Phase I of this project corroborated another concern raised in the literature, that of liability. Indeed, because CCS seeks to mitigate atmospheric greenhouse gas emissions by storing CO_2 underground on a permanent basis, a variety of concerns long have been expressed about potential liability associated with CCS sites. Who will bear this liability? What happens when the business entity that created the site is no longer in business? How far might liability extend, particularly where an unexpected event occurs but the operator engaged in state-of-the-art site assessment before building? How long will liability attach, especially since a CCS-related event could occur years or decades after site closure? The Phase I survey confirmed that risks related to these types of liability questions are a key impediment to CCS deployment. As noted in the Phase I Report: "Regardless of how liability risks from CCS use are apportioned, these liabilities must be comprehensively addressed if CCS is to reach commercialization. This is particularly true for liability risks associated with long-term storage."[27]

On both of these points, the Phase I study was consistent with the existing literature on CCS barriers. However, that research also revealed at least two clear observations that were not found in prior studies. First, Phase I of this project diverged with the existing scholarly literature, in concluding that large CCS demonstration projects

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[26] *See* Phase I Report at 103.
[27] *Id.* at 104.

were not an essential predicate condition for CCS deployment.[28] Rather, the study found widespread agreement among experts in the CCS community that CCS technology was ready for use, and that governmental funding of commercial-scale demonstration was one of the lowest needs for policy support for CCS.[29] This finding was particularly noteworthy for two reasons: It diverged from common assertions in the literature that broadscale CCS use must wait for repeated commercial-scale demonstration, and it aligned with prior DOE and subsequent EPA views of CCS technological readiness. As summarized in the Phase I Report, "[D]emonstration of CCS technology may have more to do with investor confidence than engineering capacity and technological know-how."[30]

The final conclusion supported by the Phase I data also departed from assumptions about CCS impediments commonly found in the scholarly literature. Prior studies had not identified the lack of a comprehensive regulatory regime as a key barrier to commercial-scale CCS deployment. The Phase I study, however, clearly identified this as one of the four primary barriers to CCS implementation. This view emerged both in the survey questions where respondents were asked to rank CCS barriers and in the open-ended questions where respondents volunteered what they believed to be the chief impediments to CCS use. The Phase I research thus demonstrated that the existence of a comprehensive regulatory regime was viewed as essential by the CCS community for effective CCS diffusion and commercial deployment. [31] "This is thus one of the most

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[28] *But see, e.g.,* AN INTERIM REPORT FROM THE CCSREG PROJECT, *supra* note 23; CONGRESSIONAL POLICY BRIEF, *supra* note 13; REPORT TO THE CHAIRMAN OF THE SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING, *supra* note 13.

[29] *See* Phase I Report at 104-05.

[30] *See id.* at 105.

[31] *See id.* at 106-07. *But* see, *e.g.,* CCS TASK FORCE REPORT, *supra* note 7, at 10 ("Though early CCS projects can proceed under existing laws, there is limited experience at the Federal and State levels in applying the regulatory framework to CCS. Ongoing EPA efforts will clarify the existing regulatory framework by developing requirements tailored for CCS, which will reduce uncertainty for early projects

important messages of the survey results: The CCS community craves regulatory certainty, and the certainty that is most preferred is a soup-to-nuts regulatory regime. A hodgepodge, statute-by-statute approach is disfavored."[32]

With these four concerns in mind, we turn to a discussion of the regulatory approaches at hand for incenting CCS.

III. Promoting CCS Through Regulation

In the absence of effective policy incentives, CCS faces what seems to be a Catch-22-type set of impediments. CCS will almost certainly not advance in the absence of regulatory certainty.[33] However, regulators are loath to incent (or regulate) CCS use absent certainty that CCS is ready for prime time. Additionally, some means of creating a market for CCS is viewed as an essential element of advancing deployment, thus adding another regulatory challenge.[34] Finally, a prospective regulatory framework must be implementable and consistent with existing legal regimes and standards. In sum, fostering effective levels of CCS deployment requires fashioning a regulatory framework that meshes with existing laws and policies, promotes the adoption of CCS technology, supports the emergence of a CCS marketplace, and is economically viable. Each of those objectives is difficult. Together, particularly in the absence of stalwart political support for climate change mitigation, they pose a daunting challenge indeed.

Various strategies can be employed by regulators seeking to promote nascent technologies. However, while some scholarship has been careful to distinguish between

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and help to ensure safe and effective deployment. Experience gained from regulating and permitting the first five to ten CCS projects will further inform potential changes to existing requirements and the need for an enhanced regulatory framework for widespread CCS deployment.").

[32] *See* Phase I Report at 107.

[33] REPORT TO THE CHAIRMAN OF THE SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING, *supra* note 13, at 2 (2008); *see also* PEW CENTER ON GLOBAL CLIMATE CHANGE, CONGRESSIONAL POLICY BRIEF 7 (2008).

[34] FOLGER, *supra* note 13, at 25.

these different tools, law- and policy-makers often do not, at least in explicit terms. Federal courts, for instance, often have referred to different kinds of "technology forcing" regulation as a general body of policy, without necessarily parsing the different ways these regulations incent technological change.[35]

Distinguishing between different kinds of technology forcing regulation is important because divergent policies have distinctive advantages and disadvantages. Thus, the question of which policy to employ in any given circumstance is not one that can be lumped into a single inquiry of whether or not some catchall category of "technology forcing regulation" should be employed. Nor is it a question that should be asked in a vacuum of technology-specific evidence. Not all technology-forcing regulation is created equal, and every technology is on its own unique trajectory. Smart policy considers both these possibilities of difference.

The distinction among technology forcing regulations also is important for CCS, particularly because prior policy treatment of the technology has not zeroed in on this question. The history of CCS policy is dominated by governmental efforts to promote large-scale technology demonstration projects.[36] However, as the Phase I research confirms, the chief obstacles to CCS use are not related to technology demonstration, but rather, to CCS deployment. Thus, it appears that the core question about CCS policymaking should be which tools to use to promote the technology's diffusion—not whether the technology is ready for commercial use. The aim of Phase II of this research

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[35] *See, e.g., American Petroleum Institute v. EPA*, 706 F.3d 474 (D.C. Cir. 2013); *National Petrochemical & Refiners Ass'n v. EPA*, 287 F.3d 1130 (D.C. Cir. 2002); *NRDC v. EPA*, 655 F.2d 318 (D.C. Cir. 1981); *Sierra Club v. Costle*, 657 F.2d 298 (D.C. Cir. 1981).

[36] *See* Phase I Report at 6-7.

is to help reorient analysis toward this question, and to begin closing the gap on its assessment.

To this end, the remainder of this Section focuses on two issues: First, we distinguish between different kinds of technology forcing regulation, namely, between policies aimed at promoting technology innovation and demonstration and those that seek to promote technology diffusion. Second, we outline and analyze three different types of policies for promoting technology diffusion.

A. Technology-Forcing Regulation: Innovation and Demonstration versus Diffusion

Technology-forcing regulations can have multiple aims. Some technology-forcing regulations seek to spur innovation and demonstration, while others seek to promote technology diffusion. Given the range of outcomes sought by technology-forcing regulations, it is important to distinguish within the broad category of available policies when assessing whether a given regulatory tool will promote technology in the desired and most expeditious manner.

Regulators typically determine that technology-forcing regulation is necessary when there is a market failure. Market failures can occur in a number of different ways, and much of environmental, natural resources, and energy law is deployed in an attempt to correct these failures. With respect to environmental technologies, typically two market failures are at play. They are mirror images of each other. First, technology-forcing regulation often is suggested to correct negative externalities, such as pollution from energy consumption, the cost of which is not borne by the energy producer. This is the market failure at the core of climate change—the un-internalized cost of greenhouse gas emissions—and so it is central to the question of CCS. Second, technology-forcing regulation often is suggested on the grounds that there is a "free rider" problem in technology markets. Specifically, if a technology innovator or user cannot capture the full benefit of her efforts, technology will be under-innovated or under-deployed. For instance, in the context of CCS and absent any climate regulatory regime, a power plant owner that installs CCS technology would not capture the full benefit of that equipment, because the benefit of lower greenhouse gas emissions would instead be spread across society. Thus, technology-forcing regulation is used to address these market failures. It can solve both of them because, to the extent there is an un-internalized externality, use of the technology forces the internalization of those societal costs, and to the extent a technology is under-developed or -used, the regulation sends a market signal encouraging its greater employment.

While technology-forcing regulation can be thought of in these economic terms, it also can be viewed from the perspective of technology lifecycles. All technology-forcing regulations begin from the premise that regulatory intervention may be needed to help successfully shepherd a given technology through the innovation "valley of death."[37] The innovation valley of death is premised on the concept that there are six stages of technological innovation, and no technology is sustainable until it passes to the final stage. Those stages of development are: "(1) basic research and development, (2) advanced research and development, (3) demonstration, (4) pre-commercial use, (5) use in niche

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[37] Mary Jean Bürer & Rolf Wüstenhagen, *Which Renewable Energy Policy Is a Venture Capitalist's Best Friend?: Empirical Evidence from a Survey of International Cleantech Investors*, 37 ENERGY POLICY 4997, 4998 (2009); *see also* Michael Grubb, *Technology Innovation and Climate Change Policy: An Overview of Issues and Options*, 41 KEIO ECONOMIC STUDIES 103 (2005).

markets, and (6) full commercial utilization. The valley of death spans the middle three of these stages—demonstration, pre-commercial, and niche markets." [38]

Technology-forcing regulations can be categorized depending on which side of the "valley of death" they operate. As a broad group, technology-forcing policies seek to help emerging technologies progress from initial development to full-scale commercialization. The goal is to lend sufficient support for the technology at issue so that it can successfully navigate the economic and deployment challenges marking the transition from R&D to sustainable profitability.[39]

Scholarship accordingly divides technology-forcing policies into two classes: "technology push" or "market pull."[40] The distinction between the two tracks the technology life cycle, dividing roughly at the technology valley of death. Approaches that can be characterized as technology push regulations aim to promote invention, innovation, and demonstration. These policies want to help technologies become developed, and show they are viable. They are thus referred to as "technology push" policies because they attempt to propel—to push—technology out of the laboratory and toward the market. They try to augment technology supply. By contrast, market pull regulations seek to expand the utilization of technologies that have already been shown they are viable. That is, they aim to "pull" the technology through the valley of death and into the market,

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[38] Lincoln L. Davies, *Renewable Portfolio Standards and Feed-in Tariffs*, 32 UTAH ENVTL. L. REV. 311, 321 (2012); *see also* Bürer and Wüstenhagen, *supra* note 37, at 4998.

[39] Davies, *supra* note 38, at 321; *see also* Bürer and Wüstenhagen, *supra* note 37, at 4998; Allison S. Clements & Douglass D. Sims, *A Clean Energy Deployment Administration: The Right Policy for Emerging Renewable Technologies*, 31 ENERGY L.J. 397, 407-409 (2010); Michael Shellenberger et al., *Fast, Clean, & Cheap: Cutting Global Warming's Gordian Knot*, 2 HARV. L. & POL'Y REV. 93, 108-09 (2008).

[40] Market pull policies can be delineated further and broken down into quantity-based and price-based policy approaches. Bürer & Wüstenhagen, *supra* note 37, at 4999. The primary distinction is best summarized as follows: "Quantity-based regulation directly targets technology demand; it seeks to augment demand by, for instance, mandating the use of a technology. Price-based regulation seeks to influence quantity indirectly by lowering the cost of the desired technology or by raising the costs of those that compete with it." Davies, *supra* note 38, at 320.

where consumer appetites for the technology eventually will make the product commercially sustainable. They try to increase demand for technology. They can do so in a number of ways, including by reducing costs, enhancing the commercial appeal of the technology at issue, or maximizing on economies of scale or learning by doing.

It is significant that technology push and market pull policy measures target opposite ends of the valley of death. The distinction is not merely one of convenient nomenclature; rather, the labels identify the objective of each policy. Understanding the different stages of technology development reveals that different policies in fact have different objectives. Those deployed before commercial use aim to promote invention and innovation. Those used later in the technological lifecycle aim not at innovation, but rather, at commercialization and diffusion. Each type of policy, in short, serves a different purpose. As summarized by one set of authors:

> [P]olicies to promote low-carbon innovation can basically be divided into technology-push and market-pull policies. The basic idea of technology-push policies . . . is to increase the amount of technology "supply". The rationale for market-pull policies . . . on the other hand is to increase "demand" for new technologies and provide firms and consumers with economic incentives to apply them. There is a vivid debate among climate policy scientists and modelers as to which of the two approaches is more adequate to reach long-term mitigation targets . . . .[41]

In seeking to mitigate climate change, it is thus essential to evaluate which type of policy will most effectively and efficiently promote any given technology. Using a "technology push" policy on a well developed climate mitigation technology is likely to create a policy mismatch, just as would using a "market pull" policy on a nascent technological innovation. While a the value of a theoretical (and empirical) debate over what mix of policy tools will be best in the long run undoubtedly has much to commend

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[41] Bürer & Wüstenhagen, *supra* note 37, at 4998.

it, policymakers evaluating any given proposal must be careful to calibrate their policy choice to the technology in question.

This insight has clear implications for CCS. Over a decade ago, a report issued by the Pew Center on Global Climate Change noted: “Efforts to mitigate global climate change will require technological innovations deployed on a massive scale.”[42] The Pew Center contended that the level of innovation necessitated by climate change would require the United States to utilize technology-forcing policies that focus simultaneously on technology development, deployment, and diffusion.[43]

Against that broader assessment, this Report seeks to focus on one aspect of technology-forcing regulation germane to speeding commercialization of CCS. Phase I of this Project established that current CCS impediments are primarily related to deployment, rather than resulting from demonstration or innovation-related challenges. Consequently, one critical observation of both phases of this research is that policymakers would do well to focus on diffusion and deployment strategies when it comes to CCS. While many governmental efforts have centered on CCS demonstration— and a perceived lack of commercial-scale demonstration projects is a repeated refrain as a CCS obstacle in the literature—our findings in Phase I of this research do not bear that out as a key impediment to CCS use. Rather, each of the key barriers identified in Phase I related to technology deployment.

Accordingly, our Phase II work suggests that policy analyses of how to promote CCS should be reoriented away from “technology push” measures and toward “market

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[42] U.S. TECHNOLOGY AND INNOVATION POLICIES, *supra* note 23, at 5.
[43] *Id.*

pull" tools. The remainder of this Report's analysis takes up that question. It offers an initial assessment of regulatory solutions for impediments to CCS deployment, with a particular focus on technology-forcing regulations intended to speed technology diffusion.

B. Policies for Promoting Technology Diffusion

Effective technology diffusion policies depend upon achieving a balance between the rate of technology diffusion—and how best and most efficiently to accelerate that rate—and commercial economic realities. "The central feature of most discussions of technology diffusion is the apparently slow speed at which firms adopt new technologies."[44] Some empirical support exists for the benefits of using environmental regulations to induce accelerated technology adoption.[45] Regulatory schemes can effectively encourage technology adoption by repairing the temporal and financial schisms between the societal need for technology and associated investments in technology adoption.[46]

Policies aimed at technology diffusion may have a particularly important role to play in the electricity sector because technology adoption decisions are more sensitive to up-front costs than to longer-term operating expenses,[47] and the electricity sector is notoriously capital-cost-intensive. Therefore, most scholars agree that regulations that affect up-front costs are most likely to influence a company's technology adoption

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[44] P.A. Geroski, *Models of Technology Diffusion*, 29 RESEARCH POLICY 603, 604 (2000) (observing "the following times for half the population of potential users to adopt new technologies: by-product coke ovens, 15 years; centralized traffic control, 14 years; car retarders and continuous annealing, 13 years; industrial robots, 12 years; and diesel locomotives, 9 years").

[45] David E. Adelman & Kirsten H. Engel, *Reorienting State Climate Change Policies to Induce Technological Change*, 50 ARIZ. L. REV. 835, 856 (2008) (noting that examples include regulations under the Clean Air and Clean Water Acts, positive correlations between energy prices and adoption rates of energy efficient products, and Corporate Average Fuel Economy standards).

[46] *Id.* Adelman and Engel also explain that technology *innovation* is a different animal because companies must invest resources for long periods of time prior to the respective regulation having an effect.

[47] *Id.* (quoting Adam B. Jaffe et al., *Technological Change and the Environment*, *in* 1 HANDBOOK OF ENVIRONMENTAL ECONOMICS 461, 485 (Karl-Goran Maler & Jeffrey R. Vincent eds., 2003) (observing that optimization is very hard with the large uncertainties surrounding research and development outcomes).

decisions.[48] While there is general consensus in the literature that regulations addressing up-front costs are more likely to induce technology adoption, debate continues as to the relative effectiveness of these regulations.[49]

Thus, with respect to industry adoption of CCS specifically, regulators must choose between traditional and market-based regulation. Traditional regulation includes performance requirements and design standards. Market-based mechanisms include a carbon tax, cap and trade, and subsidies. While these policies bear common features, each has its own comparative advantages and disadvantages. Consequently, some policies inevitably will be more conducive to accelerated and lasting CCS adoption than others.

Historically, regulators have used performance standards and design standards (also known as work practice or specification standards) to regulate toxic substances such as NO_x and SO_x. Scholars often refer to such regulations as "command and control" regulations, although recent scholarship more frequently uses the "traditional regulation" terminology.

Traditional regulations have many potential advantages. They are easy to promulgate, enforceable and predictable, even-handed in their application to various

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[48] *Id.*

[49] Some scholars argue effectiveness in the following order: auctioned permits, taxes and subsidies, free permits, and emission standards. *See* Paul B. Downing & Lawrence J. White, *Innovation in Pollution Control*, JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT 13, 18-29 (1986); Chulho Jung, Kerry Krutilla & Roy Boyd, *Incentives for Advanced Pollution Abatement Technology at the Industry Level: An Evaluation of Policy Alternatives*, 30 J. OF ENVTL. ECON. & MGMT. 95, 108 (1996); David A. Maleug, *Emission Credit Trading and the Incentive to Adopt New Pollution Abatement Technology,* JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT 18, 52-57 (1989); Scott R.Milliman & Raymond Prince, *Firms Incentives to Promote Technological Change in Pollution* Control, JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT 17, 247-65 (1989). Other scholars assert that taxes provide stronger incentives than permits, auctioned and free permits offer identical incentives, and standards may give stronger incentives than permits. *See* Till Requate, *Incentives to Adopt New Technologies Under Different Pollution-Control Policies*, INTERNATIONAL TAX AND PUBLIC FINANCE 2, 295-317 (1995); Till Requate & Wolfram Unold, *Environmental Policy Incentives to Adopt Advanced Abatement Technologies – Will the True Ranking Please Stand Up?*, European Economic Review 27, 235-47 (2005).

regulated entities, and adaptable to additional refinements using other, very different types of regulatory tools.[50] But it can take years to promulgate a single standard and, once promulgated, standards can be challenged in court and sometimes remanded by the court for further consideration at the agency level. Despite this potentially drawn-out enactment process, traditional regulations still significantly outpace the rate of promulgation of other regulatory options, generally by a factor ranging from three to ten times.[51]

Market-based regulations take a different tack. Rather than choosing a specific outcome and implementing it through a technology- or performance-based requirement, market-based measures identify an ultimate goal, establish a way to achieve this goal, and then attempt to harness market operations to accomplish the goal.

In theory, market-based regulations should surpass traditional regulatory tools on both efficacy and efficiency because, if designed well, they should reach the same end result but do so at a lower cost. The primary challenge for market-based regulations, then, is design. In order to be effective, a market-based regime must set a market threshold or "price" that is neither too high nor too low. If a market-based regulation misreads or misprices the market, market operations will not incent the technological innovations in the manner intended by the regulation. If the market-based tool can get the price right, however, they often are very effective. This is the case, for instance, with many feed-in tariff regimes in Europe, which have rapidly and

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[50] Wendy E. Wagner, *The Triumph of Technology-Based Standards*, 2000 U. ILL. L. REV. 83, 88-90 (2000).
[51] *Id.*

effectively driven installation of renewable energy installations at a rate much more quickly than many observers anticipated.[52]

With this outline of the possible comparative advantages and disadvantages of different technology diffusion policies in mind, an overview of available regulatory models for promoting CCS diffusion follows. The overview tracks the policy options already discussed. Each broad category of policy includes a brief case study highlighting its possible benefits and limits.

1. **Technology-Based Design Standards**

In contrast to a performance standard (discussed below), a technology-based design standard requires use of a particular technology or technique.[53] A regulation can do this in a number of ways. It might mandate the technology specifically. It might ban a technology with the knowledge that the ban will effectively require the use of an alternate, or heavily promote the alternate's use. Or it might adopt a regulatory standard that is a de facto mandate for the technology.

While technology-based design standards offer certain advantages—implementation of a particular technology, regulatory specificity and certainty, and a clear path to compliance for regulated entities—regulators must be wary of the risk to

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[52] *See, e.g.*, Toby Couture & Yves Gagnon, *An Analysis of Feed-in Tariff Remuneration Models: Implications for Renewable Energy Investment*, 38 ENERGY POLICY 955 (2010); C.G. Dong, *Feed-in Tariff vs. Renewable Portfolio Standard: An Empirical Test of Their Relative Effectiveness in Promoting Wind Capacity Development*, 42 ENERGY POLICY 476 (2012); Reinhard Haas et al., *A Historical Review of Promotion Strategies for Electricity from Renewable Energy Sources in EU Countries,* 15 RENEWABLE AND SUSTAINABLE ENERGY REV., 1003, 1026 (2011); Marc Ringel, *Fostering the Use of Renewable Energies in the European Union: The Race Between Feed-in Tariffs and Green Certificates*, 31 RENEWABLE ENERGY 1 (2006).

[53] A technology ban, such as the PCE prohibition case study included in this sub-section, is effectively a mandate in reverse.

mandate stale or out-of-date technologies.[54] Legal scholars often decry the inherent inefficiencies of technology-based design standards:

> Probably the most important, and the most generally accepted, lesson from previous attempts to induce technological change is that the government should set the performance goals, but should avoid, as much as possible, picking which specific technologies should be developed to achieve those goals. The historical record is that governments (along with everyone else) have a relatively poor record in picking which future technologies will best succeed in achieving a particular objective.[55]

Thus, while technology-based standards can be effective, they also risk massive inefficiencies: both if the regulator chooses the wrong (or less efficient) technology at the outset, and in the long-run if the chosen technology otherwise could have been outpaced by innovation that instead was stunted by the regulation.

Indeed, companies may miss otherwise achievable technological breakthroughs as they keep their noses to the grindstone, dutifully employing the mandated technology. Such innovation inhibition harms the individual companies' bottom-lines, broader societal progress, as well as efficacious protection of the environment.[56] If the ultimate policy objective is to remedy environmental externalities through technology use, a policy that locks in one technology at the expense of another that might have performed better or more efficiently cannot be considered to be truly successful.

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[54] David Gerard & Lester B. Lave, *Implementing Technology-forcing Policies: The 1970 Clean Air Act Amendments and the Introduction of Advanced Automotive Emissions Controls in the United States*, TECHNOLOGICAL FORECASTING & SOCIAL CHANGE 72, 772 (2005).

[55] Gary E. Marchant, *Sustainable Energy Technologies: Ten Lessons from the History of Technology Regulation*, 18 WIDENER L.J. 831, 836 (2009).

[56] For the opposing view, see Wendy E. Wagner, *supra* note 50, at 108-109 (2000) ("[Even amidst technology-based standards,] there are competitive advantages for the sources to stay ahead of the compliance curve and pioneer the development of new and improved control technologies. For example, industries have incentives to develop technologies that meet existing requirements more inexpensively than the currently available technology. . . . [Regardless,] even if technology-based standards do dampen [innovation] incentives, there are a number of ways that the incentives can be restored with only slight adjustments to the standards or the regulatory program more generally.").

There are many examples of technology-based design standards, including some of the most visible regulatory efforts in the history of environmental law. For instance, Congress' decision in the early 1970s to authorize EPA to phase out lead from gasoline was adopted in large part to facilitate the use of catalytic converters, which reduced other air pollutants.[57] It was well known, in short, that the gasoline design standards EPA implemented would promote catalytic converter use, which could not function with lead gasoline.[58] Likewise, Congress' adoption of a two percent oxygenate requirement in the 1990 Clean Air Act (CAA) Amendments widely was known as a clear effort to promote the use of either ethanol or methyl tertiary-butyl ether (MTBE) in gasoline; Congress' choice of the two percent number was tied heavily to the idea that either additive could be used to meet the reformulation requirement.[59]

These two examples underscore the double-edged nature of technology design standards. Whereas the phase-out of lead is widely considered a success story, the end result of the 1990 oxygenate requirement was much more mixed. Oxygenated fuel undoubtedly decreased air pollution, but MTBE exacerbated groundwater contamination from leaking underground storage tanks in a way the government never anticipated.[60] Thus, while technology-based design standards have the benefit of higher certainty in achieving the desired result, they also carry the risks of cost, technology lock-in, and, as shown by the example of MTBE, unintended consequences.

A more recent example of technology-based design standards further highlights this tool's strengths and weaknesses, and the considerations essential for implementing an

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[57] *See Ethyl Corp. v. EPA*, 541 F.2d 1 (D.C. Cir. 1976) (*en banc*), *cert. denied*, 426 U.S. 941 (1976).

[58] C. Boyden Gray & Andrew R. Varoce, *Octane, Clean Air, and Renewable Fuels: A Modest Step Toward Energy Independence*, 10 TEX. REV. L. & POL. 9 (2005).

[59] *See Oxygenated Fuels Ass'n, Inc. v. Davis,* 331 F3d 665 (9th Cir. 2003).

[60] *Id.; see also Oxygenated Fuels Ass'n, Inc. v. Pataki,* 304 F.Supp.2d 337 (N.D.N.Y. 2002).

effective technology design rule. In 1998, the South Coast Air Quality Management District ("AQMD"), the regulatory agency with jurisdiction over air emissions in the Los Angeles region, began an effort to eliminate the use of a specific chemical, perchloroethylene (PCE),[61] in the dry cleaning industry. Specifically, AQMD amended its regulations to disallow the use of PCE by dry cleaners after 2020, and to provide limited financial incentives to "first mover" dry cleaning operations who adopted non-PCE, or wet cleaning, equipment.[62]

Those regulatory efforts, and their impact on technology diffusion, were the subject of a 2004 study conducted by Timothy F. Malloy and Peter Sinsheimer. Malloy and Sinsheimer conducted a survey of 202 dry cleaners located in the greater Los Angeles region, and a series of semi-structured interviews of equipment vendors, professional cleaners, and government officials, to determine the effects of these amendments on technology diffusion.

In their analysis, Malloy and Sinsheimer argue that both the structure and implementation of a regulation determine the regulation's influence on technology diffusion.[63] Specifically, Malloy and Sinsheimer divided regulation structure into two basic types: performance standards and design standards.[64] Performance standards allow the regulated entity to choose a technology to meet an emissions limit, while design standards require the regulatee to use a certain technology. Because a design standard

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[61] Perchloroethylene can also be known as tetrachloroethylene.

[62] Timothy F. Malloy & Peter Sinsheimer, *Innovation, Regulation and the Selection Environment*, 57 RUTGERS L. REV. 183, 187 (2004).

[63] *Id*. at 198.

[64] *Id.* at 196-97.

effectively locks in a technology, it is likely to lead to broader diffusion of the mandated technology, although it also risks impairing diffusion of alternative technologies.[65]

With respect to implementation, Malloy and Sinsheimer argue that, "ostensibly flexible performance standards can be implemented conservatively, and thus transformed into something akin to design standards."[66] They note that critics of traditional regulation contend that officials implementing New Source Review (NSR) permitting programs prefer established technologies to new technologies, and therefore are reluctant to choose new technologies as part of the permitting process.[67] Additionally, the intensity of enforcement can affect the strength of the regulatory incentives created for adopting innovative technologies.[68]

With respect to their dry cleaning study, Malloy and Sinsheimer reached three general conclusions. First, absent some form of intervention, diffusion was likely to be slow because of: (1) systemic failures within the agency leading to poor communication of the benefits of wet cleaning technology; and (2) wet cleaning technologies' minor economic benefits.[69] Second, stand-alone government-initiated financial incentives and information strategies were unlikely to successfully increase the rate of diffusion. Third, a design standard directly prohibiting PCE dry cleaning, phased in over time, was likely to lead to a timelier, less costly shift to wet cleaning and other alternative technologies than a performance standard or a tax.[70] Ultimately, however, Malloy and Sinsheimer found that the selection environment, "namely, information flow, cost and benefits of the

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[65] *Id.* at 197. Malloy and Sinsheimer argue that while "a design standard can impair the diffusion of alternative pollution *control* technologies, it could still play a meaningful role in the diffusion of innovative process changes that prevent rather than control pollution." *Id.*

[66] *Id.* at 198.

[67] *Id.*

[68] *Id.*

[69] *Id.* at 188.

[70] *Id.* at 188, 224.

innovations, and regulations"[71] will vary across industries, and assessing and altering those selection environments is critical to the success of policies seeking to encourage innovation.

AQMD's PCE prohibition efforts, along with those of other California air quality management districts,[72] laid the groundwork for a statewide PCE ban. AQMD was the first entity to implement a complete phaseout of PCE.[73] In 2007, the State of California's Air Resources Board enacted amendments intended to similarly phase out the use of PCE dry cleaning machines and related equipment at a statewide level by January 1, 2023. Pursuant to those amendments California banned the installation of new PCE dry cleaning equipment as of January 1, 2008, required that older (15 years or more) PCE machines be taken out of operation as of January 1, 2010, and prohibited the use of any PCE machines as of January 1, 2023.[74] The prohibition's success rate can be best evaluated in terms of the decreasing number of PCE machines in use in California. In 1991, approximately 5,310 PCE machines were operational, dropping to 4,670 in 2003,[75] and dropping further to fewer than 2,000 by 2011.[76]

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[71] *Id*. at 224.
[72] The Bay Area Air Quality Management District, Mojave Desert Air Quality Management District, and Santa Barbara County Air Pollution Control District also participated in the PCE prohibition effort. California Environmental Protection Agency, Air Resources Board, Stationary Source Divisions: Emissions Assessment Branch, *California Dry Cleaning Industry Technical Assessment* (Feb. 2006).
[73] South Coast Air Quality Management District, *To Reduce Cancer Risks to Residents, AQMD Adopts Phase-Out of Toxic Chemical at Dry Cleaners*, Dec. 6, 2002, http://www.aqmd.gov/news1/2002/perc_adopt.htm.
[74] California Environmental Protection Agency, Air Resources Board, *Dry Cleaning Program*, http://www.arb.ca.gov/toxics/dryclean/dryclean.htm; *see also* California Environmental Protection Agency, Air Resources Board, *Fact Sheet: Amended Dry Cleaning ATCM Requirements*, March 2007, http://www.arb.ca.gov/toxics/dryclean/factsheetmarch2007.pdf.
[75] *California Dry Cleaning Industry Technical Assessment, supra* note 74, at 1-2.
[76] National Resources Defense Council, *EPA Okays California's PERC Ban*, Aug. 11, 2011, http://www.nrdc.org/living/healthreports/epa-oks-californias-perc-ban.asp.

2. Technology-Based Performance Standards

In a technology-based performance standard (sometimes referred to as an engineering standard), EPA converts the pollution reduction capabilities of a selected technology to numerical effluent or emission limits for each pollutant of concern.[77] The conversion of pollution reduction capabilities to a numerical value can be quite controversial, as it requires making assumptions about average industry pollution loads and how well the selected technology reduces pollution.[78] EPA must familiarize itself with industry's capabilities, the variety of pollution control equipment available, and how this equipment actually works when employed in the field.[79] Despite these difficulties, technology performance standards are often hailed as superior to technology design rules because they offer the regulated entity more flexibility for compliance. Thus, firms may be able to comply at a lower cost and, in theory, a technology performance standard should avoid the risk of technology lock-in that a design standard presents. As Professor Noah Sachs has observed, "Performance standards allow for design flexibility and promote manufacturer innovation to meet the target, without locking in any particular technological approach."[80]

Technology-based performance standards also have a number of other benefits. They predict emissions reductions more dependably than most market-based measures, like a cap and trade program or a carbon tax. Under a performance standard, a regulated entity cannot choose to pay additional monies in exchange for releasing more emissions.

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[77] Malloy & Sinsheimer, *supra* note 62, at 224.

[78] *Id.*; DAVID M. DRIESEN & ROBERT W. ADLER, ENVIRONMENTAL LAW, A CONCEPTUAL AND PRAGMATIC APPROACH 305 (2007).

[79] *Id.*

[80] Noah Sachs, *Can We Regulate Our Way to Energy Efficiency? Product Standards as Climate Policy*, 65 VAND. L. REV. 1631 (2012).

Rather, they must simply meet the standard. This is different from market-based measures such as a carbon tax, where the firm can continue to use its existing equipment but simply pay more in the form of a tax to do so. Moreover, technology performance standards have a different applicable scope than many market-based measures. Whereas a cap and trade program ensures emissions reductions on an industry-wide basis, performance standards ensure emissions reductions on a plant-by-plant basis. Hence, performance standards provide dependable emissions reductions and facilitate meaningful planning for the future.

Despite all of its virtues, technology-based performance standards do not ensure implementation of a given technology. And, like a design standard, they present some risk of retarding innovation.[81] Some scholars argue that because EPA converts the pollution reduction capabilities of a given technology (*e.g.*, "Technology A") to come up with the standard, that industry will likely use Technology A to comply with the standard, even if Technologies B, C, and D are available to satisfy the emissions limit—and even if a firm might well innovate Technology E to meet the limit more effectively or cost efficiently. Additionally, pollution permits may explicitly reference Technology A. While this theory may come to fruition in some cases, the multitude of other factors at play, including varying costs of varying technology, arguably diminishes assurances that industry will implement the technology EPA relied on in making the standard, and many

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[81] Richard Stewart, *Regulation, Innovation, and Administrative Law: A Conceptual Framework*, 69 CAL. L. REV. 1256, 1268-69 (1981) (arguing engineering standards give industry a "strong incentive [] to adopt the particular technology underlying the standard because its use will readily persuade regulators of compliance); *see also* DAVID M. DRIESEN, THE ECONOMIC DYNAMICS OF ENVIRONMENTAL LAW 52 (2003) (arguing that Stewart does not explain why the persuasiveness incentive outweighs the countervailing economic incentive to realize savings through an effective and cheaper innovation).

studies point to the flexibility of technology performance standards as their key advantage, as noted above.[82]

Perhaps the most well known case study for development and application of performance standards is EPA's regulation of tailpipe emissions. In 1970, under the CAA, a form of traditional regulation, a technology-based performance standard, was utilized to induce industry adoption of catalytic converters and three-way catalysts. The CAA mandated 90 percent reductions in tailpipe emissions over a four-to five-year period, and EPA was instructed to implement the necessary standards. Regulators knew industry could not meet the standard without catalytic converters or three-way catalysts.[83] Accordingly, while the 90 percent reduction was technically a performance standard, some commentators have argued that it was actually a de facto design standard.[84]

Information asymmetries influenced implementation of the tailpipe emissions regulations. Industry, due to superior knowledge regarding the technologies' reduction capabilities, convinced Congress, in April 1973, to delay the 90 percent requirements by one year.[85] Following Congress' postponement of the requirements, EPA promulgated interim standards that required 50 percent reductions. Finally, in 1975, constant, credible

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[82] *See, e.g.,* Elizabeth G. Geltman & Andrew E. Skroback, *Reinventing the EPA to Conform with the New American Environmentality*, 23 COLUM. J. ENVTL. L. 1 (1998); Brian C. Murray & Heather Hosterman, *Climate Change, Cap-and-Trade and the Outlook for U.S. Policy*, 34 N.C. J. INT'L L. & COM. REG. 699 (2009).

[83] IMPLEMENTING TECHNOLOGY-FORCING POLICIES: THE 1970 CLEAN AIR ACT AMENDMENTS AND THE INTRODUCTION OF ADVANCED AUTOMOTIVE EMISSIONS CONTROLS IN THE UNITED STATES 763, 768, 772 (noting "[i]n fact, the staff found that catalytic converters had such enormous benefits at such modest costs that it was not going to be practical to reduce emissions by 90 percent and beyond without catalysts).

[84] A de facto design standard is a standard that on its face requires only a certain level of reduction, but in reality forces industry to employ a certain technology as only that technology will achieve the required reduction.

[85] IMPLEMENTING TECHNOLOGY-FORCING POLICIES: THE 1970 CLEAN AIR ACT AMENDMENTS AND THE INTRODUCTION OF ADVANCED AUTOMOTIVE EMISSIONS CONTROLS IN THE UNITED STATES, *supra* note 83, at 772 (noting that "everyone understood that the goal could not be reached with state-of-the-art technology, but the debate was not over the 90 percent cut. It was over what could be done if the automobile industry could not meet the standard. Muskie's theory was that a bureaucrat would always extend the deadline, so he wanted Congress to make the decision.")

regulatory pressure erased the information asymmetry and forced the adoption of catalytic converters by Ford and General Motors.[86]

Unquestionably, the technology-based performance standard successfully induced industry adoption of catalytic converters. By 1975, more than 80 percent of new cars were equipped with catalytic converters. The standard pushed development and adoption of catalytic converters over three-way-catalysts because catalytic converters were an existing but unproven technology, whereas three-way-catalysts were an entirely new process.[87]

EPA's implementation of this performance standard thus shows both the advantages of this type of technology-forcing regulation and its limits. The agency's rule was effective at achieving its goal—pollution reduction—and at disseminating the technology—some form of catalyst. However, despite the agency's effort to ensure that industry would have flexibility in meeting the requirement, the performance standard effectively became a design rule. Because it left polluters only one realistic option to meet the standard, namely to employ one of the two desired technologies, one might argue that this tool, which clearly was a performance standard in theory, was actually a design requirement in practice.

3. Market-Based Regulatory Mechanisms

As noted earlier, market-based mechanisms take a different approach than traditional regulatory devices. Rather than specifying a technology design requirement or a performance based standard, market-based regulations define an achievable goal, and then look to the market to effect the most economically efficient means of achieving

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[86] *Id.* at 770.
[87] *Id.* at 775; Adelman & Engel*, supra* note 45, at 849.

that goal. Market-based policies thus are hailed for achieving the same overall environmental result as traditional regulations but at a lower cost. Market-based mechanisms also can provide incentives for continuous environmental improvement. Unlike traditional regulation, market-based mechanisms can encourage industry to continually lower pollution levels by offering a monetary incentive for each reduction, rather than mandating that polluters curb emissions to a certain level.

The caveat about design, however, is critical. No policy works well absent careful design, and market mechanisms often are criticized for poor design, including excessive loopholes or setting too low of initial thresholds.[88] Indeed, it is a common charge that market-based regimes set thresholds too low, and thus, end up being ineffective because the market "price" for, say, emissions trading certificates, is much lower than it should be. When this happens, the incentives for technological change the market is supposed to create do not register with regulated entities in a way that encourages use of the technologies policymakers seek to promote. For instance, the price of greenhouse gas certificates has lagged significantly enough in many markets that these policies are under criticism as being too weak to promote technological change toward a cleaner energy production system.[89]

With respect to climate change, potential market-based regulations include a carbon tax, a cap and trade system, and subsidies. Each might be used to promote CCS.

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[88] Robert N. Stavins & Bradley W. Whitehead, *The Next Generation of Market-Based Environmental Policies: Discussion Paper 97-10*, *Prepared for Environmental Reform: The Next Generation Project*, (Daniel Esty & Marian Chertow, eds. Yale Center for Environmental Law and Policy) 1, 18-28 (Nov. 1996).

[89] *See, e.g.*, Alexander Jung, *Hot Air: The EU's Emissions Trading System Isn't Working*, Der Spiegel Feb. 15, 2012, http://www.spiegel.de/international/business/hot-air-the-eu-s-emissions-trading-system-isn-t-working-a-815225.html.

a. Carbon Tax

A carbon tax is a price-based mechanism for reducing carbon emissions. Under a carbon tax regime, a company pays the government a specified sum of money for every ton of carbon it emits. The tax can either be uniform with respect to every additional ton emitted or it may increase on subsequent emissions as an added deterrence. In order for a tax to be effective, it must have several characteristics. "First, the tax must apply to activities of firms that already comply with all applicable emissions limitations, or that have no applicable limitations. Second, the tax must exceed the marginal costs of making additional reductions. A tax that lacks these features creates insufficient incentives to effectively reduce emissions below current levels."[90]

Among the benefits of a carbon tax is that it effectively alerts industry to the actual price associated with CO_2 emissions, at least insofar as the policymaking process can accurately estimate those costs and incorporate them into law. Consequently, a carbon tax directly passes energy decisionmaking on to individual companies, which must in turn evaluate whether rectifying emissions would be more advantageous, either economically or otherwise, than paying the associated tax. For this reason, many economists assert that a carbon tax would be the most efficient (*i.e.*, cost effective) method for reducing greenhouse gas emissions.

On the other hand, a carbon tax relies heavily on the political process to ensure that the necessary amount of greenhouse gas reductions will be achieved. Moreover, a carbon tax does not guarantee reductions in the quantity of CO_2 emissions because companies can simply opt to pay the tax rather than employ CCS or another emissions control device.

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[90] *Id.* at 339-40.

Another quandary is how to spend carbon tax revenues. Presumably, the increased tax revenue could be utilized for purposes of ameliorating the deleterious effects of CO_2 emissions. However, there is no guarantee that any given Congress might prescribe that result. Moreover, even if that kind of requirement were built into the tax, use of a carbon tax would not necessarily ensure industry use of CCS—or any other technology, for that matter. Rather, a tax incentivizes *pollution reduction* in whatever way industry sees best fit to achieve them, not necessarily any certain kind of *technology adoption*.[91]

In any case, beyond the consideration of granting industry an opportunity to evade acting on the priority of reducing emissions, a carbon tax is a virtual non-starter politically. Partially due to social aversion to taxes as a general prospect, and partially due to partisan divides, enacting an additional tax long has faced stiff opposition in the United States—and is likely to continue encountering the same kind of resistance going forward.

b. Cap and Trade

A cap and trade system is a quantity-based mechanism in which the regulator caps yearly emissions at a certain level. The regulator then determines which industries should be subject to the cap and either awards or auctions (or both) permits to entities within the regulated industry.[92] Each permit is worth a certain number of units of emissions, and the total number of permits dispensed in one year cannot exceed the cap. Then, because the cost of cutting emissions is not the same for every regulated entity

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[91] Cost is particularly relevant when assessing methods of incenting CCS deployment in the electricity sector, as CCS is on the more expensive end of the available climate mitigation options. *See, e.g.*, DEPLOYMENT OF CLIMATE CHANGE MITIGATING TECHNOLOGIES IN THE ELECTRICITY (2008).

[92] Nadia Zakir, *Responding to Climate Change Through Market Forces*, 16 AUG BUS. L. TODAY 19 (2007).

within the industry, an entity with low-compliance costs can sell its permits to an entity with high-compliance costs. In this way, both entities realize an economically favorable outcome because the low-compliance cost entity makes money from the sale and the high-compliance cost entity saves money by not paying the penalty.

Unlike a carbon tax, a cap and trade system predicts emissions reductions to a comparatively greater degree of certainty. While a cap and trade system cannot guarantee company-specific reduction levels, it can predict industry-wide reductions. It is true that entities can choose to pay a hefty fine rather than keep emissions below the mandated level. However, entities are unlikely to do this because it would be economically detrimental, particularly given the option to buy permits from another entity. Prediction of industry-wide reduction levels thus helps future planning and provides regulators social capital in support of the cap. Additionally, a cap and trade system encourages companies to innovate, because if a company finds a way to emit less carbon, it stands to make money through the sale of the corresponding permits due to its technological innovation offsets.

However, cap and trade systems, like a carbon tax, rely heavily on accurate policy design. Just as if a carbon tax is not set at the right level, if a cap is set too low, or if too many permits are awarded, a cap and trade system will result in less pollution reductions than traditional regulation. This might be the result of the political process, which has been a common criticism of the acid rain cap and trade program under the Clean Air Act. Many observers have asserted that overallocation of permits to grandfathered facilities resulted in underperformance of the program.[93] Cap and trade programs also can prove less effective in the event of an information asymmetry. Information asymmetries can result when industry knows more than the regulator about a technology's realistic ability to curb emissions.[94] "If firms argue that meeting a standard is impossible, and regulators have no foundation to contradict them, it is unlikely that regulatory pressure will persuade the firms to [adopt a technology aimed at meeting the defunct standard]."[95] Regulators can avoid this outcome by erasing the information asymmetry with respect to a particular technology or by setting less ambitious standards to begin with.[96]

c. Subsidies

A subsidy is any government-directed intervention that decreases the cost of producing a specific good or service, or increases the price which otherwise would be charged for that good or service.[97] Subsidies alter market risks, market rewards, and costs in ways that favor certain activities or groups.[98] Subsidies are the mirror image of a tax. Rather than making an activity (*e.g.*, polluting) more expensive, they make a different activity (*e.g.*, producing electricity with less pollution) less expensive. Thus, at least in theory, a properly set subsidy should have the same advantages and disadvantages of a

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[93] *See, e.g.,* Byron Swift, *How Environmental Laws Work: An Analysis of the Utility Sector's Response to Regulation of the Nitrogen Oxides and Sulfur Dioxide Under the Clean Air Act*, 14 TUL. ENVTL. L.J. 309 (2001).

[94] Gerard & Lave, *supra* note 54, stating "because firms often have greater information about their own technological capabilities than regulators, they (firms) might be able to exploit this information asymmetry by hiding their true innovative capabilities, under investing in R&D, and claiming that the standards cannot be met."

[95] *Id.*; *see also* Jay P. Kesan & Rajiv C. Shah, *Shaping Code*, 18 HARV. J.L. & TECH. 319, 335-36 (2005) ("The government must closely interact with firms to obtain information on their capabilities; these firms, however, have an incentive to withhold and mislead the government in order to ensure that technology-forcing standards are lax and easily met rather than optimized to address societal concerns.

[96] *Id.*

[97] ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, SUBSIDIES AND ENVIRONMENT; EXPLORING THE LINKAGES 7, 8 (1996).

[98] DAVID MALIN ROODMAN, PAYING THE PIPER: SUBSIDIES, POLITICS, AND THE ENVIRONMENT 12 (Jane A. Peterson ed., Worldwatch Institute 1996).

tax. Most commonly, subsidies are direct government payments that help hold down prices for consumers or prop them up for producers.[99]

Subsidies often are advocated for as stimulating the economy by cutting taxes and launching job programs.[100] Additionally, from a political perspective, some forms of subsidies are easy to pass because they are seen as a way government can support under-produced goods needed by society rather than as a top-down penalty. However, unless set sufficiently high, subsidies may be less likely to compel industry behavior than strict regulation with the risk of penalties, because a company that chooses to forego receiving a subsidy does not receive the same kind of stigma one that fails to comply with the law might. Moreover, subsidies bear a distinct disadvantage when compared to taxes. Whereas a tax generates revenue, a subsidy drains it from the government coffers. Thus, subsidies often find themselves in the crosshairs of policymakers looking to cut costs, particularly in times of economic downturn. This risk means that a subsidy may not be as stable as other types of technology-forcing policies.

Indeed, the overall effectiveness of subsidies is somewhat in question. A 1996 German study by the Organization for Economic Cooperation and Development found that firms typically take advantage of subsidies only when other regulations require the firms to undertake the expenditures.[101] However, another study, published in 2008, found that introducing subsidies generates a positive effect by reducing ambiguity, facilitating decisionmaking, and inducing decisionmakers to adopt more expensive technologies.[102]

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[99] *Id.*
[100] *Id.* at 11.
[101] ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, ECONOMIC INSTRUMENTS FOR ENVIRONMENTAL PROTECTION (1989).
[102] Rob Aalbers et al., *Technology Adoption Subsidies: An Experiment with Managers,* 31 ENERGY ECONOMICS 431-42 (2009).

Jung et al. likewise find subsidies effective, but place them somewhere in the middle of the pack in terms of different policy options. They concluded that auctioned permits provide the most incentive to adopt new abatement technology, issued permits provide the least incentive, and emissions taxes and subsidies fall in the middle.[103]

d. A Case Study: SO_2 and NO_x Emissions

EPA's efforts in the 1990s to reduce SO_2 and NO_x emissions offers a real world case study of a market-based regulatory mechanism, in this case, cap and trade. EPA utilized an industry-wide mass standard under Title IV of the CAA, known as an emissions cap, to reduce SO_2 and NO_x emissions.[104] This market-based cap and trade regime often is cited as a prime example for moving policy away from traditional regulation and toward market-based measures. To implement the cap, allowances equivalent to a ton of SO_2 were assigned to affected generating units based on historical generation rates. Each new unit had to buy all of its necessary allowances. Implementing scrubbers, a proven technology, was one way affected units could meet the cap.[105]

Initially, scrubbers thrived under Title IV and its emissions cap. In fact, due to low compliance costs, scrubbers accounted for 3.5 million tons of SO_2 emissions reductions.[106] However, due to low low-sulfur coal prices in the early 1990s, many firms canceled scrubber contracts, because compliance costs using low-sulfur coal dipped below the costs associated with installing scrubbers.[107]

EPA's experience with SO_2 and NO_x regulation under Title IV of the CAA thus demonstrates both the up- and downsides of relying on market-based regimes to incent

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[103] Jung et al*.,* *supra* note 49, at 108.
[104] Swift, *supra* note 93, at 314.
[105] *Id.* at 316-21.
[106] *Id.* at 330-34.
[107] *Id*. at 335-38.

technological change. On the one hand, the policy effectively encouraged the adoption of scrubbers early on, in part because of good policy design. On the other, as implementation of the program matured, firms moved away from scrubber installation and chose a different compliance alternative: using a different kind of coal. Indeed, market-based programs specifically contemplate that regulated entities will change the way they comply over time by choosing more cost-effective options, rather than adhering to a single type of technology choice.

The pollution trading regimes implemented under the CAA thus make clear the challenges of relying on market-based systems to induce technology adoption. Market-based systems yield potentially unreliable technology diffusion results, as they are by design vulnerable to emerging cost-effective alternative technologies. Hence, in the SO_2 and NO_x case study, once low-sulfur coal became more cost-efficient, industry installation of scrubbers declined.

IV. Technology Diffusion Policy and CCS

Understanding the different types of policies that can be used to promote technology diffusion establishes a useful frame for analyzing how best to encourage commercial-scale CCS deployment. When this analytical framework is overlaid against a reliable inventory of the hurdles to broadscale deployment CCS faces, a roadmap for promoting the technology should emerge.

This Section seeks to outline the initial contours of that roadmap. It does so by applying the analytical framework of technology diffusion policies detailed above against the different obstacles to CCS deployment identified in Phase I of this research. It then weighs that analysis against both the Phase I study's findings on preferred promotion policies for CCS and a recent modeling study assessing the viability of different policies to promote CCS. Finally, this Section briefly assesses the EPA's recently proposed rules effectively mandating CCS implementation for certain new-build power plants in the context of this broader analysis.

We reach three conclusions. First, not only must any policy used to promote CCS diffusion be "market pull" rather than "technology push," it also must be CCS-specific. That is, while the policy need not promote any particular type of CCS technology, it must distinguish between CCS as a climate mitigation tool and other options. Second, the policy should include flexibility to allow industry wide berth in deciding how to comply. This might best be done through a technology performance standard, such as what EPA is proposing to adopt, or it might be through a market-based regime, if and only if that regime specifically promotes CCS. Finally, a policy to promote CCS likely will not be enough alone. The Phase I data point heavily toward other needed policies, such as liability limits and a comprehensive regulatory regime. Combining a CCS diffusion policy with these measures is likely to be more successful than using only the diffusion policy.

A. CCS Under the Technology Diffusion Policy Lens

The clear modern trend is toward market-based regulation in both environmental and energy law. Examples are prevalent and far-ranging. The case study of SO_2 and NO_x markets, discussed above, is a highly cited example of market-based environmental regulation that works, and it has served as the model for other types of modern environmental regulation. Energy law, too, increasingly uses market-based regulations, such as the Federal Energy Regulatory Commission's utilization of market share and concentration screens to allow electricity producers to sell power at bargained-for prices rather than under traditional cost-of-service regulation. When it comes to CCS, the tendency thus might well be to argue for a market-based regulation to promote this technology's use. The idea carries substantial appeal at first glance.

On more careful consideration, however, it seems unlikely that a pure market-based regime, standing alone, is likely to be the best tool to incentivize CCS deployment. Rather, it seems almost certain that some kind of technology-specific regime will be necessary, likely combined with other regulatory measures. This is, at least in part, because of the broader market in which CCS might be deployed.

CCS is not an end in itself, but one possibility for achieving other ends. In this regard, CCS might rightly be seen as operating in two different but interrelated markets. First, CCS technology is most likely to be used in conjunction with coal-fired electricity generation. However, coal-fired power does not produce a unique product. Rather, it produces the same fungible commodity that any generation facility produces: electricity. Thus, coal-fired generation equipped with CCS technology must be compared against other kinds of power generation options. Second, CCS technology is one of many different possible options for mitigating climate change, *i.e.*, for reducing greenhouse gas emissions. There are many other options for achieving this objective, including but not limited to using other power generation sources with lower greenhouse gas emissions, such as natural gas, nuclear, and renewables; implementing efficiency measures, whether in the electricity sector or otherwise; reducing overall consumption; or eliminating emissions in other sectors, such as in transportation. Thus, CCS also cannot be considered alone as a climate risk-reducing technology. It competes against other options, both on the public stage and in any regulatory regime that is adopted.

With this in mind, it quickly becomes clear that some type of technology-specific policy is needed to promote CCS use. While scholars have long criticized such policies for the potential cost and risk of technology lock-in, technology-based design standards are likely the best option for promoting CCS adoption. This is precisely because a technology design standard would promote CCS specifically, rather than any broad set of possible climate mitigation tools.

However, EPA is currently limited in how it might use a design standard to promote CCS use. Design standards under the CAA[108] are termed work practice standards. As currently constituted, the Hazardous Air Pollutants section of the CAA greatly limits EPA's ability to implement such standards: EPA can appropriately implement a technology-based work practice standard only where the pollutant at issue cannot be either captured or monitored.[109] As CO_2 meets neither of those requirements, EPA would face great difficulty in enacting a technology-based work practice standard to promote CCS.

Of course, EPA could promote CCS in another way using a technology-based performance standard, and that is effectively what the agency's proposed NSPS rules would do. As addressed above, technology performance standards can have significant advantages over technology design standards, if they are written in a way that actually affords flexibility for compliance. The risk is that they will not be, and thus lock in a single technology choice. In the case of a technology performance standard for CCS, it

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[108] 42 U.S.C. § 7412.
[109] *Id.*

would be essential that the policy be specific enough to promote CCS as a broad class of technologies, but not so specific that it forces industry to adopt a certain mix or configuration of this technology. For instance, the regulation might mandate use of CCS through a CO_2 emissions limit, but specify that any type of capture technology could be used, any type of transport technology could be used, and any kind of long-term CO_2 sequestration could be used, so long as the firm in question can corroborate and confirm the mandated CO_2 emissions reduction. This way, CCS as a class of climate mitigation technology would be deployed, but industry would maintain the flexibility to implement—or innovate—any specific technology within that class. This would set the technology performance policy apart from a design standard requiring a specific kind of CCS technology, but would also likely be more effective than any given market-based regime.

Market-based climate regimes face at least two large hurdles in seeking to promote CCS. First, whatever regime is employed would need to send a strong enough signal—that is, set a high enough price for greenhouse gas emissions—that it would incentivize CCS use. This alone may be difficult enough, particularly in light of the lack of action at the federal level in seeking to regulate climate change to date. The risk that, if ever enacted, a Congressional policy to regulate greenhouse gas emissions would be discounted sufficiently that it would not promote CCS, which substantially increases the cost of coal-fired electricity generation,[110] cannot be discounted.

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[110] The cost implications of CCS are significant. The IPCC estimates that with CCS, the cost of electricity from a pulverized coal power plant would increase from 4-5¢/kilowatt hour (KWh) to 6-10¢/KWh. IPCC, CCS SUMMARY FOR POLICYMAKERS 10 (2005). For natural gas combined cycle and IGCC plants, increases are projected to be from 3-5¢/KWh to 4-8¢/KWh, and from 4-6¢/ to 5-9¢/KWh, respectively. *Id.*

Second, because it raises the cost of coal-fired electricity, CCS would face stiff competition from other climate mitigation strategies in a market-based regime. To the extent a power producer could reduce its emissions less expensively by, for instance, installing wind farms or retrofitting an existing coal plant to natural gas rather than installing CCS equipment, the firm inevitably would make that choice. A market-based regime would not only welcome that result, but encourage it. Its policy objective of climate mitigation would be met, and that objective would come at a lower cost than CCS would entail.

This analysis applies equally to each of the available market-based regimes, and it can be seen easily in the context of a carbon tax. Practically, enactment of a carbon tax is unlikely to ensure adoption of CCS. Under a carbon tax regime, industry will first determine which is more cost-effective: paying the tax or reducing emissions. Only if industry determines reducing emissions is more cost-effective will it face the second decision: which technology is most cost-effective. If CCS is that technology, industry will adopt CCS. However, regulators cannot be confident industry will continue to use CCS given that new technologies will emerge that may be more cost-effective.

Thus, in determining how to promote CCS diffusion, it seems clear that a technology-specific policy is needed. Moreover, because a technology performance standard provides more flexibility than a technology design rule, this—or some other mechanism that provides industry flexibility and room for additional innovation—likely should be the preferred option.

For instance, a market-based regime could be set up that requires a general amount of emissions reductions but mandates that a percentage of those reductions be met by CCS technology. This would be akin to a solar "carve out" provision in state renewable portfolio standards.[111] Those market-based regimes require electric utilities to provide a certain portion of their electricity from renewables, and the solar "carve out" provisions then say a segment of the larger renewables portion must be met by solar power. This retains the flexibility of a market-based or performance-standard regime but ensures that a general class of technology will be deployed.

A similar tool could be used for CCS. Congress could adopt, for instance, a "carbon reduction standard" or a "clean electricity generation standard," each of which might respectively require electricity producers to reduce their greenhouse gas emissions by a give percentage or supply a given amount of their power using a defined class of clean energy technologies. [112] Either of these market-based policies alone would not necessarily encourage the use of CCS, just as a carbon tax or a cap and trade system would not. However, if a CCS "carve out" provision were included in either regime, the policy should have the effect of promoting CCS use while retaining industry flexibility.

No matter which policy is used, however, the point remains: to promote CCS, at least in the current state of the market, some type of technology-specific policy is needed. Indeed, consistent with our analysis, David Driesen, a preeminent legal scholar in the area of technology-induced regulations, believes that, taken as an abstract proposition, a work practice standard would most effectively induce industry adoption of CCS.[113]

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[111] Greg Buckman, *The Effectiveness of Renewable Portfolio Standard Banding an Carve-outs in Supporting High-cost Types of Renewable Electricity*, 39 ENERGY POLICY 4105 (2011); Chip Gaul & Sanya Carley, *Solar Set Asides and Renewable Electricity Certificates: Early Lessons from North Carolina's Experience with Its Renewable Portfolio Standard*, 48 ENERGY POLICY 460 (2012).

[112] For a discussion of past Congressional proposals relevant to CCS, *see* ARNOLD REITZE, FEDERAL CONTROL OF GEOLOGICAL CARBON SEQUESTRATION, TOPICAL REPORT (2010).

[113] Email correspondence from David Driesen to David Johnson, on file with authors.

Driesen observes, "[I]f the goal is defined narrowly as trying to get a particular technology adopted then a technology based work practice standard is probably best."[114]

B. Empirical Assessments of CCS Policy

This Report's suggestion that the policies used to promote CCS be technology-specific but retain regulatory flexibility largely comport with other existing empirical assessments of possible CCS policies. Two are important here. The first is our Phase I study, which did not just ask survey participants about obstacles to CCS deployment but also solicited views on the shape of CCS policy. The second is a mathematical study conducted by Otto and Reilly in 2008.

1. Phase I Study

The results of the policy design questions from the Phase I study confirm in at least two ways the analytical assessment here that some kind of technology-specific but flexible policy should be employed to promote CCS.

First, the overwhelming findings of that study suggesting that CCS cost and cost-related issues are the key impediment to CCS deployment underscore that some kind of regulatory intervention is necessary to encourage CCS use. For instance, in response to the open-ended query of what the most significant obstacle to CCS use is, 38.4 percent of respondents identified CCS cost, 21 percent identified uncertainty about climate regulation, and 13 percent identified CCS liability—all three factors that are cost-related.[115] Likewise, in response to the ranking questions where respondents were asked to numerically score the greatest barriers to CCS, cost came in first, uncertainty about

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[114] *Id.*

[115] Phase I Report at 71-75.

climate change second, and liability third.[116] All of this data confirms that because of its cost, any policy used to promote CCS must grapple with that barrier. And, because, as shown above, a generally applicable climate regulatory regime would not necessarily put CCS at the front of the utilization line, some kind of technology-specific policy that targets CCS is likely necessary to incent its use.

Second, the responses to the questions asking specifically about which policies should be used to promote CCS use also confirm that a flexible policy that addresses CCS cost is necessary. Well over forty percent of respondents to the Phase I open-ended policy design questions identified some kind of cost measure as their preferred policy for promoting this technology (22.7 percent tax incentives or credits, 10.9 percent liability limits, 10 percent carbon tax, 0.3 percent guarantee of utility cost recovery).[117] Similarly, the ranking questions placed tax incentives for CCS first, a carbon tax second, the guarantee of utility cost recovery third, and liability limits fourth in terms of preferred policies.[118] Emission performance standards were also generally favored, coming in fifth in the ranking questions with a mean score of 4.75 on a 1 (most promising) to 11 (least promising) scale.[119] All these data point toward a CCS promotion policy that addresses the technology's cost and also allows for flexibility in how firms meet it.

The Phase I data, however, do complicate the general analytical assessment that a technology-specific, flexible regulation should be used to encourage CCS diffusion. In both the open-ended and ranking questions, the option of "imposing technological

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[116] This is based on the mean catchall obstacle scores. The mean aggregated category-wide scores are slightly different but in the same vein. Using those scores, the lack of a comprehensive CCS regulatory regime moves up from fourth to second, and CCS liability falls from third to fourth.

[117] Phase I Report at 88-90.

[118] *Id*. at 87-88.

[119] *Id*. at 88-90.

mandates" scored very low—essentially at the bottom—of all the possible options. In the open-ended questions, this option only received 2.1 percent of responses.[120] In the ranking questions, it came in second to last among all options, with a mean score of 6.27, ahead only of "other."[121] These data convey a clear message that the CCS industry does not favor a straight technological mandate. Nevertheless, that statement does not necessarily equate with a conclusion that CCS promotion technology should not be technology-specific: The option of "technological mandates" was undefined and thus open to interpretation in a number of different ways. Respondents might well have assumed it meant mandating a very specific type of CCS technology, rather than requiring use of any kind of CCS technology generally. Certainly that interpretation of the data would comport with general industry reluctance to be boxed in by government and the desire of the CCS industry to see its technology promoted. Further, the comparatively high rank of emissions performance standards would appear to demonstrate that the CCS community believes technology-specific policies of some kind are necessary. Indeed, given that virtually all of the most favored policies—such as tax incentives, utility cost recovery, liability limits, carbon tax, and emissions performance standards—go to cost but anticipate regulatory flexibility, overall the Phase I data would seem to confirm rather than rebut our analytical conclusions in this Report.

2. Mathematical Modeling of CCS Regulatory Alternatives

Further confirmation for the suggestion that CCS promotion should occur under a technology-specific, flexible policy is provided by a 2008 study conducted by Vincent

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[120] *Id.* at 88-89.

[121] *Id.* at 85-86.

Otto and John Reilly.[122] In that study, the authors assessed the comparative efficacy of various permutations of CCS regulatory alternatives. Specifically, Otto and Reilly used mathematical models to predict the CCS adoption inducement potential of: (1) differentiated[123] CO_2-trading schemes; (2) a combination of differentiated CO_2-trading schemes and an adoption subsidy; (3) a combination of differentiated CO_2-trading schemes and a directed research and development (R&D) subsidy; and (4) a combination of differentiated CO_2-trading schemes and differentiated R&D subsidies.[124] They concluded that adoption subsidies combined with a differentiated carbon trading scheme would be most effective at encouraging CCS use—providing substantial support for this Report's suggestion of a CCS-specific, but flexible, policy to promote CCS use.

a. Differentiated CO_2 Trading Schemes

Otto and Reilly's model predicted that, prior to 2023, CCS would have a difficult time entering the marketplace due to up-front costs associated with the technology. However, Otto and Reilly found that, as a result of pricing CO_2 emissions, trading schemes would sufficiently improve the economic competitiveness of the CCS technology over time such that companies would be willing to adopt it. In other words, if adopted today, a generally applicable carbon limit would not suffice to promote CCS, because of CCS's high cost (and thus, comparative disadvantage with respect to other trading regimes). This finding is consistent with our suggestion here that an appropriate promotion policy for CCS must target CCS as such, and not climate mitigation tools generally.

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[122] Vincent M. Otto & John Reilly, *Directed Technical Change and the Adoption of CO_2 Abatement Technology: The Case of CO_2 Capture and Storage*, 30 ENERGY ECONOMICS 2879-98 (2008).

[123] In this context, "differentiated" denotes varying the subsidy across CO_2-intensive and non-CO_2-intensive sectors.

[124] Otto & Reilly, *supra* note 122, at 2884-86.

b. Combined Differentiated CO_2 Trading Schemes and CCS Adoption Subsidy

Otto and Reilly found that, in contrast to relying solely on differentiated trading schemes, that same trading scheme approach combined with an adoption subsidy would immediately induce CCS adoption. The explanation for this difference is that the adoption subsidy corrects for positive technology externalities related to the CCS technology. The authors note, "by subsidizing the use of the CCS technology, [CCS is pulled] out of its development phase" more quickly than if no subsidy exists.[125] "By directly compensating for the markup over the cost of conventional electricity, the CCS technology becomes competitive from the moment the adoption subsidy is introduced and immediately substitutes for the conventional technologies used in the CO_2-intensive electricity sector."[126] Notably, this too is consistent with our suggestion for a technology-specific, flexible CCS promotion policy. It reconfirms the notion that CCS itself must receive some kind of clear financial support if it is to be deployed on a broadscale, rather than expecting CCS to compete on its own in the larger market of climate mitigation strategies.

c. Combined Differentiated CO_2 Trading Schemes and Directed R&D Subsidy

While Otto and Reilly found that CO_2 trading schemes employed in conjunction with an adoption subsidy immediately induced CCS adoption, they conversely found that a trading scheme employed in conjunction with a directed R&D subsidy proved less effective. The authors explained this conclusion:

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[125] *Id.* at 2884.

[126] *Id.*

> Whereas the adoption subsidy directly improves competitiveness of the CCS technology by lowering its output price, the directed R&D subsidy only indirectly improves competitiveness by lowering one of the various input prices [(the R&D input price)]. It is only when sufficient knowledge capital has been accumulated that the input costs of knowledge capital services decreases to the extent that the CCS technology becomes competitive and gains market share.[127]

Thus, Otto and Reilly suggested that a differentiated trading scheme with an R&D subsidy would be less effective than a trading scheme with a diffusion subsidy.

Again, this is consistent with our conclusions in a number of respects. It reconfirms the suggestion from the Phase I data that CCS is readily deployable and need not need further demonstration to be a viable climate mitigation strategy. The contrast between Otto and Reilly's finding on this option versus an adoption subsidy shows how critical an obstacle cost is to CCS use. And the fact that an adoption subsidy would promote CCS use in their model but and R&D subsidy would not underlines the need for CCS-specific promotion, rather than general climate mitigation technology promotion.

d. Combined Differentiated CO_2 Trading Schemes and Differentiated R&D Subsidies

Otto and Reilly's model found that differentiated R&D subsidies proved more effective than directed R&D subsidies—but less effective than adoption subsidies—when utilized in conjunction with differentiated CO_2 trading schemes. With respect to R&D subsidies in general, the authors noted that R&D subsidies are "not necessarily the most effective instruments to induce adoption of new technology because they only indirectly improve competiveness of new technology."[128] Accordingly, while this option induced

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[127] *Id.* at 2885.
[128] *Id.* at 2886.

adoption faster than trading schemes alone and/or trading schemes with a directed R&D subsidy, it lagged behind the trading scheme with an adoption subsidy.

Based on their analysis, the authors thus concluded that while policymakers often favor general funding for research and development, in terms of achieving technology diffusion, other options are likely to be more effective:

> Although R&D subsidies are the first-best instruments to internalize technology externalities, they are not necessarily the most effective instruments to induce adoption of new technology. For that purpose, an adoption subsidy is preferred. Such a subsidy directly improves the competitiveness of the CCS technology by compensating for its markup over the cost of conventional electricity. Consequently, the CCS technology immediately substitutes for the conventional technologies used in the CO_2-intensive electricity sector.[129]

Again, consistent with the above discussion of their other findings, Otto and Reilly's conclusion on this score substantiates our policy analysis on multiple grounds.

C. Evolving Context: EPA's Proposed NSPS for New Coal-Fired Power Plants

Any assessment of EPA's proposed rules for new coal-fired power plants by definition must be tentative. Because the rules are still only a proposal, and not final, their ultimate shape remains uncertain. Moreover, only once the rules are actually implemented will it be possible to determine their effect. Until then, everything is speculation. Nevertheless, examining the proposed rules provides some context for weighing how CCS policy may take shape, even if that context is evolving.

EPA's recently proposed NSPS for new coal-fired plants may prove to be yet another case study of EPA regulating emissions through performance standards. At the time of the Phase I Report, EPA was in the process of promulgating regulations regarding

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[129] Otto & Reilly, *supra* note 122, at 2879-98.

greenhouse gas emissions from fossil fuel-fired power plants and refineries. As noted in the Phase I Report, these regulations have the dual potential to add regulatory certainty while incentivizing CCS deployment. EPA has since proposed, withdrawn, and then re-proposed those rules, the latter version of which was released for comment on September 20, 2013.[130]

EPA's proposed rule concludes that partial CCS[131] for new coal-fired power plants satisfies the performance standard articulated in Section 111(b) of the CAA, namely that such emission limits be premised on the "best system of emission reductions . . . adequately demonstrated" (BSER).[132] As part of this BSER determination, EPA was obliged to evaluate the technical feasibility of CCS, the reasonableness of the costs of CCS, the effective reduction of CO_2 emissions that would be achieved by utilizing CCS technology, and whether mandating partial CCS would advance development of CCS technology.[133] In its proposed rule, EPA sets forth at length why and how requiring partial CCS for new coal-fired power plants satisfies the CAA's BSER standard.[134]

Specifically, EPA determined that each element of CCS technology has been demonstrated at either the pilot or commercial scale, and that coal-fired power plants with integrated CCS technology are both in existence and being constructed.[135] EPA also found that the costs of partial CCS were reasonable, on the basis of the costs faced by utilities seeking to lower carbon emissions or diversify their fuel sources. Using this

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[130] 79 Fed. Reg 1429.
[131] For purposes of EPA's proposed rule, partial CCS has a CO_2 capture rate of less than 90 percent, while full CCS has a CO_2 capture rate of 90 percent or greater. *Id.* at 1470.
[132] *Id*. at 1449-51; *see also* 42 U.S.C. § 7411(b).
[133] 79 Fed. Reg. 1449-51.
[134] *Id.* at. 1463-87.
[135] *Id*. at 1474-75.

framework, EPA first compared the costs of a new nuclear plant to a new partial CCS coal-fired plant. The agency then found those costs to be sufficiently equivalent as to make the costs of a partial CCS mandate reasonable under CAA Section 111.[136]

EPA also conducted a second cost comparison, namely, the difference between new coal-fired and new gas-fired power plants. Although new coal-fired plants are intrinsically more expensive than new gas-fired plants ($33 more per megawatt hour (MWh), EPA found the additional costs of CCS (a further $18/MWh) to be reasonable.[137] EPA implied that only a small minority of new power plants will be coal rather than gas in any event, and relied on this as part of its rationale for finding partial CCS costs unreasonable for new gas-fired power plants.[138]

Finally, EPA concluded that a partial CCS mandate would advance the development of CCS technology, as "any new fossil fuel-fired utility boiler or IGCC unit will have to install partial CCS capture in order to meet the emissions standard."[139] In other words, EPA specifically anticipates that its proposed NSPS will be a kind of technology diffusion policy, one tied directly to CCS.

EPA's proposal is not without controversy. When EPA originally proposed its NSPS for CO_2 emissions from new coal- and gas-fired power plants in April 2012, EPA received more than 2.5 million comments.[140] In light of those comments, and "continuing changes in the electricity sector," EPA withdrew its original proposed NSPS, and subsequently issued the revised and now proposed NSPS. That proposal is currently open

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[136] *Id*. at 1514-19.

[137] *Id*. at 1518-19. EPA further noted that the increased costs of integrating partial CCS technology could be passed on to the utilities' customers. *See id.* at 1523.

[138] *Id*. at 1449-52.

[139] *Id.* at 1480.

[140] *Id*. at 1429.

for comment until March 10, 2014. As of January 31, 2014, 1689 comments had been submitted for review and response.[141]

Political and legal challenges to EPA's proposed rule – well in advance of virtually inevitable objections to the content of the final rule – are already underway.[142] The legal "battle lines," as one law firm termed them, "are thus clearly drawn on two fronts: "(1) can EPA effectively preclude the use of coal for electric generation in places where CCS cannot be feasibly used; and (2) can EPA force technology based on projects in planning or still under construction, or must CCS be demonstrated based on a working CCS system in existence today"?[143] As challenges along these lines—and certainly others—work their way through the agency and in all likelihood the courts, a final, implemented rule regulating CO_2 emissions from new power plants is certain to be at least, if not years, away.

In the context of this Report's assessment of different possibilities for CCS promotion, the EPA proposed rules are notable on a number of fronts. Interestingly, EPA has chosen to use a technology performance standard to promote CCS. This is fully consistent with our analysis that a CCS-specific but flexible policy should be used if government regulation is to be used to help commercialize this technology. Indeed, as

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[141] *Id.*

[142] *See, e.g.,* Jean Chemick, *Energy and Commerce Votes to Scrap EPA Regs for Power Plant Emissions*, GREENWIRE, Jan. 28, 2014, http://www.eenews.net/greenwire/2014/01/28/stories/1059993590; Sonal Patel, *New Lawsuit Challenging EPA Carbon NSPS Highlights EPACT 2005 Conflict*, POWERMAGAZINE, Jan. 23, 2014, http://www.powermag.com/new-lawsuit-challenging-epa-carbon-nsps-highlights-epact-2005-conflict/; Amy Harder, *Manchin-Whitfield Bill Could Stifle EPA Power-Plant Regulations*, NATIONAL JOURNAL, Oct. 28, 2013, available at http://www.nationaljournal.com/energy/manchin-whitfield-bill-could-stifle-epa-power-plant-regulations-20131028.

[143] ReedSmith, Client Alert, *The Battle Over EPA's Proposed New Source Performance Standards For Coal Fired EGUs: Adequately Demonstrated or Impermissible Technology Forcing?,* Oct. 3, 2013, http://www.reedsmith.com/The-Battle-Over-EPAs-Proposed-New-Source-Performance-Standards-For-Coal-Fired-EGUs-Adequately-Demonstrated-or-Impermissible-Technology-Forcing-10-03-2013/; *see also* McGuireWoods, *supra* note 18; Latham & Watkins, Client Alert Commentary, *EPA Proposes New Greenhouse Gas Performance Standards for New Power Plants*, Sept. 27, 2013.

we describe above, it seems that either a technology performance standard such as the one EPA proposes to use or a market-based regime that ensures some guaranteed use of CCS would be the best policy mechanisms to achieve this goal.

Nevertheless, there also are clear gaps in EPA's proposed approach. As EPA itself acknowledges, because coal-fired power competes with other types of electricity generation, an effective mandate of CCS for coal plants may not substantially advance use of the technology. Indeed, even in the context of a broader carbon regulatory regime, this may not be enough. Further, our Phase I study demonstrated a number of other measures are strongly desired by the CCS community, including liability limits and a comprehensive, stable, and predictable CCS regulatory regime—the latter of which received the most number of responses in our open-ended question about preferred policy options. And, as the Otto and Reilly study demonstrated, subsidies for CCS use are more likely to be effective at promoting technology diffusion than other options. Thus, it must be clear that while certainly a step in the right direction for those who advocate CCS use as a climate mitigation tool, the proposed EPA NSPS rules cannot be the entire policy package. They are only part of it.

V. Conclusion

Data gathered in Phase I of this project clarified that the CCS community is predominantly concerned with cost/carbon pricing, liability, and a desire for comprehensive regulation. Thus, if government is to promote greater use of CCS as a climate mitigation lever, any policy adopted must address these obstacles.

In doing so, policymakers have many tools at their disposal. Often these options are lumped into a single category, referred to as "technology-forcing" regulation. A critical initial distinction, however, is in how policy seeks to "force" technology. For those technologies that are still nascent, "technology push" measures that seek to incentivize innovation and R&D investment tend to be the appropriate response. For technologies farther along the development spectrum, however, "market pull" policies that seek to deploy technologies commercially by creating greater demand for them should be the policy of choice. The Phase I data, plus recent assessments both by DOE and the EPA, make clear that CCS is such a technology. It is ready for deployment now, and thus the policy of choice should be some brand of "market pull" measure.

Of the various available "market pull" or "technology diffusion" policies, our analysis shows that whatever is chosen for CCS must bear two characteristics. First, it should be CCS-specific, so that it clearly aims to promote CCS itself rather than any type of climate mitigation technology. Second, it should maintain flexibility, so that industry is not compelled to employ one certain brand or type of CCS technology. In all likelihood, this means a technology performance standard should be used, in very much the same way EPA proposes. However, a market-based regime also could be used, so long as it remains CCS-specific in a meaningful way, such as solar "carve out" provisions are currently used in state renewable portfolio standards. Our conclusion in this regard comports with our Phase I study, a mathematical study modeling CCS policies, and prior performance of technology forcing regulation in other areas.

Another important observation of this Report is that a "market pull" policy for CCS alone will not be enough. The Phase I data show that that while the CCS community very much supports governmental incentives for CCS, four are specifically believed to be most effective in spurring diffusion of CCS technology: carbon pricing, caps on liability arising from CCS, economic incentives for CCS deployment, and a comprehensive CCS regulatory scheme. The research data from Phase I also demonstrate a CCS community preference for tax incentives, such as production tax credits, over alternative economic supports, such as technological mandates, CCS subsidies, and R&D funding.[144] Thus, at a minimum, a technology performance standard for CCS should be combined with a comprehensive regulatory regime and liability limits if government is serious about promoting the technology. Other options, such as adoption subsidies or tax credits, might also be considered.

Admittedly, design standards have one major drawback in that they may mandate stale technologies. To avoid this drawback, regulators could enact a de facto design standard coupled with an adoption subsidy. As shown by the study on tailpipe emissions and in the mathematical models, de facto design standards effectively promote technology adoption by linking a performance standard with a given technology. Moreover, such standards promote CCS adoption while also leaving innovation incentives in place. Coupling a subsidy with the de facto design standard may ensure that the technology will be economically competitive from the law's inception.

EPA has opted to utilize a performance standard in its recent proposed mandate of partial CCS. While EPA's regulatory model may be legally feasible, it is unclear how EPA's proposed NSPS would succeed in addressing the questions of carbon pricing and liability. Further, an EPA-mandated emissions standard standing alone constitutes neither a holistic nor a cooperative federalist regulatory framework for CCS.

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[144] *See* Phase I Report at 84-90.

Even the best conceptual regulatory model for the challenges that impede CCS technology diffusion will not alone be sufficient to address the CCS community concerns underscored by the Phase I data. CCS commercialization would be more successfully incented by comprehensive federal legislation rather than the regulatory device of an EPA emissions limit alone, however well crafted and fairly implemented that EPA limit may be.

In many ways, this news is not new at all. While CCS technology continues to mature and two different cabinet-level agencies now acknowledge it as a commercially viable climate mitigation tool, the hurdles to commercial-scale diffusion faced by CCS remain. In the end, a high-level political and legislative commitment to developing a long-term climate policy— with an articulated role for CCS technology and a policy for addressing carbon costs—is critical if broadscale domestic CCS deployment is to succeed.