COLUMBIA LAW SCHOOL

SABIN CENTER FOR CLIMATE CHANGE LAW

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U.S. Environmental Protection Agency
EPA Docket Center
Mail Code 28221T
1200 Pennsylvania Avenue NW
Washington, DC 20460

Re: Proposed Revisions to the New Source Performance Standards for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Generating Units, Docket ID No. EPA-HQ-OAR-2013-0495

To Whom It May Concern:

The Sabin Center for Climate Change Law and the undersigned experts on carbon capture and sequestration ("CCS") technologies submit these comments in response to the Environmental Protection Agency ("EPA")'s proposed revisions to the final rule titled "New Source Performance Standards for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Generating Units" published on October 23, 2015 ("2015 rule").

The 2015 rule established new source performance standards ("NSPS") for CO_2 emissions from coal-fired power plants which reflected the emissions reductions that could be achieved by using post-combustion CCS technologies to capture and store a percentage of the facility's CO_2 emissions (16-23% depending on the type of coal used). This was based on EPA's conclusion that partial CCS was technically feasible, adequately demonstrated, and available for installation at coal-fired power plants, and therefore part of the best system of emissions reduction ("BSER") for CO_2 emissions from this source category. EPA is now proposing to reverse course on its determination that partial CCS should be part of the BSER based on a revised assessment of costs and geographic availability. As detailed in the proposal, removing partial CCS from the BSER would result in significantly weaker CO_2 performance standards.

We strongly oppose this proposal and take issue with EPA's stated rationales for revising the BSER determination. In particular, we believe that EPA has reached erroneous conclusions with respect to the feasibility and geographic availability of CCS for coal-fired power plants. Below, we explain why CCS remains an adequately demonstrated system for reducing CO_2 emissions from coal-fired power plants, and we respond to some of EPA's rationales for reversing course on the BSER determination.

1. CCS is an adequately demonstrated system for reducing CO_2 emissions from coal-fired power plants.

There is ample evidence to support EPA's original determination that CCS is an adequately demonstrated system for reducing CO_2 emissions. A group of scientists with expertise in CCS (including the undersigned scientists) submitted an amicus brief in the lawsuit challenging the 2015 rule which summarizes the evidentiary basis for the BSER determination.[1] The key points from that brief are as follows:

- CCS technologies have been proven through decades of experience in industrial applications and are now being successfully deployed on a large scale to capture and permanently store CO_2 emissions from power plants.
- In particular, all components of the CCS system used in the 2015 BSER determination (post-combustion capture, pipeline transport, and deep saline storage) have been adequately demonstrated through experience with both the individual components (which traces back to the 1930s)[2] and, more recently, with fully integrated projects.
- Large-scale, integrated projects that are currently in operation today demonstrate the feasibility of capturing and storing CO_2 emissions from power plants at a scale even larger than that contemplated by the 2015 rule. In particular, the Boundary Dam facility in Canada demonstrates the feasibility of capturing CO_2 at a large scale, transporting it via pipeline, using it for enhanced oil recovery ("EOR"), and storing it in deep saline formations. The Petra Nova project in the United States, which has recently come online, is yet another example of a successfully operating large-scale integrated power-sector CCS project.
- There are also many power plants and industrial boilers with smaller but nonetheless substantial CCS systems, which capture approximately 20-75% of the emissions that would need to be captured from a 500 MW plant under the 2015 rule. The successful operation of these facilities further supports EPA's conclusion about the viability of CCS as an emissions control measure for power plants.
- The costs of CCS continue to decline with operational experience and technological innovation, making CCS an increasingly viable option for controlling CO_2 emissions from this source category.

These points are fleshed out in greater detail in the amicus brief, which we have attached to this letter for inclusion in the rulemaking docket.

[1] Brief for *Amici Curiae* Carbon Capture and Storage Scientists in Support of Respondents, North Dakota v. EPA, No. 15-01381 (Dec. 21, 2016).

[2] These components are highly modular and easily linked, and it would therefore be appropriate to reach conclusions about the overall technical feasibility of CCS based on evidence that each component is adequately demonstrated. Moreover, as discussed above, there are also projects in operation which demonstrate that these components can be successfully integrated.

2. *Geologic sequestration ("GS") is technically feasible and widely available throughout the United States.*

In the 2015 rule, EPA performed a geographic analysis in which it determined that GS sites such as deep saline formations, oil and gas reservoirs, unmineable coal seams, and active EOR operations were widely available throughout the United States. For this analysis, EPA relied on estimates of GS availability in the NETL Carbon Storage Atlas ("Atlas"). EPA now asserts that GS sites are not as widely available as previously believed. EPA cites two reasons for this new conclusion: (1) "the estimates in the Atlas do not take into account economic or regulatory constraints, only physical constraints" and thus the "Atlas shows an estimate of potential storage areas, but not economically viable storage areas";[3] and (2) some of the storage estimates, particularly those for saline reservoirs and unmineable coal seams, are too uncertain to support regulation.[4]

With regards to the first point: It is true that the storage estimates in the Atlas are based on physical constraints, but EPA was aware of this when it promulgated the 2015 rule and it only relied on the Atlas to assess the physical availability of CO_2 storage sites. This physical assessment was accompanied by a lengthy and detailed assessment of economic viability which accounted for additional economic and regulatory constraints, as well as an estimate of carbon storage costs derived from the *NETL CO_2 Saline Storage Cost Model*.[5] EPA even revisited the question of CO_2 storage costs in this very proposal and concluded, using that same model, that the storage costs per ton of CO_2 sequestered had not increased since it published the 2015 rule.[6] . It is therefore extremely misleading for EPA to suggest that its prior reliance on the Atlas was in error because the Atlas doesn't account for economic constraints, since EPA never used the Atlas for that purpose.

With regards to the second point: EPA's assertion that GS estimates are too uncertain to support regulation is contradicted by a wealth of evidence compiled by EPA when it promulgated the 2015 rule as well as more recent research on GS availability. Specific findings which undermine EPA's new position are detailed below.

i. General findings on geographic storage potential and availability

When EPA promulgated the 2015 rule, the federal government estimated that the United States' total geologic CO_2 storage potential was at least 2,400 billion tons (DOE)[7] or 3,000 billion tons (USGS).[8] This reflected the minimum bound of the potential storage capacity of saline

[3] 83 Fed. Reg. at 65,442.
[4] *Id.* at 65,443.
[5] *See* 83 Fed. Reg. at 64,558-73; EPA, *Regulatory Impact Analysis for the Final Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units*, EPA-452-R-15-005 (Aug. 2015) (Chapter 4 discusses cost impacts).
[6] 83 Fed. Reg. at 65,438. EPA justifies its claim that costs will be higher than previously projected by arguing (without evidence) that costs would increase *with lower levels of capture*; however, the actual transport and storage cost estimate at 3.2 Mt/year, the metric used in the 2015 rule, is exactly the same ($11 per ton).
[7] The United States 2012 Carbon Utilization and Storage Atlas, Fourth Edition, U.S. Department of Energy, Office of Fossil Energy, National Energy Technology Laboratory (NETL) (2012).
[8] USGS, National Assessment of Geologic Carbon Dioxide Storage Sources (2013), EPA-HQ-OAR-2013-0495-0044.

formations, oil and natural gas reservoirs, and unmineable coal seams. As a point of reference: 3,000 billion tons of capacity is enough to store the captured CO_2 from approximately 85,000 500-MW coal-fired plants operating for 100 years (each capturing 354,000 MT CO_2 / year).[9] The latest (Fifth) edition of DOE's *Carbon Storage Atlas* ("Atlas V") contains revised estimates of geologic storage capacity ranging from 2,618 to 21,978 billion tons.[10] In other words: there is an enormous amount of geologic storage potential in the United States. *Atlas V* also found that these geologic storage sites are located throughout North America.[11]

ii. Saline storage potential and availability

EPA's conclusion in the 2015 rule that GS was widely available was based exclusively on its assessment of saline reservoirs; other storage options were assessed as alternative and complementary compliance pathways, but EPA did not rely on these options in its BSER determination.[12] This was a reasonable approach, as saline storage is a widely available and well-proven method for CO_2 sequestration. Indeed, saline formations are found throughout the U.S. and have enormous CO_2 storage capacity.[13] *Atlas V* estimates that the total storage capacity of saline formations in the U.S. ranges from 2,379 – 21,633 billion tons CO_2.

With regards to geographic scope, EPA found in the 2015 rule that 39 states had onshore and/or offshore saline storage potential.[14] While there are some states with limited or no saline storage capacity, many of them are located adjacent to one or more states and/or offshore reservoirs that do have significant saline storage capacity.[15] Figures 1 and 2 (next page) illustrate the broad geographic availability of on-shore saline storage and offshore geologic storage (which is primarily saline storage, but also includes other offshore formations).[16]

[9] As a point of reference, there are less than 1,000 coal-fired power plants in the U.S. (average capacity: 315 MW), and only a few planned units; thus, theoretical storage capacity is orders of magnitude larger than what would be needed to store CO2 emissions from both planned and existing units. IEA, *Electricity*, https://www.eia.gov/electricity/data.cfm.

[10] NETL, *Carbon Storage* Atlas (Fifth Edition) (2015).

[11] *Id.* at 24-31 (maps showing CO_2 storage potential in different types of formations in North America).

[12] 80 Fed. Reg. 64,510, 64,579 (Oct. 23, 2015).

[13] Michael Szulczewski et al., *Lifetime of Carbon Capture and Storage as a Climate-Change Mitigation Technology*, 109(14) PNAS 5185 (2012).

[14] 80 Fed. Reg. at 64,576 (citing DOE research).

[15] E.g., Minnesota is located next to North Dakota, which has an estimated 71.94 – 234.71 billion tons of saline storage capacity; Iowa and Wisconsin are located next to Illinois (19.68 – 213.07 billion tons); and New Jersey is located next to Pennsylvania (17.34 billion tons) and New York (4.37 billion tons).

[16] Both figures are from NETL (2015), *supra* note 10. According to NETL, the total CO_2 storage capacity of offshore saline formations in U.S. federal waters is 331.62 - 4199.74 billion tons CO_2. *Id.* at 111. *See also* NETL, Mid-Atlantic U.S. Offshore Carbon Storage Resource Assessment Project, https://www.netl.doe.gov/project-information?k=FE0026087&show=ppp; David S. Goldberg et al., *Carbon Dioxide Sequestration in Deep-Sea Basalt*, 105 PNAS 9920 (2008); Romany M. Webb & Michael B. Gerrard, *Overcoming Impediments to Offshore Carbon Dioxide Storage: Legal Issues in the U.S. and Canada* (Sabin Center for Climate Change Law, 2019); Romany M. Webb & Michael B. Gerrard, *Policy Readiness for Offshore Carbon Storage in the Northeast* (Sabin Center for Climate Change Law, 2017).

Figure 1. Saline Formations for CO_2 Sequestration in North America (NETL 2015)

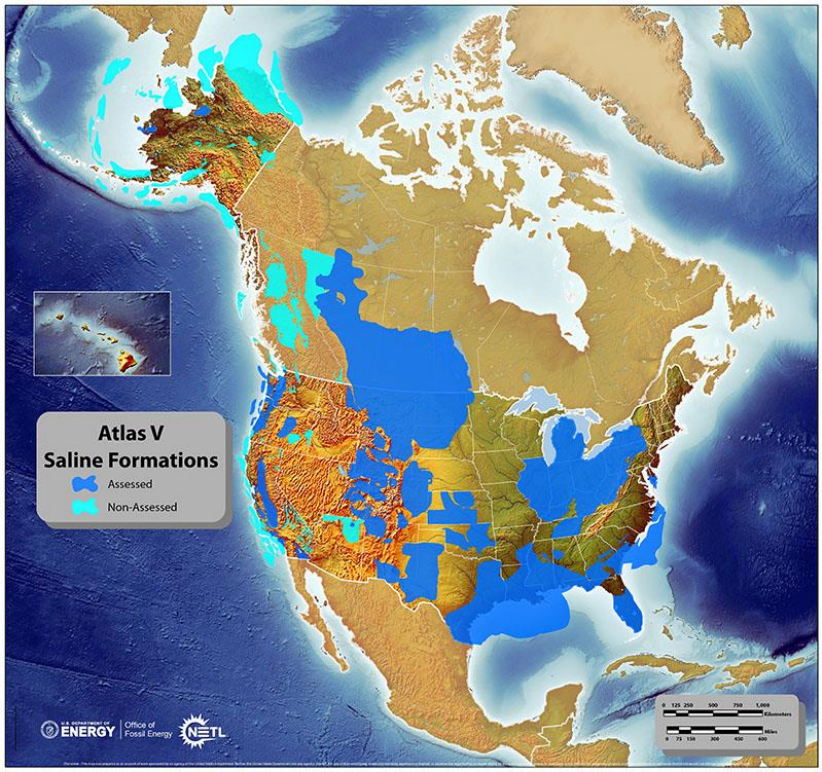
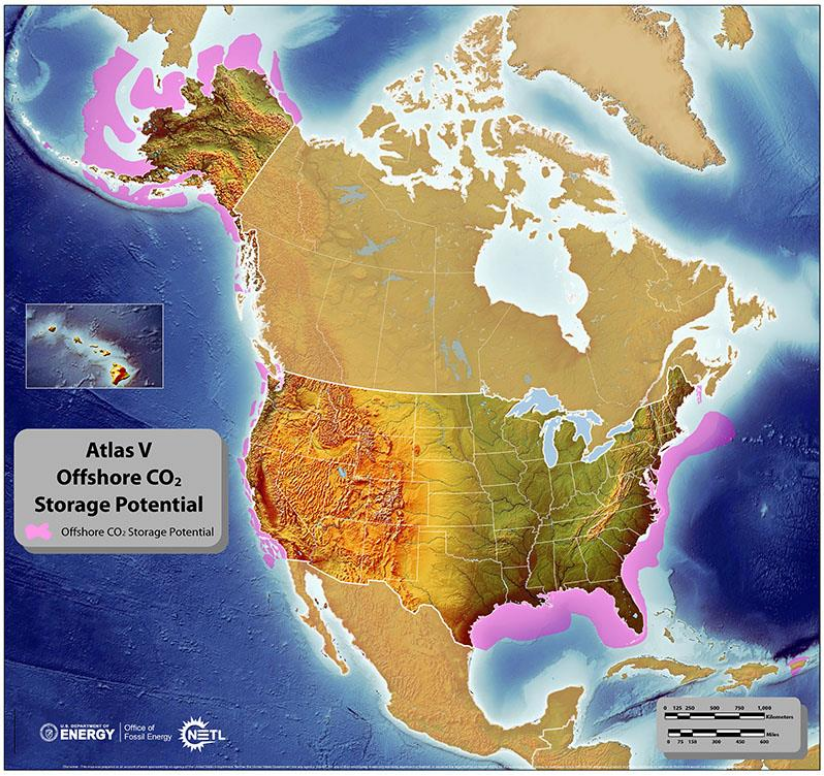


Figure 2: Offshore CO_2 Storage Potential in North America (NETL 2015)



To support its assertion that saline storage is too "uncertain" to support regulation, EPA also suggests that the Archer Daniels Midland (ADM) Illinois Basin Decatur Project "only reflects the feasibility of saline injection and storage at one location in the United States" and "has not yet proven that GS in saline formations can be done throughout the United States (at scale)."[17] In doing so, EPA ignores more than a century of experience with subsurface evaluation and injection. The physical equations and computer models used to evaluate GS sites are mature and robust, and sufficient data is available in most basins to reach general conclusions about GS availability and storage potential,[18] and NETL has systematically documented the viability of storage in dozens of basins with reasonable certainty.[19]

Deep saline storage at the scale needed to support compliance with the 2015 rule has been proven technically viable through decades of experience and many large-scale projects. As noted in a recent DOE report:

> Several CO_2 storage projects around the world have demonstrated the feasibility of injecting and storing CO_2 at the million tonne (Mt) per year scale. These include the long-running Sleipner project (Norway), which started in 1996 and has stored ~17 Mt of CO_2 to date, and more recent projects, including the Illinois Basin Decatur Project (USA) and the QUEST project in Alberta (Canada). These projects, along with a wealth of injection experience from the oil and gas industry over decades underpinned by extensive research, provide confidence in the subsurface storage concept intrinsic to CCUS.[20]

Notably, all three of the projects highlighted by DOE in this statement are saline injection projects. DOE is also tracking a variety of other projects that are also underway which demonstrate the viability of saline storage. Based on an-depth assessment of storage projects, DOE concludes that the technology is mature at the level of 1-4 megatons CO_2 per year[21] – significantly more than the amount of emissions that would need to be captured and sequestered from a new coal-fired power plant for compliance with the 2015 rule.[22] Many additional saline storage projects are also underway to further improve the knowledge base for and reduce the costs of large-scale saline storage.[23]

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[17] 83 Fed. Reg. at 65,442.

[18] *See* Susan D. Hovorka et al., *Sequestration of Greenhouse Gases in Brine Formations – CO_2 Brine Database*, http://www.beg.utexas.edu/gccc/research/brine-main; Susan D. Hovorka et al., *Technical Summary: Optimal Geologic Environments for Carbon Dioxide Disposal in Brine Formations (Saline Aquifers) in the United States* (2003).

[19] NETL (2015), *supra* note 10.

[20] DOE, *Accelerating Breakthrough Innovation in Carbon Capture, Utilization, and Storage: Report of the Mission Innovation Carbon Capture, Utilization, and Storage Experts' Workshop* (2017) at 4-3.

[21] *Id.* at 4-4.

[22] EPA estimated that a new 500-MW supercritical pulverized coal unit would need to capture and store approximately 354,000 metric tons of CO_2 per year. 80 Fed. Reg. at 64,574.

[23] One example is the Big Sky Carbon Sequestration Partnership (BSCSP) which is working to identify saline storage opportunities and implement storage projects in Montana, Wyoming, Idaho, South Dakota, eastern Washington, and Oregon. BSCSP is conducting a large-scale (~1 million metric tons CO_2 or more) storage demonstration project in the Kevin Dome formation in Montana, which has the potential to act as a regional CO_2 storage center due to its specific geologic properties and proximity to sources of anthropogenic CO_2. NETL, *Kevin Dome Project* (2017).

iii. Availability of other storage options

In promulgating the 2015 rule, EPA recognized that there are other carbon storage and utilization options which would support compliance with the standards, including the geologic storage options discussed above (active EOR operations, oil and gas reservoirs, and unmineable coal seams) as well as some more novel techniques for storing and utilizing carbon that are currently under development and could help reduce compliance costs in future years. The existence of these other storage options further supports EPA's original conclusion that partial CCS is technically feasible and viable across the United States.

With regards to other geologic options: As noted in a recent DOE report, the CCS community has "learned significantly from CO_2-enhanced oil recovery how CO2 behaves in different geologic formations, and what types of chemical and physical interactions can occur between CO_2, water, hydrocarbon, and minerals."[24] Due to the wealth of experience in this area, DOE describes geologic storage approaches (including storage in active EOR and oil and gas reservoirs) as "conventional technologies" for storing CO_2.[25] The International Energy Agency (IEA) Greenhouse Gas R&D Programme online monitoring selection tool provides a useful summary of the state-of-the-art in these storage techniques as well as numerous examples of their deployment in active projects.[26] Based on an assessment of the IEA project data, DOE concludes that practitioners now have a wealth of data to "select, integrate, and deploy technologies to address the site- and project-specific monitoring requirements for geologic CO_2 storage.[27]

Researchers are also currently working to increase the diversity of options for geologic CO_2 storage. For example, researchers have been evaluating the potential for CO_2 storage in basalt formation, which would rely on geochemical reactions between the CO_2 and basalt to mineralize the CO_2,[28] and have demonstrated that this form of in situ carbon mineralization is a technically viable storage option.[29]

Finally, there are approaches currently under development to transform CO_2 into useable materials that could be sold to offset the costs of CCS systems.[30] These include: ex situ carbon mineralization (which would allow the mineralized carbon to be used as a material for construction or other applications), and using captured CO_2 as a chemical feedstock.[31] Using these approaches, scientists have successfully turned CO_2 into materials such as concrete and

[24] DOE (2017), *supra* note 20, at 4-1.
[25] Id. at 4-11.
[26] IEA, *Monitoring Selection Tool*, https://ieaghg.org/ccs-resources/monitoring-selection-tool.
[27] DOE (2017), *supra* note 20, at 4-11.
[28] Heleen de Coninck & Sally M. Benson, *Carbon Dioxide Capture and Storage: Issues and Prospects*, 39 ANNU. REV. ENVIRON. RESOUR. 243, 252 (2014).
[29] Juerg Matter et al., *Rapid Carbon Mineralization for Permanent Disposal of Anthropogenic Carbon Dioxide Emissions*, 352 SCIENCE 1312 (2016). *See also* Jennifer Wilcox, *The Role of Mineral Carbonation in Carbon Capture*, in CARBON CAPTURE (2012).
[30] For an overview of utilization options, see NAS, *Gaseous Carbon Waste Streams Utilization: Status and Needs* (2019); DOE (2017), *supra* note 20, Section 3.
[31] Berend Smit, Ah-Hyung (Alissa) Park, and Greeshma Gadikota, *The Grand Challenges in Carbon Capture, Utilization, and Storage*, 2(55) FRONT. ENERGY RES. 1, 2 (2014). *See also* NAS, *Direct Air Capture and Mineral Carbonation Approaches for Carbon Dioxide Removal and Reliable Sequestration: Proceedings of a Workshop-in Brief* (2018).

carbon monoxide (which can then be used to make a range of materials including fuels, plastics, and pharmaceuticals).[32]

3. There is no basis for concluding that the water requirements for CCS would reduce the overall geographic availability of CCS to the extent that that the 2015 BSER determination is unreasonable.

To further bolster its conclusion that CCS is not available throughout the U.S., EPA asserts that the water requirements for carbon capture systems "would limit the geographic availability of potential future EGU construction to areas of the country with sufficient water resources."[33] EPA fails to support this assertion with any in-depth assessment of the potential impact of the 2015 rule on water consumption (e.g., EPA does not quantify the total estimated increase in annual water consumption for any hypothetical plants) and whether water resources are available for that projected increase. While it is true that most existing CCS systems require a substantial amount of water to operate, these water requirements are much smaller than the overall water requirements for a new coal-fired power plant, and there is no evidence that the marginal increase in water requirements would play a significant role in siting decisions for new power plants.

In making this assertion, EPA also fails to fully discuss the various technical options for reducing water consumption that can be implemented at new coal-fired power plants.

For example, in the 2015 rule, EPA noted that water used in coal combustion processes can be recycled, thereby decreasing the need for new water withdrawals, and cited Boundary Dam as an example of a CCS facility that recycles water.[34] In this new proposal, EPA suggests that its prior discussion of water recycling at Boundary Dam was deficient as it "should have considered that for new lignite-fired power plants owners/operators would likely dry the lignite prior to combustion", which would result in less water in the flue gas that could be captured and recycled.[35] But EPA fails to acknowledge that using pre-dried lignite also reduces overall cooling water requirements at coal-fired power plants,[36] and thus this approach is another example of a potential water saving measure that could be implemented at a new power plant.

4. The performance of existing CCS facilities shows that the 2015 NSPS is technically achievable.

In the 2015 rule, EPA determined that CCS was technically feasible based on the successful deployment of CCS technologies in both industrial applications and power-sector projects. EPA now claims that recent experience at two large-scale power-sector projects (Boundary Dam and

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[32] *CO_2 Can Be Turned Into Sustainable Concrete*, THE CHEMICAL ENGINEER (Mar. 16, 2016); Song Lin et al., *Covalent Organic Frameworks Comprising Cobalt Porphyrins for Catalytic CO_2 Reduction in Water*, 349 SCIENCE 1208 (2015).
[33] 83 Fed. Reg. at 65,443.
[34] 80 Fed. Reg. at 64,593.
[35] 83 Fed. Reg. at 65,443.
[36] Ye Yao et al., *Low Temperature Drying Process Improves Heat Rate and Water Balance for Power Plants*, Conference: The Clearwater Clean Coal Conference (2016); Anne M. Carpenter, *Water Conservation in Coal-Fired Power Plants* (IEA Clean Coal Centre 2017) at 12.

Petra Nova) casts doubt on the technical feasibility of CCS in this sector. But contrary to EPA's claim, the performance of these projects actually reinforces the agency's prior conclusion that CCS is a technically feasible CO_2 measure for coal-fired power plants.

Regarding the Boundary Dam project, EPA claims that "[the project] experienced multiple issues with the performance of the capture technology during its first year of operation (2014-15)" and that "the capture equipment was operating with lower reliability than designed" at that time.[37] It is true that Boundary Dam has experienced some performance problems, but none of these problems cast doubt on the feasibility of capturing CO_2 at the rate required by the 2015 rule. To the contrary, even with some initial performance issues, the Boundary Dam project has demonstrated that it is capturing a significantly higher proportion of CO_2 emissions than what would be required under the 2015 rule. The facility was designed to capture approximately 90% of emissions from Boundary Dam Unit 3 (approximately 1 Mt per year), as compared with the 16-23% required under the 2015 rule.[38] Last year, the project was down for repairs for several months following a severe storm, but was still able to capture more than 50% of the annual emissions from Unit 3.[39] After it resumed normal operations, it captured 77,660 metric tons of CO_2 in November 2018 and 70,397 metric tons of CO_2 in December 2018 .[40] Lessons learned from the Boundary Dam project will also help reduce CO_2 capture costs for future projects: potential reductions in capital costs costs have been evaluated and are projected at 67% less expensive than they were for Boundary Dam Unit 3 on a cost per ton of CO_2 basis.[41]

Regarding the Petra Nova project, EPA claims that it has "not demonstrated the integration of the thermal load of the capture technology into the EGU steam generating unit (i.e., boiler" steam cycle" but rather "the parasitic electrical and steam load are supplied by a new 75 MW co-located natural gas-fired CHP facility."[42] EPA misinterprets the situation at Petra Nova. The decision to install the new CHP facility is not evidence of any problem with integrating the capture unit with the electrical output of boilers at the facility; rather, this decision was made because the project owners saw a favorable business opportunity to provide additional power sales during the construction of the capture facility. Contrary to EPA's statement, experience at Petra Nova actually shows that a fully integrated CO_2 capture system at a new power plant is feasible at the capture levels required under the 2015 rule: the project currently captures approximately 90% of the CO_2 emitted from the flue gas slipstream at which it is installed (roughly 33% of the total power plant emissions). [43]

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[37] 83 Fed. Reg. at 65,444.

[38] International CCS Knowledge Center, *The Shand CCS Feasibility Study* (2018).

[39] To calculate percent captured, we divided the total CO_2 captured in 2018 (625,996 tons) by an estimate of total annual operating emissions (1,100,000 tons CO_2) which is based on SaskPower's statement that the project is designed to capture 1 MT or 90% of total emissions from Unit 3. *See* SaskPower, Press Release: Strong year for Carbon Capture and Storage at Boundary Dam PowerStation (Jan. 17, 2019), https://www.saskpower.com/about-us/media-information/news-releases/strong-year-for-carbon-capture-and-storage-at-boundary-dam-power-station.

[40] SaskPower, *Boundary Dam Status Update* (Dec. 2018); https://www.saskpower.com/about-us/our-company/blog/bd3-status-update-december-2018; SaskPower, *Boundary Dam Status Update* (Nov. 2018); https://www.saskpower.com/about-us/our-company/blog/bd3-status-update-november-2018.

[41] International CCS Knowledge Center (2018), *supra* note 38.

[42] 83 Fed. Reg. at 65,444.

[43] EIA, *Petra Nova is One of Two Carbon Capture and Sequestration Power Plants in the World* (Oct. 31, 2017), https://www.eia.gov/todayinenergy/detail.php?id=33552.

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Thank you for this opportunity to comment on the proposal to amend the New Source Performance Standards for new coal-fired power plants. For the reasons discussed above, we believe that EPA has reached erroneous conclusions about the feasibility and availability of CCS as an emissions control measure. We urge EPA to revise its analysis to reflect the wealth of research and existing projects which show that CCS is adequately demonstrated, technically feasible, and available throughout the U.S., consistent with the analysis it conducted for the 2015 rule, and accordingly, to reinstate its prior BSER determination. We have attached the scientific reports and other resources cited herein for inclusion in this rulemaking docket.

Sincerely,

/s *Jessica Wentz*

JESSICA WENTZ
Senior Fellow and Associate Research Scholar
Sabin Center for Climate Change Law
(707) 545-2904 x. 19
jwentz@law.columbia.edu

(corresponding author)

/s *Julio Friedmann*

JULIO FRIEDMANN
Senior Research Scholar
Center for Global Energy Policy
Columbia University

/s *Howard Herzog*

HOWARD HERZOG
Senior Research Engineer
MIT Energy Initiative
Massachusetts Institute of Technology

/s *Susan Hovorka*

SUSAN HOVORKA
Gulf Coast Carbon Center
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

/s *Ah-Hyung (Alissa) Park*

AH-HYUNG (ALISSA) PARK
Lenfest Chair in Applied Climate Science
Director, Lenfest Center for Sustainable Energy,
The Earth Institute
Department of Earth and Environmental Engineering
Department of Chemical Engineering
Columbia University

/s *Jennifer Wilcox*

JENNIFER WILCOX, PH.D.
James H. Manning Chaired Professor of Chemical Engineering
Worcester Polytechnic Institute