EO 12866_GHG EGU New Sources 2060-AT56 TSD Reliability of Currently Available CCS Final Rule_20201214

MEMORANDUM

From: The Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency

To: EGU NSPS Docket (EPA-HQ-OAR-2013-0495)

Date: December 2020

Subject: Availability/Reliability of Currently Available CCS

Introduction

Some commenters questioned the availability/reliability of the currently available CCS systems. To address these comments, the EPA investigated available data on carbon capture and storage (CCS) systems reliability. The goal is to determine if reliability of the carbon capture equipment is lower than other control equipment, and if the system would have to be oversized to overcontrol during periods of operation to account for periods of non-capture to achieve the overall design capture rates. EPA researched and reviewed stakeholder comments and publicly available reports to determine what levels of reliability (*e.g.*, 95% availability) the Boundary Dam and Petra Nova carbon capture equipment has been able to achieve. The findings of this research are summarized below.

SaskPower's Boundary Dam

Overview:

The Boundary Dam is an 824MW coal-fired plant located in Estevan in Saskatchewan, Canada. Owned by SaskPower, it consists of six production units. The plant's production Unit 3, which opened on October 2, 2014, is touted as the world's first commercial-scale carbon capture and storage (CCS) process on a coal-fired power plant. Unit 3 at the Boundary Dam coal–fired power station in Saskatchewan, Canada, completed a refurbishment program in October 2014 that included retrofitting CO_2 capture facilities with a capture capacity of approximately 1 Mtpa of CO_2. The majority of the captured CO_2 is transported via pipeline and used for enhanced oil recovery at the Weyburn Oil Unit, also in Saskatchewan. A portion of the captured CO_2 is transported via pipeline to the nearby Aquistore Project for dedicated geological storage.[1]

Facts:

- Company/Alliance: SaskPower
- Location: Unit #3, Boundary Dam Power Station, Estevan, Saskatchewan, Canada
- Feedstock: Coal

[1] https://sequestration.mit.edu/tools/projects/boundary_dam.html and https://www.power-technology.com/projects/sask-power-boundary/

- Size: Original 139 MW gross upgraded to 160 MW gross; Net after CO_2 capture retrofit (1 Mt/yr) is 110 MW net
- Capture Technology: Post-combustion amine
- CO_2 Fate: EOR in Weyburn field (90% of CO_2). Transportation is via 66 km pipeline built by Cenovus. Any CO_2 not used for EOR is to be used at the Aquistore project 2 km away
- Timing: Started in October 2014. Fully operational in 2016.

Stakeholder Comments Related to Reliability:

UARG (12621) p.25-26: The EPA's cost estimates fail to provide for a design margin in the partial CCS system to ensure that the process equipment can reliably meet the target CO_2 emission rate. Conventional design practice (along with pressure from investors and public utility oversight agencies) dictates that a design margin must be provided when implementing an emissions control system in order to account for unanticipated issues. Cichanowicz CCS Report at 7-3. This is especially true where the control technology is evolving (or, as is the case for CCS, commercially unproven). The EPA's cost estimates assume that a new coal-fired EGU will treat 17.8 percent of its flue gas stream at a 90 percent CO_2 removal rate in order to achieve an overall 16 percent reduction in the unit's emission rate. This design assumes, however, that the unit's CCS system will perfectly achieve 90 percent capture from the slipstream on a continuous basis. This kind of flawless performance is extremely unlikely—particularly given experience at the Boundary Dam CCS installation, where the system was designed for 90 percent capture but was unable to exceed 65 percent capture shortly after its startup and was only active 40 percent of the time during that period. In reality, an EGU developer would include a design margin to account for this uncertainty by allowing for treatment of a larger portion of the unit's emissions, with a corresponding increase in cost. Additionally, rather than supporting a finding of adequate demonstration, experience with CCS at Boundary Dam—which was been plagued by operational and design failures—actually shows that more experience is needed before CCS is ready for widespread application.

UARG (12621) p.27,32-34: Boundary Dam has been plagued by technical problems and outages resulting from fundamental problems in the design of the capture system itself, showing that more work is needed before CCS can be applied on a fleetwide scale. Sask Power has described these problems as "design defects; deficient equipment; flue gas heat losses; and amine degradation challenges." *Cichanowicz CCS Report at 3-5*. Although several major issues arose at the plant, the most significant is that high flue gas temperatures and particulate content interfered with the amine-based chemical system used at Boundary Dam for separating CO_2, which reduced the CO_2 capture rate and necessitated more frequent cleaning of CCS components. Fly ash was also found to be adhering to surfaces inside the flue gas path. *Id*. As a result, the capture system operated only about 40 percent of the time during the unit's first year of operations, and CO_2 capture rates still averaged well below the design value of 90 percent for several years after operations commenced. *Id. at 3-6*. The CCS system had to be taken offline every four to five weeks to clean system components[2]. These performance shortfalls are believed to have cost the company (and Canadian taxpayers) $27 million in penalties and lost revenue. *Id. at 3-6*.

[2] Adam Duckett, The Privilege of Being First, The Chemical Engineer (May 1, 2018), https://www.thechemicalengineer.com/features/the-privilege-of-being-first/ ("Duckett Article").

There are some indications the supplemental projects Sask Power has undertaken have improved the performance and reliability of the Boundary Dam CCS system, although it is unclear if the plant has been able to sustain the performance benchmarks it was designed for. But nonetheless, the fundamental design problems encountered at Boundary Dam indicate that engineers are still figuring out how to apply CCS at coal-fired utility boilers. While experience at Boundary Dam may inform future demonstration projects, it is not sufficient to show CCS is adequately demonstrated.

AEP (12641) p.6: In response to the solicitation for comment C-10, AEP has previously provided extensive comments that CCS has not been adequately demonstrated due to technical, financial, legal, regulatory and practical considerations. The comments remain valid and attached Appendix A and C for detailed comments. With respect to Boundary Dam's first-year (and subsequent years) of operations, the issues experienced present significant concerns regarding the technical feasibility of fully integrated CCS, and do not support the determination that the technology has been adequately demonstrated. In fact, the performance seems to align with many of the expectations identified in public comments and in EPA's proposed rules, which highlighted many of issues associated with first-of-a-kind projects (issues that Boundary Dam is experiencing). Those comments also identified that the experience of multiple CCS projects operating over multiple years would be needed before the technology could be proven to be adequately demonstrated as technically feasible. (AEP provided summaries of various reports on the Boundary Dam project in chronological order (2013-2015 timeframe), to provide context on the experiences of that facility during that period.)

AEP (12641) p.89-90: Operation and performance risks specific to the geologic storage or EOR systems introduces integration concerns as these risks can impact the performance or constrain the operation of the capture system and power plant. For example, a CCS project aligned with an EOR system would be constrained by the assurance that the demand for CO_2 from the EOR operator always meets or exceeds the CO_2 produced by the power plant. When, not if, but when the demand for CO_2 from the EOR operator is insufficient, then the power plant would be forced vent captured CO_2 to the atmosphere, curtail operations or shutdown. Power plants are developed, and in many states are regulated, on the basis of being able to reliably meet a specified demand for electricity – an essential public need. Subjecting the availability of power generation to the availability to EOR operations fails to ensure that the obligation to provide reliable power can be met. Likewise, similar constraints are reasonably to be expected to occur with geologic storage systems where a host of known and unknown variables could constrain the availability and performance of injection wells. AEP experienced these types of constraints during the operation of the validation-scale CCS project. The scope of these risks coupled with a number of legal and regulatory uncertainties associated with long-term geologic storage is another indication that CCS has not been adequately demonstrated to be technically feasible or commercially viable.

EDF (12739) p.17: Even if the EPA were accurately characterizing Boundary Dam's first-year performance, it would be arbitrary and capricious for the EPA to base its analysis entirely on that time period, considering that the unit has operated successfully for several subsequent years. In 2018, the Boundary Dam CCS facility achieved 94 percent availability (excluding periods when it was offline due

to non-CCS-related issues at the power plant).[3] The facility captured over 625,000 metric tons of carbon in 2018, and has captured approximately 2.5 million metric tons of carbon over its lifetime so far.[4]

CATF, NRDC, et al (12611) p.17: Between October 2015 and August 2017, SaskPower implemented major improvements to the process to address solvent degradation, replacing certain piping and equipment sections made with carbon steel with stainless steel, revamping temperature and process controls to meet design specifications and to minimize fouling, and other changes aimed at improving safety and maintenance.[5] The improvements were successful, and by October 2017, the plant had achieved design capacity and the ability to maintain 85 percent operational availability for on-going future operation.[6] The unit experienced downtime during the summer of 2018, but that was related to damage caused by a severe storm – outside of this downtime, the unit was 94 percent available.[7] By the end of January 2019, the unit had captured 2,516,679 tonnes of CO2 since commencing operation and achieved a high capture rate, including a peak one-day rate of 2,580 tonnes for the month of January.[8]

Updates/News/Notes related to Reliability:

-Developments in 2020/2019:

- In a January 2020 article[9], Howard Matthews, the vice-president of power production at SaskPower, said "After five years of hard run time on the BD 3 boiler, we've seen a couple of tube leaks. Of course, when the boiler's not operating, there's no flue gas and no steam for the CCS facility and it takes CCS offline," said Matthews. There will be some scheduled maintenance at Boundary Dam this year. They will not be to the same degree as the two-month shutdown of a year ago (2019), but there will be regularly scheduled maintenance for cleaning work in the tower, absorber and heat exchangers. Nothing unusual is slated, which means there should be very good performance in 2020, Matthews said. "It does take a bit of time when you come offline," said Matthews. "Things cool down and you have to get the chemical back into spec and the temperatures back correct, and then go back online with the compressors." He believes there has been some really good progress on the facility over the past five years. SaskPower's game plan when it embarked on the CCS facility was, first and foremost, to prove the technology and to show it would work as intended. Matthews believes they have done that.

  They also wanted to improve reliability. "We've seen substantial improvement in reliability with some of the work that we've done in the past couple of years," said Matthews. Now their focus is surrounding cost reduction, and trying to get their costs for CCS as low as possible. "The whole

[3] See BD3 Status Update: December 2018, SASKPOWER (Jan. 11, 2019), https://www.saskpower.com/about-us/our-company/blog/bd3-status-update-december-2018.
[4] *Id*.
[5] Michael Monea, An Update Report on the Integrated CCS Project at SaskPower's Boundary Dam Power Station, GHGT-14 (Oct 22, 2018) (Attach. E).
[6] *Id*.
[7] SaskPower, BD3 Status Update: December 2018 (Jan. 11, 2019), https://www.saskpower.com/about-us/ourcompany/blog/bd3-status-update-december-2018.
[8] SaskPower, BD3 Status Update: January 2019 (Feb. 13, 2019) https://www.saskpower.com/about-us/ourcompany/blog/bd3-status-update-january-2019.
[9] https://www.estevanmercury.ca/news/business-energy/saskpower-pleased-with-performance-of-ccs-facility-1.24052833

point of this is with reliability and cost improvements, to give the best information that we can to the decision-makers going forward. Those decisions won't be made for some time. We continue to work on reliability and reducing our costs," said Matthews. The December report for the CCS facility, released last week, shows that it captured 57,590 tonnes of CO2. The average daily capture rate in December was 2,504 tonnes per day, with a peak one-day capture rate of 2,863 tonnes. The acid plant also returned to service in late December and produced 104 tonnes of sulfuric acid. The CCS facility was online 72 per cent of the time in December, compared with an average of 70 per cent for the previous 12 months.

- In a news release[10] issued in November 2019, SaskPower announced that the facility reached three million tonnes of carbon dioxide (CO_2) captured since start-up. They also released data[11] showing the following 12-month averages from December 2018 through December 2019:
  - 70 percent of days online (the monthly target is 85%)
  - 101.3 MW of power produced
  - 51,343 tonnes of CO_2 volume captured
  - 51.3 percent of max capacity (the monthly target is 65%)

- In a November 2019 article[12], Joel Cherry, a consultant for media relations and issues management with SaskPower, said that while there have been challenges associated with the facility, since it was the first of its kind in the world, it has continued to make gains. It went through a planned two-month maintenance shutdown earlier this year, which allowed SaskPower to ensure it was operating efficiently. Recent outages at Unit 3 have dealt with such problems as a shorted wire in an electrostatic precipitator or a boiler tube leak. But operations have been about as strong as expected since a two-month scheduled shutdown ended in May 2019. A shorter shutdown is scheduled to start (week of Nov 10th 2019), and will last about 14 days. The shutdown will be on the capture island side. "Like any other facility, the CCS facility requires periodic maintenance to ensure it continues to operate safely and smoothly. There's always more that we can do to try to improve performance there, but overall I think we're pleased with the performance of the facility," said Cherry.

-Developments in 2018/2017:

- In an interview[13] with the Mercury in early January 2018, Howard Matthews, the acting vice-president of power production at SaskPower, said despite challenges the facility encountered in 2017 it captured 506,000 tonnes of CO_2. When the CCS facility opened in 2014, with technology that was the first of its kind in the world, Matthews said the problems encountered were with the

[10] https://www.saskpower.com/about-us/our-company/blog/bd3-status-update-november2019
[11] https://www.saskpower.com/about-us/our-company/blog/bd3-status-update-december-2019
[12] https://www.estevanmercury.ca/news/business-energy/boundary-dam-ccs-facility-eclipses-a-major-milestone-1.24000770
[13] http://www.estevanmercury.ca/news/local-news/the-past-year-brought-successes-and-challenges-for-ccs-facility-at-boundary-dam-1.23145809 and https://ccsknowledge.com/newsroom/the-past-year-brought-successes-and-challenges-for-ccs-facility-at-boundary-dam

chemistry, including the different amine solutions used. But the issues in summer 2017 were largely with the piping for the CO_2 compressor, which takes the captured CO_2 and compresses it.

In June and early July 2017, the facility was brought offline, so that some planned improvements in the capture process could take place. Those upgrades included adding proper valve isolations to allow crews to carry out future equipment cleaning without shutting down the entire facility. They also added other reserve pieces of equipment, such as heat exchangers, so that those can be maintained without a shutdown. But when SaskPower started putting the CCS facility back online in July, it ran into challenges with the piping arrangement of the compressor. Those compressor issues resulted in a shutdown that was much larger than originally anticipated. The capture facility did not come back online until September.

Matthews said the chemistry components of the facility have been performing well and the CCS facility had its best month ever in October 2017, with more than 85,000 tonnes of CO_2 captured. However, in November, the boiler at Boundary Dam Unit 3 ran into problems, knocking it offline for several weeks. "Because the boiler is offline for some repairs in the turbine, there's no steam and there's no flue gas in the CCS," said Matthews. "By definition, if the power plant unit goes offline, it takes CCS off, but it has nothing to do with CCS." Since Unit 3 went back online on in December 2017, it has been capturing 2,500 to 2,700 tonnes of CO2 per day, close to the pace established in October. Matthews noted that the 506,000 tonnes of CO_2 was captured in 2017 and the plant was online for ~60 percent of the year.

- Developments in 2016:

- *June*: To avoid paying a $91 million penalty, SaskPower renegotiated its CO_2 supply contract with Cenovus. That renegotiation means annual revenues are reduced from $25 million to $16-17 million. Over the 30-year project life this represents reduced revenue of $240 million to $270 million and will further weaken the project economics.[14] Cenovus sold its Saskatchewan interests in 2017 to Whitecap Resources.[15]

  Several major publications have noted what they deem poor economics of the project, among them *The Economist*[16], *The MIT Technology Review,*[17] and *The New York Times.*[18] An April 2016 Parliamentary Budget Office report found that CCS at Boundary Dam doubles the price of electricity.[19]

  Financial concerns appear to fall into three main areas:

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[14] http://leaderpost.com/news/politics/saskpower-renegotiated-contract-to-avoid-90m-penalty
[15] http://www.cbc.ca/news/canada/saskatchewan/cenovus-selling-majority-stake-in-weyburn-oil-project-1.4400817
[16] https://www.economist.com/news/business-and-finance/21622238-although-saskatchewans-new-carbon-capture-facility-start-technology-still
[17] https://www.technologyreview.com/s/533351/a-coal-plant-that-buries-its-greenhouse-gases/
[18] https://www.nytimes.com/2014/07/22/science/corralling-carbon-before-it-belches-from-stack.html and https://www.nytimes.com/2015/10/06/business/energy-environment/companies-struggle-to-make-carbon-capture-viable.html
[19] http://www.cbc.ca/news/canada/saskatchewan/carbon-capture-power-prices-1.3641066

- negative earnings before interest, taxes, depreciation, and amortization, in part due to the pioneering nature of the project;
- the existence of cheaper alternatives, such as wind turbines, which urgently need to be developed; and
- the potential for substantial losses for initial investors (Saskatchewan taxpayers and SaskPower ratepayers), in excess of $1 billion.

- *April*: SaskPower announced that Boundary Dam was operational every hour of the month of March, exceeding their reliability target of 85%[20]. March marked the second time in three months that the plant has been operating throughout the month. 83,497 tonnes of carbon dioxide were captured in March. A total of 757,000 tonnes of CO_2 have been captured at Boundary Dam since the operational start-up in the fall of 2014.

- *January*: Boundary Dam's CCS project successfully operated two successive months with 99% online in January. This brings total capture to 625,000 tons of CO_2 since capture started in 2014[21].

- Developments in 2015:

- *October*: SaskPower announced that it has encountered a number of problems with the capture portion of its Boundary Dam Project[22]. While the exact problems have not been published, it did announce on September 14, 2015, that a new 90,000 kg cylinder would "improve the reliability of the storage for the amine solution being used to capture the CO_2." The issue has resulted in the capture portion to only work 40% of the past year. This has resulted in only 0.4Mt/yr capture of CO_2 since the project started. However, when it was working the capture rate was at the anticipate 90%. The decreased volume of captured CO_2 has created additional problems with the Cenovus Energy who signed a 10-year agreement to purchase the CO_2 for their EOR project. SaskPower now has to pay penalties for the CO_2 shortfall. Saskpower said that the project is on track to be fully operational by the end of 2016.

NRG's Petra Nova at W.A. Parish

Overview:

The Petra Nova project[23], located at NRG's W.A. Parish power generating station near Houston, Texas is reported to be the world's largest post-combustion carbon capture[24] system, capturing carbon dioxide (CO_2) for use in enhanced oil recovery (EOR). At 240 megawatts, the project is a joint venture between NRG Energy and JX Nippon Oil and Gas Exploration Corporation, and received support from the U.S.

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[20] http://www.captureready.com/EN/Channels/News/showDetail.asp?objID=4617&isNew=

[21] http://www.estevanmercury.ca/news/business-energy/bd3-operated-as-advertised-in-january-1.2173858

[22] http://www.powermag.com/saskpower-admits-to-problems-at-first-full-scale-carbon-capture-project-at-boundary-dam-plant/

[23] http://www.nrg.com/generation/projects/petra-nova/

[24] https://www.energy.gov/fe/science-innovation/carbon-capture-and-storage-research/carbon-capture-rd/post-combustion-carbon

Department of Energy (DOE). It uses a process jointly developed by Mitsubishi Heavy Industries and the Kansai Electric Power Co. which utilizes a high-performance solvent to separate the CO_2 from the flue gas produced by conventional coal combustion.[25]

Funded in part by the DOE and originally conceived as a 60-megawatt electric (MWe) capture project, the project sponsors expanded the design to capture emissions from 240 MWe of generation at the Houston-area power plant, quadrupling the size of the capture project without additional federal investment. During performance testing, the system demonstrated a carbon capture rate of more than 90 percent. The Petra Nova coal-fired power plant is one of only two operating power plants with carbon capture and storage in the world, and it is the only such facility in the United States.

Petra Nova's post-combustion CO_2 capture system began operations in January 2017. The 240-megawatt (MW) carbon capture system that was added to Unit 8 (654 MW capacity) of the existing W.A. Parish pulverized coal-fired generating plant receives about 37% of Unit 8's emissions, which are diverted through a flue gas slipstream. Petra Nova's carbon-capture system is designed to capture about 90% of the CO_2 emitted from the flue gas slipstream, or about 33% of the total emissions from Unit 8. The post-combustion process is energy intensive and requires a dedicated natural gas unit to accommodate the energy requirements of the carbon-capture process. The carbon dioxide captured by Petra Nova's system is then used in enhanced oil recovery at nearby oil fields. Enhanced oil recovery involves injecting water, chemicals, or gases (such as carbon dioxide) into oil reservoirs to increase the ability of oil to flow to a well.[26]

Facts:

- Company/Alliance: Petra Nova Holdings: a 50/50 partnership between NRG Energy and JX Nippon Oil & Gas Exploration Corp.
- Location: Unit 8, W.A. Parish plant, Thompsons, 60KM from Houston, Texas, USA
- Feedstock: Coal
- Size: 240 MW slip stream from 610 MW unit.
- Capture: 1.4 Mt of CO_2 captured annually (90% capture)
- Capture Technology: Post-combustion: KM-CDR amine scrubbing CO_2 developed by MHI and KEPCO
- CO_2 Fate: 82-mile pipeline for onshore EOR in Hilcorp's West Ranch Oil Field in Jackson County, Texas
- Timing: Project was originally scheduled to start at the end of 2016. The project began commercial operations on January 10, 2017.

Stakeholder Comments Related to Reliability:

UARG (12621) p.31: Experience at Petra Nova does not support widespread application of CCS because the project is economical only if NRG Energy is able to sell captured CO_2 for EOR at a price of at least

[25] http://sequestration.mit.edu/tools/projects/wa_parish.html
[26] https://www.netl.doe.gov/research/coal/project-information/fe0003311

$50 per barrel (Cichanowicz CCS Report at 3-7 to 3-8). Opportunities for EOR are limited to just a few areas of the country, and while Petra Nova's location near a willing purchaser for captured CO_2 helps to make CCS economical under the plant's unique circumstances, for most utility boilers the costs of transporting captured CO_2 to suitable EOR sites will be prohibitive. In any event, the Petra Nova project has been in operation only since January 2017. Several years of operation under variable load conditions are needed before EPA could draw conclusions about the long-term performance of CCS at Petra Nova.

ACC (12510) p.3: There are only two operating utility-scale CCS projects, Boundary Dam in Canada and Petra Nova in the United States (in Texas). While it is encouraging that these projects have successfully been brought online – and Petra Nova's startup was on time and on budget – they do not provide evidence of adequate demonstration for widespread deployment. Additionally, both are tied to EOR for revenue. The sale of CO_2 for EOR is a positive in the overall economics and was important to the development of these projects. However, many parts of our country have no access to mature oil fields, or they lack access to geologic storage, and these are limitations to further CCS development. The very high cost of CCS continues to be a major barrier to industry-wide use.

EDF (12739) p.18: In the Proposal, the EPA has also requested comment on whether the government support provided for the Boundary Dam and Petra Nova projects "raises concerns as to the extent to which developers are willing to accept the risks associated with the operation and long-term reliability of CCS technology." As shown above, Boundary Dam does not raise doubts about the operation and long-term reliability of CCS technology, and EPA does not even suggest as much about Petra Nova. In the Response to Comments accompanying the 2015 Final Rule, the EPA directly addressed questions about the role of government support. For instance, EPA observed that, even if that support was originally dedicated to supporting technologies that were not yet "viable" or "in commercial service," "that does not reflect the state of these technologies today."[27] Furthermore, "major types of energy used to generate electricity are routinely the beneficiaries of government subsidies or support," and therefore subsidies are not "conclusive that the technology is not or will not be commercially viable."[28] Indeed, the private sector provided the vast majority of funding for Petra Nova.[29] This investment in these advanced facilities is a strong, tangible sign of private sector interest in the further development and deployment of this technology.[30]

Updates/News/Notes related to Reliability:

-Developments in 2020/2019:

- An August 2019 Financial Times article[31], makes the following points regarding Petra Nova:

[27] Response to Comments on the 2014 Proposed Rule (Aug. 3, 2015) at 2-129 to 2-130

[28] *Id*. at 2-133

[29] Petra Nova W.A. Parish Fact Sheet: https://sequestration.mit.edu/tools/projects/wa_parish.html; DOE Petra Nova info: https://www.energy.gov/fe/petra-nova-wa-parish-project

[30] Federal funding in nascent pollution control technology is not unusual and has led to signal successes in later commercial deployment. See Memorandum from Mike Laney, RTI International, on History of Flue Gas Desulfurization Use in United States – 1970-1976, at unnumbered p. 3 (July 11, 2015)

[31] https://www.ft.com/content/52552bf8-c024-11e9-89e2-41e555e96722

Boundary Dam says it has removed 2.8m tonnes of CO_2 since it launched, while Petra Nova says that when it is operating at 100 percent capacity it removes 90 percent of the CO_2 at its plant, or 5,200 tonnes a day — the equivalent of taking 350,000 cars off the road.

But David Schlissel, of the Institute for Energy Economics and Financial Analysis, says both plants have not lived up to their hype. The Petra Nova plant captures just over a third of the total flue gas from just one of four coal-fired units, he says. And Boundary Dam has an overall capture rate of 51 percent, he says — well below the 90 percent target.

Mr. Schlissel estimates that the cost of adding carbon capture and storage to an average US coal plant is almost four times the cost of solar and storage in parts of the US. In addition, using the CO_2 to extract oil only adds to emissions when the oil is burnt, he says.

"It's really expensive and the coal plants can't compete [with wind or solar and storage]," he says. "It's basically a plan to keep uneconomic coal plants operating. It's a fantasy."

-Developments in 2018/2017:

- *October 2017*: DOE Article[32]
  The Petra Nova project reached a major milestone, capturing more than 1 million tons of CO_2 for use in EOR. The project has been successfully demonstrating an advanced amine-based CO_2-capture technology that removes 90 percent of the CO_2 emitted from a flue gas stream. The project began commercial operations on January 10, 2017. On April 13, 2017 Secretary of Energy Rick Perry attended a ribbon cutting ceremony for the project, where he noted that Petra Nova "demonstrates that clean coal technologies can have a meaningful and positive impact on the Nation's energy security and economic growth." The CO_2 captured from Petra Nova is used for EOR at the West Ranch Oil Field, which has increased oil production from 300 barrels per day when it began operations to about 4,000 barrels per day today.
- *October 2017*: Quora article[33] *expressing concerns about parasitic load*: In the case of Petra Nova, NRG built a 75MW gas fired power station[34] next to the facility to generate the electricity and steam needed to run the CCS process. The CCS process is projected to consume 45MW of so called *parasitic load* and result in an additional 446,000 tons of CO_2 emissions annually — reducing the net CO_2 sequestered to 0.95 Mtpa, which represents just 6.2% of the Parish plant's 2015 emissions.
- *August 2017*: Petra Nova was selected as POWER magazine's plant of the year[35] for 2017. POWER magazine noted that at 240 MW, Petra Nova is more than double the power capacity of

[32] https://www.energy.gov/fe/articles/doe-supported-petra-nova-captures-more-1-million-tons-co2
[33] https://www.quora.com/Does-the-best-CCS-power-station-in-the-world-provide-a-model-for-Australia
[34] https://www.forbes.com/sites/uciliawang/2014/07/15/nrgs-1b-bet-to-show-how-carbon-capture-could-be-feasible-for-coal-power-plants/2/#70cbf5a5321b
[35] http://www.powermag.com/capturing-carbon-and-seizing-innovation-petra-nova-is-powers-plant-of-the-year/?printmode=1

SaskPower's Boundary Dam project (POWER's 2015 Plant of the Year), and it is designed to capture 60% more CO_2—or about 1.6 million tons per year. When POWER visited the facility in June 2017, it had already captured more than 600,000 tons.

- *April 2017*: DOE article[36] At its current level of operation, Petra Nova will capture more than 5,000 tons of CO_2 per day, which will be used for enhanced oil recovery (EOR) at the West Ranch Oil Field. The project is expected to boost production at West Ranch from 500 barrels per day to approximately 15,000 barrels per day. It is estimated that the field holds 60 million barrels of oil recoverable from EOR operations.

[36] https://energy.gov/articles/secretary-perry-celebrates-successful-completion-petra-nova-carbon-capture-project