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Canada's Proposed Clean Electricity Regulations – Implications for CCUS

A review of information to date on the Government of Canada's proposed Clean Electricity Regulations as it relates to carbon capture, utilization and storage.

INTRODUCTION

A clean supply of electricity from low and non-emitting sources will be an essential part of Canada's ambitions to reduce CO_2 emissions 40 to 45 per cent below 2005 levels by 2030 and to achieve net-zero greenhouse gas emissions by 2050.

Nationally, about 85% of power already comes from non-emitting sources. For the remaining electricity producers, the Government of Canada's proposed Clean Electricity Regulations will reduce carbon emissions from fossil fuel generated electricity by implementing performance standards starting in 2035.

The Knowledge Centre has prepared this review document to aid industry and other organizations in navigating the proposed Clean Electricity Regulations (CER) as they pertain to carbon capture, utilization, and storage (CCS/CCUS) considerations.

Information in this document includes an aggregated account of federal documentation provided by Environment and Climate Change Canada. This document provides ease of reference but should not be used to take the place of detailed requirements. It does not represent a full account of all aspects of the CER.

The draft CER was published on August 19, 2023. Environment and Climate Change Canada is soliciting comments until the consultation period closes on November 2, 2023. The final regulations are expected to be published in the *Canada Gazette Part II* in 2024.

OVERVIEW, APPLICATION & ENFORCEMENT

This review document begins with an overview, application, reporting and enforcement of the proposed regulations. It then explores key messages around implications for CCS, the history of electricity regulations in Canada, and timelines for compliance. The document does a deep-dive into how CCS is treated within the proposed Clean Electricity Regulations, and how it is treated in the United States. Finally, it explores lessons learned from CCS on power generation to date, the value of sharing knowledge, and concludes with other considerations and insights.

Overview of CER

On August 19, 2023, Environment and Climate Change Canada released the *draft Clean Electricity Regulations* (CER) and accompanying Technical Backgrounder and Regulatory Impact Analysis Statement (RIAS)[1] under the statutory authority of *the Canadian Environmental Protection Act, 1999.*

The 2022 National Inventory Report indicates that in 2020 about 15% of Canada's electricity came from emitting sources that use fossil fuels – resulting in 62 million tonnes (Mt) of CO_2 emissions.[2] According to the RIAS, without the CER, power generation that comes from emitting sources is expected to reach just over 6% of Canada's power supply by 2050. On the other hand, with the CER, the government expects emitting power to account for close to 1% of the electricity system in the same timeframe. **Therefore, the CER accounts for around a 5% reduction in emitting power in Canada.**

The CER is intended to minimize greenhouse gas (GHG) emissions from Canada's electricity systems in support of the G7 countries' commitment to net-zero electricity systems by 2035 and net-zero economies by 2050.[3] The CER intends to set a technology-neutral emissions standard for electricity that is sold to the grid as of 2035.

The proposed regulations limit carbon emissions to an emission performance standard of 30 tonnes of CO_2 per GWh of electricity produced (30 t/GWh) a year.

The performance standard will take effect on the latter of January 1, 2035, or 20 years after a unit is commissioned (with some exceptions). Carbon capture, utilization and storage (CCS/CCUS) will be a key means of reducing carbon emissions from fossil-fuel generated electricity, and therefore **the CER intrinsically involves CCS development**.

The 30 t/GWh value would result in an emissions intensity of natural gas electricity generation with carbon capture achieving nearly a 95% capture rate, which may be attainable by 2035, but not without challenges.

The final version of the CER is expected to be published in 2024. Eligible generating units must be registered with the Ministry by the end of 2025, and emissions intensity restrictions will take effect starting January 1, 2035.

Application, Reporting & Enforcement

The regulations will apply to electricity generating units, which means an assembly comprised of any equipment that is physically connected and operates to generate electricity. A unit includes a boiler or combustion engine, and may also include duct burners, heat recovery systems, steam turbines, generators, and emission control systems.

The regulations apply to a unit that **meets all of** the following three criteria on or after January 1, 2025:

- ✓ Electricity generation **capacity of 25 MW** or more
- ✓ Generates electricity using **fossil fuel**
- ✓ Is connected to an electricity system that is **subject to NERC** standards (That is, the requirement does not apply to electricity generating units unconnected to the larger grid, industrial facilities generating power for internal use, and/or emergency backup generators at public and private facilities.)

Only units that are net exporters of electricity to the grid in a calendar year are subject to the regulation for that year.

Owners of new and existing units must demonstrate their awareness of these regulatory obligations by issuing a Registration Report to the Minister by December 31, 2025 (or within 60 days of the unit being commissioned if it is commissioned after January 1, 2025).

A short report must be submitted to the Minister, containing the net exports of the applicable units for each calendar year.

Exemptions may be granted if a declaration is submitted to the Minister, stating that net exports from the unit are less than or equal to 0 MW for the calendar year.

A report must be submitted for each calendar year the regulation applies to a generating unit. The report must contain information including:

- ✓ Emissions intensity
- ✓ Total emissions
- ✓ Total fuel consumed
- ✓ Total generation and
- ✓ Operating hours

Enforcement falls under the *Compliance and Enforcement Policy for the Canadian Environmental Protection Act.*[4] If the emissions intensity limits are not met, enforcement actions may include financial penalties, injunctions, or even criminal prosecution. While the regulation requires a "responsible person" to submit applications and annual reports, it is unclear if this person assumes any liability for compliance, or if prosecution could extend to a company's CEO, board members, or others.

ELECTRICITY REGULATION OVERVIEW

The CER currently proposes a 40 t/GWh limit for units that abate emissions with CCS for the first 7 years of operation or up to 2039, and a 30 t/GWh limit thereafter. **We propose that the emission intensity limit for the CCUS exemption under the CER is revisited.** Any regulation that fosters CCS should help to enable the deployment of the technology by supporting the best efforts of industry to reduce emissions, foster innovation, and rely on continuous improvement and optimizations. For the CER to not hinder the application of CCS to meet limits it must:

- Recognize the developmental and optimization cycles required for applying CCS at a commercial scale for gas-fired electricity generation;
- Grant additional leniency for operators who install, operate, and optimize CCS equipment in good faith to extend the useful life of existing generating units;
- Reduce risks on investments in novel CCS technologies and applications; and
- Be closer aligned with US proposed power regulations.

Key Message

CCS is an important technology for reducing emissions in all sectors and the price of carbon is an important part of supporting a business case for CCS. Incentives offered by the federal government have begun to help drive CCS projects to be **a choice** for companies to prevent pollution. The CER effectively requires CCS for fossil fuel electricity generation facilities, taking away the choice of how to reduce emissions and making them somewhat **technology-forced.**

There may be unintended consequences from requiring too stringent and punitive emissions intensity limits through the CER. If the limits are unachievable or there is a question of whether they could be met, this would disincentivize investments in CCS projects in the electricity generation sector.

CCS is a proven solution for reducing emissions from base-load electricity generation

- CCS projects in all sectors can look to improve capture capacity and reduce project risks by accessing lessons learned from SaskPower's Boundary Dam CCS facility (the world's first fully-integrated post-combustion CCS on coal-fired power).
- There are no current operating CCS facilities on natural-gas fired electricity generation at a commercial scale. This means it will take time and iterations to prove CCS on natural gas-fired power.

Unintended consequences from extraneous emissions intensity limits

- To meet the proposed limit, CCS facilities must achieve and maintain a 95% CO_2 capture efficiency, which may be attainable under steady-state conditions in the future but is unlikely to be achievable under normal or unforeseen operational fluctuations and based on current operational experience averaged over a year-long period.
- Having too stringent of an emission intensity limit could lead to longer shutdowns or enforcement actions on facilities even with effective capture units. Base load power may be at risk if those facilities are unable to meet the requirement.
- Considering major public and private investments associated with these developments, penalizing owners who implement CCS in good faith could lead to a misrepresentation of the capabilities of CCS by the power generation industry and the public.
- Many companies operate multiple units that will be subject to the CER. Consideration should be given under the CER for companies that operate these multiple units because of the substantial capital cost of implementing them across their power fleet.
- For coal, the CER also requires increased capital outlay given that units must switch to natural gas and then have CCS attached, when similar emission reductions could be achieved from applying CCS on coal directly without conversion.
- Despite its successful, almost decade of operations, Boundary Dam's CCS facility (and all coal-fired generation facilities) will not enable the power unit to meet the emissions intensity limit and, thus, would no longer be permitted to operate.

Flexibility and leniency for CCS operators

- The CER does not include provisions for external emergency conditions for CCS facilities such as equipment or CO_2 pipeline failures. This may put baseload power at risk in areas with high reliance on natural gas and CCS. Allowing provisions for unforeseen circumstances (e.g. a single-point equipment failure such as a compressor), and leniency in terms of enforcement for operators that demonstrate investments in abatement and capture optimizations, is strongly recommended.

Timelines for compliance

- Natural gas-fired units have varying timelines for compliance between 2035 and 2044, depending on whether the unit was converted from coal and the unit's commissioning date. Natural gas- and coal-fired power generation units are typically designed for 30- and 50-year lifespans, respectively. Using a prescribed 20-year life will require many units to add CCS or shut down well before their expected end-of-life.
- The federal government, in supporting documents for the CER, expects that 35% of currently emitting units will implement CCS. This would represent at least a doubling of CCS projects entering development stages across all industries by 2035. Competition for labour and resources during this period may delay or increase the cost of projects. Demand for these resources is further driven by time-limited Canadian and international incentives (45Q and the CCUS Investment Tax Credit) and increasing carbon prices.

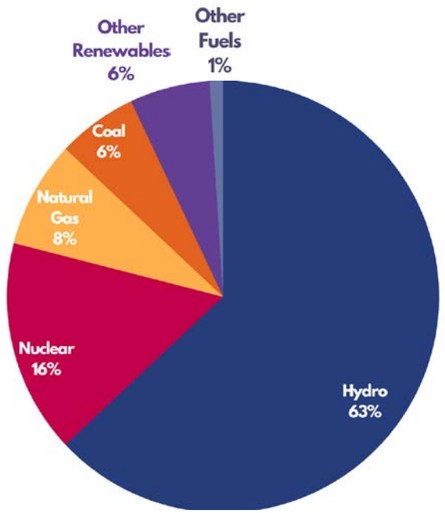
Applying next generation CCS technologies

- CCS using amine technology is not experimental. Major demonstration projects like Boundary Dam CCS ensure lessons can be learned and shared to improve efficiency and reduce costs and investment risks for future projects. Having a hard and punitive emissions intensity limit represents a significant challenge for major investments in the next wave of CCS technologies being used and tested at a commercial scale within the Canadian electricity generation sector.
- The CER assumes that technology improvements justify a reduction in the emissions intensity limit from 40 to 30 t/GWh, however, the limit itself may reduce the willingness of electricity producers to choose emerging capture technologies and in turn, the ability of Canadian innovators to lead these efforts.
- This is misaligned with Canada's Carbon Management Strategy's first key priority of accelerating innovation, and research, development and deployment - including the scale up and viability of CCS technologies across sectors.[5]

OVERVIEW OF ELECTRICITY REGULATION IN CANADA

Canada's Electricity Landscape

Canada has a vast natural landscape, and as such, the natural resources that fuel power generation vary across the country. Some regions have access to hydro-generated electricity, some have developed nuclear power, while others have an abundance of fossil fuels that are the primary base loads of power generation. These natural resources, with other renewable technologies in the mix, have been used to reliably power the homes of Canadians and reflect the state of energy security for the nation.



Electricity Generation by Source in Canada, 2020 (2022 National Inventory Report)

Even with regional differences, Canada operates with a high percentage of clean electricity today, with 85% of power coming from non-emitting sources. 63% comes from hydro, 16% from nuclear, and 6% from other renewables. When applying the provisions of the CER to the remaining power sources, the RIAS expects the CER to impact 125 units of various sizes across Canada.

Alberta, Saskatchewan and Nova Scotia are the provinces with the most emitting generation sources in Canada, with over 78% of their power coming from fossil fuels. As a result, they will face more significant impacts from the CER. The RIAS assumes new provincial interties will be constructed to help distribute low-emission power to regions currently dependent on fossil fuels. This is particularly important in Atlantic Canada given that there are fewer known geological storage opportunities for CO_2 compared to Alberta and Saskatchewan.[6]

Evolution of Electricity Regulations in Canada

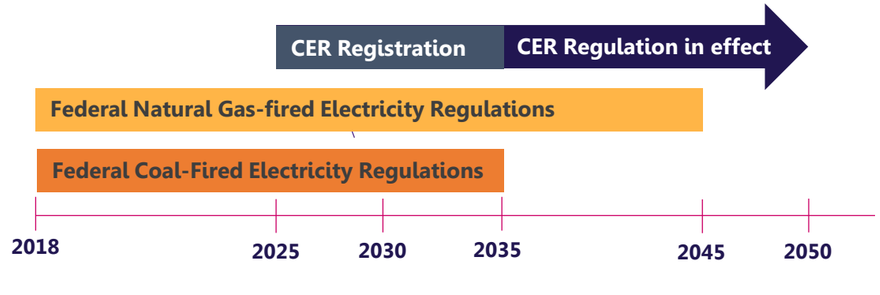
Federal legislation

The *Canadian Environmental Protection Act (CEPA)* provides the authority for the government to make regulations to manage pollution in Canada. Electricity regulations are made under CEPA. The current electricity regulations for coal and natural gas-fired power will be repealed by the CER in 2035 and 2045 respectively.

In 2012, the *Regulations Amending the Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations (Coal Regulations)*[7] were published. They were amended in 2018 to accelerate emissions reduction commitments under the Paris Agreement, phasing out unabated coal-fired electricity generation by 2030. They will be repealed in 2035.

The *Regulations Limiting Carbon Dioxide Emissions from Natural Gas-fired Generation of Electricity (Natural Gas Regulations)*[8] limits CO_2 emissions from natural gas fueled power generation beginning in 2019. It includes emissions limits for generating units converted from coal to natural gas. Currently, new fossil fuel-fired units must meet an average annual performance standard of 420t/GWh if they are larger than 150 MW, or 550t/GWh if they have a capacity smaller than 150 MW.

Gas plants commissioned before 2025 have a 20-year useful life before they need abatement. They can fall under the Natural Gas Regulations until 2045 at the latest, at which point they will need to comply with the CER. Therefore, the Natural Gas regulations are set to be repealed in 2045, however, the CER applies to most power plants starting in 2035.



The Output-Based Pricing System for carbon pricing came into effect in 2019 under the *Greenhouse Gas Pollution Pricing Act*. In 2030, the price on carbon is expected to reach $170/t. Electricity generated from gaseous fuel will be fully exposed to that price in 2030, if the unit was commissioned on or after January 1, 2021.[9]

Equivalency agreements

Because the environment can be regulated by both federal and provincial jurisdictions, equivalency agreements under CEPA act to minimize duplication. Currently, Nova Scotia and Saskatchewan have equivalency agreements with Canada, as their regulations are considered equal to, or more stringent than, federal regulations. As such, in those jurisdictions, federal electricity-related regulations stand down.[10] Both agreements terminate on December 31, 2024, but they include renewal considerations. Since the Coal and Natural Gas regulations are set to be repealed, new equivalency agreements may be pursued.

Electricity regulations and CCS

Canadian legislation does not specifically dictate that CCS must be added to fossil fuel power generation. However, the stringency of the CER enables CCS as a tool for achieving the requirements. **The economic model in the RIAS assumes 56% of emitting units would continue operating under the limited hour exemption, 35% would implement CCS, and 9% would be retired early.** Clarity is required around how these assumptions were made and which units are expected to implement CCS.

TIMELINES FOR COMPLIANCE

Timelines

The draft legislation includes a phased approach that is intended to allow existing units time to develop a compliance strategy and build the necessary infrastructure to meet the annual emission performance standard of 30 t/GWh. Timelines for compliance vary primarily by fuel type and date of commissioning.

CER Timelines for Compliance by Fuel Type

	Units commissioned before 2025	Units commissioned after January 1, 2025 or increased capacity by > 10% since registration
Natural Gas	Commissioning year plus 20 years (before 2045)	January 1, 2035
Coal	Any coal: January 1, 2035	
Coal to Gas Conversion	1975 or earlier: January 1, 2035	
	Commissioned after 1975: 2035-2039	

For all generating units

Units commissioned before January 1, 2025 must meet emission intensity limits by January 1 of the year following the unit's prescribed end-of-life. The prescribed end-of-life is defined as December 31 of the calendar year that is 20 years after the commissioning date.

Gas and coal-fired power generation units are typically designed for 30- and 50-year lifespans, respectively. **Using a prescribed 20-year life will require many units to add CCS or shut down well before their expected end of life.**

Units that combust coal or petroleum coke

The 30 t/GWh limit starts January 1, 2035. Coal-fired units typically have emissions around 1000 t/GWh. **Even if CCS is installed at 95% capture efficiency, it will not be possible to reduce emissions from coal below 30 t/GWh by 2035.** This restriction will primarily impact Saskatchewan and Nova Scotia, which both have several coal-fired power plants.

Units converted from coal to gas

Generating units converted from coal to gas are considered "significantly modified", not new units: their commissioning date remains the original commissioning date of the coal fired plant.

For units commissioned in 1975 or later, their useful life may end as late as December 31, 2029. Depending upon their initial emissions intensity, these units may be eligible for useful life extensions. Converted units must comply with the CER after their useful life extension period ends, as defined in the *Coal Regulations.* The CER's RIAS declares that "significantly modified units have no pathway to operate without a performance standard past 2039". Clarity is required on this timing, but it could mean **a later requirement to install CCS – up to 4 extra years.**

How timelines impact CCS considerations for power generation

The visual below is an aggressive timeline for developing a CCS facility, showing a project taking a minimum of six years from feasibility to operation. This timeline is optimistic considering external factors such as supply chain capacity, skilled labour availability, and permitting processes, which may increase the time (and/or cost) required for projects. Government policies are expected to exacerbate competition for talent and resources during the period required to build CCS infrastructure.

- International incentives, such as 45Q in the US and comparable incentives in Europe are stimulating demand for CCS inputs.
- Canada's CCUS Investment Tax Credit will be available for projects until 2040, but incentives halve in 2031.
- To access the CER's seven-year 'grace period' to optimize capture projects to reduce emissions from 40 to 30 t/GWh, projects would need to begin operations in 2032.

Given that the federal government expects that 35% (an estimated 40 projects) of currently emitting units will implement CCS under the CER, and that the timeline for most units to comply is 2035, the requirements are likely unachievable for many units and may result in fully functional stranded assets.

CAPTURE REQUIREMENTS WITHIN THE CER

Exemptions

The CER has several exemptions for units to exceed the 30 t/GWh emissions intensity limit:

Emergency circumstances exemption: If the province or operator of the provincial electricity system orders the unit to produce electricity, the unit may be exempt from the regulation for that emergency period. **Capture facilities using amine-technology have relatively long start-up periods, therefore units used in emergency circumstances would run unabated for several hours after startup even if a capture facility is present.**

450 hours exemption: As an alternative to the 30 t/GWh performance standard, gas-fired units can operate at any emissions intensity up to a total of 150 kilotonnes per year, if they operate for less than 450 hours (18.75 days) in that calendar year.

Under 25 MW exemption: Units producing under 25 MW are excluded from the regulation because they are not expected to significantly contribute to Canada's electricity sector emissions.

Onsite electricity use exemption: Units not connected to NERC standard electricity systems are exempt. This would include units that are mainly for internal use, such as in industrial complexes, and emergency backup generators for hospitals and other public or private facilities.

Net import exemption: Units not exporting a net positive amount of electricity in a calendar year are also exempt. Such exemptions may be granted if a declaration is submitted to the Minister, stating that net exports from the unit are less than or equal to 0 MW for the calendar year. **This is relevant to industrial processes considering adding CCS and combined heat and power (CHP) units alongside CCS**. The CER emissions limit will only apply to these facilities if they export a net positive amount of power to the grid annually.

CCS Exemption

Units with new CCS facilities may be partially exempt. The proposed regulation recognizes that carbon capture plants may not perform as expected in their first years of operation. **There is an operating experience window of up to seven-years to bring emissions intensity down.** The 30 t/GWh regulation will apply in 2040 and later, as the regulation assumes carbon capture technology will have improved to the point the exemption is no longer needed.

How it works:
Until December 31, 2039, electricity generating units may have an emissions intensity up to 40 t/GWh (i.e. **approximately a 91% capture efficiency rate**) if:

- The unit includes a carbon capture unit that started operating within the last seven calendar years
- Documentation demonstrates the unit operated at or below 30 t/GWh for two periods of at least 12 hours, at least four months apart, in the calendar year for which the annual report is generated.

A unit's total emissions can exclude the quantity of emissions captured by CCS only if those emissions are permanently sequestered in a deep saline aquifer for the sole purpose of CO_2 storage, or a depleted oil reservoir for the purpose of enhanced oil recovery (EOR). Importantly, the CCUS Investment Tax Credit considers EOR an ineligible use of CO_2. Clarity is required on whether certain forms of utilization are considered storage.

Meeting Emissions Limits with Carbon Capture

Capture efficiency rates: Currently, some amine-based carbon capture vendors guarantee 95% capture rates. It might be possible to achieve this under consistent conditions in the future. However, considering current yearly operational experiences and potential unexpected changes, it seems unlikely. While the regulation recognizes this may not be immediately achievable for first-of-a-kind capture plants, it does not include accommodations for start-up and transient conditions that will occur during normal operations. Investments in capture efficiency improvements have diminishing returns and become less economical as capture efficiency approaches 100%.

Capture plant start-up time: Capture plants will typically not be able to start up until after the generating unit starts up, because amine capture plants need to be warmed up with steam from the main boiler. This may result in unabated flue gas being released for several hours upon unit startup. This is particularly significant for peaker plants, as they may start up and shut down frequently, resulting in large amounts of uncaptured emissions.

Provisions required to accommodate external factors: The CER does not include provisions for emergency conditions for CCS facilities such as equipment or CO_2 pipeline failures. The CCUS-ITC, in contrast, does not penalize capture facilities for unforeseen upset conditions, while generating units would be forced to shut down under the CER or risk exceeding emission limits. This puts baseload power at risk in areas with high reliance on natural gas and CCS.

Capture plant optimization: Carbon capture is a developing technology, and time will be required to optimize new capture plants for their particular flue gas and environmental conditions. Time will be required to optimize all capture plants, beyond a 2039 timeline. The sharing of knowledge between projects will be essential to accelerate the development of highly efficient and reliable capture systems.

95% capture or a 30 t/GWh limit will be difficult to achieve under normal operational fluctuations. 40 t/GWh, or a capture rate of approximately 91%, may be more reasonable when startups and transient conditions are considered. If 40 t/GWh was set as the standard, matching American regulations, a higher limit for early operations of CCS plants would need to be determined. At minimum, the proposed cutoff of 2039 of the 40t/GWh exemption for CCS should be extended to a minimum of seven years after project completion regardless of the year completed.

Consequences to operations of ensuring below 30 or 40 t/GWh for CCS: It will be challenging for new CCS facilities to measure and forecast intensity in real-time. If a unit is trending towards missing its target for the calendar year, a decision will have to be made between shutting down power generation or risking enforcement actions. Shutdowns would negatively impact both base load power supplies and the ability to gain CCS operating experience. Enforcement actions against facilities with CCS could be considered unjust given the substantial capital costs (in the hundreds of millions of dollars) to comply with the CER and power generators' good-faith efforts to reduce emissions as much as they can. Additionally, considering the major role governments are committing to investing in these projects (e.g. through the CCUS-ITC) shutting down electricity generation operations for effective, yet underperforming, capture facilities could be considered a misuse of public funds.

COMMENTARY ON PROPOSED US EPA ELECTRICITY STANDARDS

Comparing Proposed US Regulations

Understanding the requirements in the US is important, given the existence of interties and regional electricity realities that exist with a shared NERC grid system.

The US Environmental Protection Agency (US EPA) has proposed emissions standards for fossil-fuel fired generating units under the *US Clean Air Act* in section 111.[11] These standards are generally less stringent than the proposed Canadian regulations.

- ✓ Coal-fired power is allowed to continue to operate. Emissions control requirements start in 2030 for coal-fired units and for other existing steam generating units.
- ✓ Natural gas-fired units that do not co-fire with hydrogen, are only required to meet an emissions standard that will require CCS if the unit has a capacity factor exceeding 50% and has a capacity of over 300MW.
- ✓ There are various capture rates required for CCS depending on circumstances.

For coal facilities planning to operate past 2039, an emissions reduction of 88.4% or CCS with a capture efficiency of 90% will be required. For existing gas-fired units, emissions limiting requirements start between 2032 and 2038. For new gas-fired units, limits apply as soon as they are constructed and become more stringent between 2032 and 2038.[12]

The US EPA has set different standards depending on the utilization rates of generating units.

- "Low load" or peaking units are defined as combustion turbines operating at a capacity factor of less than 20% (compared to the CER's 5%).
- "Intermediate load" is between 20% and a source-specific upper bound.
- "Base load" is for units operating above the intermediate load bound.

Low load facilities must use low emitting fuels with standards of performance from 120 to 160 lbCO_2/MMBtu (186-248 t/GWh) depending on the type of fuel combusted. Base and intermediate load facilities will be required to meet standards in a phased approach. Base load facilities must meet a standard based on 90% CO_2 capture using CCS by 2035 (compared to CER 95%) with an associated standard the equivalent of 40.8 t/GWh.

Similar to Canada, to govern power within their jurisdiction, states must submit plans to the US EPA that are at least as stringent as the US EPA's emission guidelines.[13]

The process for how the US EPA determines the prescribed emission intensity levels for power generation and application of CCS is well articulated.

Clean Air Task Force response to US EPA

Our colleagues at the Clean Air Task Force, in partnership with the Nature Conservancy and the Natural Resources Defence Council, provided an in-depth response on the impact the US EPA regulations would have and proposed recommendations to ensure the effective and efficient deployment of CCS across power emitting facilities in the US.[14]

In particular, they note that section 111 is "technology-forcing" – as is the Canadian CER. Importantly, if CCS technology is forced under regulations, it should require achievability. Achievability means it is within the realm of the adequately demonstrated system's efficiency, although it need not necessarily be routinely achieved within the industry prior to its adoption.

The response makes it clear that after the US EPA makes this determination, "it must exercise its discretion to choose an achievable emission level which represents the best balance of economic, environmental, and energy considerations." Under this analysis, "the amount of air pollution [is] a relevant factor to be weighed when determining the optimal standard."

Reviewing courts have upheld the US EPA standard on the basis of:

1) Literature reviews and operation of one plant in the US;
2) Various test programs;
3) Pilot plant technology; and
4) Testimony from experts and vendors.

CATF clarifies that the US EPA may also base standards upon "the reasonable extrapolation of a technology's performance in other industries" and project "technological improvements" based on "known elements" of existing pollution control systems, including where the US EPA has concluded "manufacturers could 'improve, test, and apply' technology during the lead time period" for compliance.

> *"Section 111, like many other Clean Air Act provisions, is a technology-forcing. Congress expected standards of performance under Section 111 to "press for the development and application of improved technology," and the statute "looks toward what may fairly be projected for the regulatory future, rather than the state of the art at the present." Following this approach, for the purposes of Section 111, An adequately demonstrated system is one which has been shown to be reasonably reliable, reasonably efficient, and which can reasonably be expected to serve the interests of pollution control without becoming exorbitantly costly in an economic or environmental way. An achievable standard is one which is within the realm of the adequately demonstrated system's efficiency and which, while not at a level that is purely theoretical or experimental, need not necessarily be routinely achieved within the industry prior to its adoption."*

APPLYING LESSONS LEARNED FROM CCS ON POWER GENERATION

Lessons Learned from CCS on Power Generation

There are only two large-scale CCS facilities in the world operating on power plants – SaskPower's Boundary Dam Unit 3 and Petra Nova in Texas.

SaskPower's Boundary Dam Unit 3 (BD3)

BD3's CCS facility was designed for a 90% capture rate. It has proven that it can capture 90% of the CO_2 it receives, but operational issues mean the capture plant has not been able to accept the full volumes of the generator's flue gas flow.

For example, a major compressor failure reduced the plant's efficiency in 2021, but repairs and optimization projects have improved performance in 2023. When the CCS facility is operating with high availability and not experiencing downtime due to equipment failures, it can reduce BD3's emissions below 400 t/GWh.[15]

SaskPower's CCS facility was the first of its kind, and with such first of a kind projects, success comes from learning by doing. Technical issues encountered at the facility included amine degradation resulting from fly ash ingress. There have been consistent modifications during the past eight years to stabilize operations, improve reliability, and maximize capacity.

Many capacity issues experienced with BD3 can be avoided on new CCS projects by applying lessons learned at the facility. It is encouraging to note that some suppliers of technology for upcoming CCS projects are currently guaranteeing 95% capture rates.

Like all coal-fired power generation facilities in Canada, carbon capture will not be able to bring BD3's emissions intensity below 30 t/GWh. Therefore, **under the CER, it appears likely that BD3 will be forced to shut down in 2035**.

Petra Nova

The Petra Nova carbon capture plant was also designed for a 90% capture efficiency. In the first three years of operation, it captured 92.4% of the CO_2 from the gas it processed. Petra Nova shut down from mid-2020 until mid-2023. It is important to be clear that the stoppage at Petra Nova was reported as being due to low crude prices thwarting the oil-production efforts of the project, not as the result of something happening, or not happening, within the CO_2 capture process. [16]

SUMMARY OF BD3 CCS INFORMATION

- SaskPower's CCS facility is not capturing 90% of emissions from BD3, though that is its nameplate capacity.
- To maintain long-term reliable operation, most of the total flue gas from the BD3 power generation unit is processed by the CCS facility. The smaller portion that cannot be processed through the CCS facility is released into the atmosphere.
- Recent performance has shown that the CCS facility can capture at least 90% of the CO_2 from the partial flue gas stream it processes.
- To ensure a higher level of overall equipment reliability and process efficiency, SaskPower has optimized the CO_2 capture rate at a target of 65-70% of total BD3 emissions on an ongoing basis.

Sharing Knowledge on CCS

The lessons learned from early deployments of CCS are shown to play an essential role in reducing CCS project costs for subsequent developments. The technologies that enable CO_2 capture, transport and storage are not static. Investments can be de-risked, in part, through knowledge sharing. The cost of CCS has been viewed as a limitation to broader acceptance, but costs will continue to decline by applying technological refinement at all stages of development. Operational insight is crucial to driving greater reductions in cost, complexity, and emissions.

As the International Energy Agency has highlighted, "experience indicates that CCUS should become cheaper as the market grows, the technology develops, finance costs fall, economies of scale are reached, and experience of building and operating CCUS facilities accumulates."[17] Importantly, with lessons learned being inserted into CCUS projects, the result will be lower costs. This means fewer investor dollars and government dollars are required.

ADDITIONAL CONSIDERATIONS

Emissions Measurement

Emission intensity is the tonnes of CO_2 emitted by unit of electricity generation per year, divided by the amount of electricity generated in that year, in GWh. Total emissions include CO_2 produced by combustion of fossil fuels for electricity generation, including emissions associated with production of steam or hydrogen for electricity production. **Emissions due to the combustion of biomass are subtracted from the unit's total emissions.**

Emissions from steam or hydrogen production must be included in the intensity calculation regardless of their location or supplier. This would require the electricity generator to obtain information about the hydrogen's emission intensity from the supplier to include it in the generation intensity calculations. Clarity is required on this issue.

From the RIAS: **"For clarity, in cases when hydrogen is used as a fuel in the electricity generating unit, the combustion of that hydrogen does not directly produce any CO_2 emissions from the unit; therefore, any CO_2 emissions associated with the hydrogen's production must also be quantified and included in the unit's total emissions."** This appears to be a way for the CER to indirectly require CCS when producing hydrogen from natural gas if the end use is for power generation.

If fossil fuels are used to generate useful thermal energy as well as electricity (cogen), the CER allows the emissions attributed to thermal energy to be subtracted from total emissions. Note also that the CCUS-ITC allows for dual-use heat and power production at a proportional rate of its use in CCUS processes. This accounts for the energy penalty of adding CCUS to industrial and power generation processes.

CO_2 emission quantities can be measured using a fuel-based method or a Continuous Emissions Monitoring System (CEMS). A fuel-based method will include calculations of CO_2 produced by combustion of fossil fuels and from sorbent-based SO_2 emissions control systems. CCS systems are implicated since low levels of SO_2 are required pre-CO_2 capture.

Cost Benefit Analysis

The government performed a Cost Benefit Analysis (CBA) on the proposed regulations. This includes capital for increased electrical system capacity and carbon capture facilities. Simple numbers may not encompass the difficulty of getting large capital expenses approved, especially for companies with many generating units requiring abatement, or those who have recently spent large amounts of capital converting units from coal to natural gas. This may be particularly relevant in Saskatchewan, where nearly all expenses to comply with the CER will be borne by a Crown corporation.

Government expenses for CER compliance include the impacts of the Clean Technology ITC but do not include the CCUS-ITC, which may result in billions of dollars in federal tax credits.

The CBA includes an increase in fixed operating and maintenance (O&M) expenses for power production, but a decrease in variable O&M. The addition of CCS is expected to cause a significant increase in both fixed and variable O&M costs, so clarification is required on what is included in these costs.

Technology Readiness Levels

CCUS technologies are at varying levels of maturity today. While some CCUS technology has been deployed at scale, other technologies require further development. This includes, including potential innovation that seeks to have better performance and lower cost. Canada's Carbon Management Strategy acknowledges:

> To develop and deploy carbon management technologies on the scale required to achieve net-zero emissions in Canada by 2050, industry, government, and research institutions must work together to accelerate innovation that supports technology development, scale-up, piloting, demonstration, and de-risking across different sectors, applications, and stages of development.

Technology Readiness Levels (TRLs) are a common framework to compare the maturity of technologies. The TRLs levels used by Innovation, Science and Economic Development (ISED)[18] are:

TRL	Short Definition
1	Basic principles observed and reported.
2	Technology concept and/or application formulated.
3	Analytical and experimental critical function and/or characteristic proof of concept.
4	Component(s)/subsystem(s) and/or process validation in a laboratory environment.
5	Semi-integrated component(s)/subsystem(s) and/or process validation in a simulated environment.
6	System and/or process prototype demonstration in a simulated environment.
7	Prototype system ready (form, fit, and function) for demonstration in an appropriate operational environment.
8	Actual technology completed and qualified through tests and demonstrations.
9	Actual technology proven through successful deployment in an operational setting.

The Global CCS Institute's report on *Technology Readiness and the Cost of CCS* includes a TRL assessment and key technology vendors of the CO_2 capture technologies.[19] Amine liquid solvent CCS technology is at a TRL 9 since it has been demonstrated at Boundary Dam and Petra Nova power plants. The same technology has yet to be applied at commercial scale on natural gas power. **While it is acknowledged that CCS is a vital tool to reduce emissions for natural gas power in the years to come, emissions intensity limits which depend on CCS technology that has not yet had the benefit of demonstrated application should be granted time to achieve the desired outcomes.**

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