How to Decarbonise Coal-Fired Power Plants

Framework Step:

STEP 4. Support and contribute to innovation leading to new products and services
Innovation in the extractives sector can also lead to new products and services fostering new areas of comparative advantage for host countries. Initial comparative advantage in natural resources can be leveraged to push the production possibility frontier outwards and create dynamic comparative advantages through diversification. If a country uses its resource endowment in this way, over time, resources will become proportionally less important within their economy.

4. A What can host governments do?

- Support research and development efforts to identify, adapt, and transfer technology, making sure that these efforts are responsive to private sector demands. In doing so, develop ties with local universities, public research institutions, and participate in collaborative initiatives.

- Identify changing trends in global consumption and production patterns (progressive ore grades decline and increasing labour, transport, energy, processing, capital/ equipment costs), changes to end uses for minerals (innovation in final products), and carbon emissions trading.

4. B What can extractives industries do?

- Invest in specialised technologies for planning, handling, processing, maintenance, operational monitoring and recycling (excavation, concentration, ore prospecting, monitoring of the state of the environment) that reduce environmental impact.

STEP 1. Adopt a comprehensive long-term vision and implementation strategy to build competitive and diversified economies and create in-country shared value out of natural resources.

1.B. What can extractives industries do?

- Identify areas for pre-competitive collaboration with industry peers and stakeholders, including major contractors and suppliers (e.g. collective identification of skills requirements and solutions to common environmental challenges).

Tags:

☐ local employment
☐ local supplier participation and development, including SMEs
☐ marginalised groups (women, indigenous people)
☐ skills development and upgrading
☐ access to credit
☐ shared infrastructure (transport, water, power)
☐ technology transfer
☒ innovation
☐ economic diversification
☒ Other: decarbonisation

Problem Statement:

Driven by higher energy demand in 2018, global energy-related CO_2 emissions rose by 1.7% to a historic high of 33.1 Gt CO_2. While emissions from all fossil fuels increased, the power sector accounted for nearly two-thirds of emissions growth. Coal used in power alone surpassed 10 Gt CO_2, mostly in Asia. Coal-fired power plants were the single largest contributor to the emissions growth observed in 2018, with an increase of 2.9%, or 280 Mt, compared with 2017 levels, exceeding 10 Gt for the first time. Overall, coal-fired electricity generation accounted for 30% of global CO_2 emissions. In conventional coal-fired electricity generation, large amounts of CO_2 are produced during combustion of the fuel in the air. Separating CO_2 from the other flue gases after combustion of the fuel is expensive. The Boundary Dam Power Station Unit 3 in Canada was upgraded to an integrated Carbon Capture and Storage Demonstration project when its life was extended through the replacement of the 139 net MW Unit with a new 160 MW Unit in 2013, contributing to emission savings on the one hand and security of power supply on the other.

Parties Involved:

- SaskPower: is owned by the provincial government Saskatchewan, and is a vertically integrated electric utility, which is also the owner and project developer for the Boundary Dam carbon capture project, which became operational in 2014.
- Government of Canada
- Government of Saskatchewan
- The Knowledge Centre: is a not-for-profit partnership that is fully funded by BHP as part of their GHG mitigation initiative, and staffed with carbon capture experts that are seconded from SaskPower. The Knowledge Centre's mandate is to accelerate the deployment of Carbon Capture, Utilisation and Storage (CCUS) to mitigate GHG emissions by sharing lessons learned from Boundary Dam, from follow-on work, and by working collaboratively with those moving forward with improvements and deployments of CCUS.

Common ground:

SaskPower wanted to extend the life of Boundary Dam and reduce CO_2 emissions from the coal-fired power plant. The government of Canada shared the objective of reducing carbon emissions from coal-fired power plants and provided financial resources to support the development and application of CCUS technology. Federal coal-fired regulations were not in place at the time this decision was made but were being consulted upon.

SaskPower studied several carbon capture technologies for the Boundary Dam plan. Post-combustion was selected and subsequently implemented. The project was supported by a one-time CAD 240 million grant from the Government of Canada. Instead of building a new Natural Gas Combined Cycle plant at the same cost, SaksPower decided to integrate the CCSUS technology into an existing coal plant, with a projected revenue stream from the sale of the CO_2 for Enhanced Oil Recovery (EOR) increasing the economics of the project.

Actions taken*:*

Boundary Dam is a large-scale CCUS project in Saskatchewan, Canada, which commenced in 2014 and in which CO_2 is separated from power station flue gases. The construction began in spring 2011, while the project was commissioned between 2013-2014. The construction was completed in summer 2014.

The CCUS technology on Boundary Dam, which concerns Unit 3 (out of six original Units, 2 of which are retired and 3 are not CCUS) is one of the 18 largest post-combustion commercial CCUS facilities in the world, sized at 1 Million tonnes of CO_2 / year and one of the two largest coal power plants in Canada. The life of the power station has been extended by 30 years through the refurbishment of the power unit and the capture facility construction. The refurbishment included the complete replacement of the steam turbine and generator, which were at their end of life, to provide adequate steam extraction to the capture facility while maximising the output of the power plant. Capture involves taking out other components before the amine removes the CO_2. The construction costs of the life extension and addition of SO_2 and CO_2 abatement technology amounted to CAD 1.5 billion which were taken on by the provincial crown utility SaskPower.

The captured CO_2 is sold and transported by pipeline to nearby oil fields in southern Saskatchewan where it is used for EOR. CO_2 not used for EOR is stored in the Aquistore project, a research and monitoring project, which analyses the effects of storing CO_2 deep underground in a layer of brine-filled sandstone. Since 2000, some 22 million tonnes of CO_2 have been successfully stored underground in the reservoirs. The research programme has shown that the CO_2 remains safe underground and has provided in 2012 a best practices manual to help other companies thinking of storing CO_2 in similar formations. The royalty regime for oil in Saskatchewan has allowed the project to return dividends, which have offset the project costs.

The capture rate has increased since its launch with reduced outages over time. While the plant captured 800 Kt of CO_2 between November 2015 and October 2016, the total capture of the plant reached 2 Mt by March 2018. Between January and April 2018, the facility reached an availability factor of 98.3%. The total capture of the plant reached 3 Mt by November 2019. Boundary Dam's Unit 3 CO_2 emissions were designed to be as low as 120-140 tonnes of carbon dioxide per gigawatt hour (t/GWh) and are well below the ceiling of 420 t/GWh set by Canadian regulations on coal-fired power plants.

The *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity* regulations, which came into effect on July 1, 2015, set a stringent performance standard for new coal-fired electricity generation units and units that have reached the end of their useful life (nominally 50 years). The level of the performance standard was fixed at 420 t/GWh and has now been updated to phase out all unabated traditional coal-fired power plants by 2030. The aim of these regulations is to implement a permanent shift to lower or non-emitting types of generation, such as high-efficiency natural gas, renewable energy, or fossil fuel-fired power with CCUS. Amendments were published in December 2018, titled "Amendments to the Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations", which accelerate the phase-out of conventional coal-fired electricity units. CCUS is the only method by which coal-fired power generation plants (old and new) can achieve these emission targets. Therefore, in Canada, a coal-fired power plant past its retirement date must be retrofitted with carbon capture technology or closed by 2030.

On January 3, 2018, the Government of Saskatchewan published *The Management and Reduction of Greenhouse Gases* regulations. The regulations improve province-wide GHG emissions caps on electricity generating facilities, emitting annually more than 10 metric kilo tonnes of carbon dioxide equivalent from 2018 to 2029. The caps are the maximum cumulative GHG emissions permitted from the Saskatchewan electricity utility sector and were established to ensure that the GHG emissions outcomes under the Saskatchewan electricity regulations will be equivalent to or better than those expected to occur under the federal regulations.

Conventional lignite coal-fired power generation (used in Saskatchewan, Canada) emits roughly 1,100 tonnes of CO_2/GWh (t/GWh). Traditional natural gas-fired power facilities emit in excess of 500 t/GWh. Newer and continuously operating combined-cycle facilities operate as low as 375t/GWh and when used as a backup to intermittent non-emitting renewable energy can contribute to an effective emission intensity less than 300t/GWh. In contrast, Boundary Dam Unit 3 was designed to capture up to 90% of the CO_2 in the flue gas and operate as low as 120-140 t/GWh. The greatest gains in CO_2 emissions reductions in an electrical system without the ability to add hydro or nuclear facilities are realised with CCUS.

Obstacles:

- Optimisation is a major concern whereby a balance between efficiency gains versus capital and operating costs is required. Potential project risks for increased operating costs can be mitigated. Proactive measures to evaluate the capture technology “amine” and its maintenance costs, which are of most concern for effective management of ongoing operating costs, can be minimised by executing pilot testing. In addition, reduction of the size, cost and complexity of systems required to validate the maintenance and operation costs of specific amine and flue-gas combinations should be considered on a technical level.
- Regulations in Canada encourage moving away from coal-fired power generation without CCUS; and while there is a significant revenue opportunity to utilise and sequester CO_2 for EOR operations in Canada, low oil prices have softened the demand for the CO_2. The economics of retrofitting coal with CCUS are further challenged by an abundant supply of natural gas, which is available at such low prices and persisted long enough to have found a new norm in North America. Against these headwinds, CCUS deployment will not occur without cooperative approaches, reduced administrative burden, and appropriate incentives and financing mechanisms.

Enabling factors:

- The Boundary Dam CCUS project was realised before the introduction of stringent requirements on carbon dioxide emissions from coal-fired generation of electricity in 2015 but in anticipation of necessary compliance with subsequent regulations. It was supported by a federal grant of CAD 240 million for the realisation of the project, towards covering the project’s overall costs amounting to CAD 1.5 billion.
- Canada is one of the first countries to have adopted laws on emission reduction from coal-fired power plants. In 2011, the federal government announced strict performance standards for new coal-fired units and those that had reached the end of their life cycle. Rebuilding the ageing Unit 3 at Boundary Dam with carbon capture technology enabled the project operator, SaskPower, to meet these standards, while the sale of CO_2 for EOR provided a revenue stream to help offset the additional cost for carbon capture.
- In the oil fields of Saskatchewan, EOR incentives exist in the form of a Crown and Freehold Royalty Regime. This allows for only 1% of the royalties and taxes to be collected until capital costs are recovered, followed by a regular net-income-based fee structure. With costs being reduced for CCUS, the sale of CO_2 to an EOR project may provide adequate

motivation for a CCUS retrofit financed by the private sector. While this is a specific local benefit, such incentives may be needed to encourage CCUS deployment.

- Canadian regulations regarding long-term CO_2 storage liability are often built into existing regulations, including the *Crown Minerals Act* and the *Oil and Gas Conservation Act*. In Saskatchewan, a company that has stored carbon is liable for the injection site as long as the owner exists and is financially stable; whereas in Alberta the liability transfers to the province after a set amount of time regardless of the state of the company. The province of Alberta also makes it mandatory for CCUS operators to contribute to a Post-Closure Stewardship Fund, which is used for ongoing monitoring, maintenance, and remediation.

Lessons Learned:

- Boundary Dam demonstrates that post combustion CO_2 capture can be achieved at commercial scale on an existing coal plant with a facility that is designed to capture up to 90% CO_2.
- Replication is possible, yet, the fundamental requirement is the identification of suitable geological storage sites with the specific characteristics that allow the permanent removal of CO_2 from the atmosphere. Many coal deposits are associated with sedimentary basins that offer effective storage sites. Coal-fired power plants, which are a significant source of CO_2 emissions can sometimes be located near storage sites. Other available storage options include: deep saline formations sealed by a cap rock for permanent storage; coal-bed methane, in which CO_2 is injected into coalbeds to exchange CO_2 with methane (in this scenario, which is still in research phase, CO_2 binds to the coal and is stored permanently); Enhanced Oil Recovery (EOR), which involves injecting CO_2 to increase oil production from mature oil fields; and depleted oil or gas fields that are no longer economic for oil or gas production, but have established trapping and storage characteristics (for more details on secure geological storage of CO_2 see: https://www.globalccsinstitute.com/archive/hub/publications/191013/fact-sheet-secure-geologic-storage-co2.pdf).
- Based on the understanding of post-combustion systems, investments in future projects can be de-risked based on the application of past understandings. There has been recent global momentum to drive CCUS forward but ultimately a stall in large-scale deployment. The cost of CCUS is often viewed as a limitation to broader acceptance, but costs will continue to rapidly decline by applying technological refinement at all stages of development. Operational insight is crucial to driving greater cost reductions, reductions in complexity, and emissions reductions. A feasibility study based on lessons learned shows the capital cost for the second generation is projected to be 67% less than the Boundary Dam facility on a dollar per tonne of CO_2 basis. Factors such as scale, modularisation, simplifications and other lessons learned as a result of building and operating the Boundary Dam facility contribute directly to these reductions.
- Cooperative approaches to developing CCUS are critical at this early stage where competition is less important than accelerated uptake. The Knowledge Centre is tasked with sharing lessons learned from operational insight. This practical form of cooperation should be heightened in order to ensure that potential facilities save time and efforts in developing workable CCUS projects. Such experience-based decision-making can avoid costly delays or allow projects to proceed. Cooperation should begin at an early stage. Understanding commonalities with previously deployed CCUS facilities can help direct development considerations. For example, the main factors include location, space requirements, and age.

- Multi-stakeholder initiatives may aid in driving development. This comes not only in the form of CO_2 infrastructure hub but can also come from a shared cost burden or greater concentrated knowledge of the various stages of the process – such as the energy system, the industrial facility, the nearby oil fields or other considerations.
- Regulatory considerations mainly consist of enforcement and liability. Enforcement regulations for CCUS stem from the need to ensure safety and security, proper storage, and monitoring and verification (at injection and after). Regulations in Canada were designed to facilitate CCUS development by removing barriers to the storage and long-term security of CO_2. Prior to 2010, there had been uncertainties over the long-term liability for the stored carbon and access to pore space (underground storage spaces) to store the carbon. The granting of ownership rights reduced overall risk/cost. Many places that have existing oil and gas regulations can reduce administrative burden by amending those regulations to incorporate CCUS as was done in Canada.
- The lack of regulations specifically for CCUS should not limit development. In fact, regulations do not always come before national policy commitments or project-level developments especially since regulations alone are unlikely to drive CCUS. Setting up a variety of CCUS incentives or royalty regimes can drive market shifts favouring CCUS. These driving factors can shape a cleaner energy system but are also important for industrial non-energy sources of emissions that are hard to abate.
- Financing of projects has been largely supported by funding from both federal and provincial governments in Canada and are the basis of new opportunities for CCUS deployment in Norway, amongst other regions. Government contributions are beneficial, but such funding can extend further when combined with private funding. The involvement of multilateral development banks is critical, especially for developing and emerging countries in Asia.

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