MARCH 2020

OVERVIEW OF ORGANISATIONS AND POLICIES SUPPORTING THE DEPLOYMENT OF LARGE-SCALE CCS FACILITIES

DOMINIC RASSOOL
Senior Consultant - Policy and Finance

CHRISTOPHER CONSOLI
Senior Consultant - Storage

ALEX TOWNSEND
Senior Consultant - Economics

HARRY LIU
Technical Adviser - CCS Project

GLOBAL CCS INSTITUTE

CONTENTS

1.0 INTRODUCTION 3
2.0 THE CASE FOR A CCS DELIVERY BODY 4
3.0 REVIEW OF ENABLING ENVIRONMENTS FOR DEPLOYMENT OF CCS 7
4.0 UNITED STATES 8
5.0 CANADA 12
6.0 JAPAN 16
7.0 NORWAY 18
8.0 AUSTRALIA 20

1.0 INTRODUCTION

This report explores the potential role of Delivery Bodies to help enable the deployment of CCS. It also provides an overview of the organisations involved in the deployment of large-scale CCS facilities, and the policy and regulatory frameworks that have supported this deployment.

WHILE THERE ARE CURRENTLY RELATIVELY FEW CCS FACILITIES IN OPERATION AND IN DEVELOPMENT, THERE ARE SIGNIFICANT DIFFERENCES IN THE ENABLING ENVIRONMENTS FOR CCS DEPLOYMENT.

2.0 THE CASE FOR A CCS DELIVERY BODY

This section provides an overview of the role and value of delivery bodies, specifically for the deployment of CCS technology. Given the relatively small number of CCS facilities that are currently in operation globally, it is difficult to assess the effectiveness of the different CCS delivery bodies in a quantitative way. Therefore, the discussions that follow are done so qualitatively.

While there are currently relatively few CCS facilities in operation and in development, there are significant differences in the enabling environments for CCS deployment. Some countries have a more developed CCS industry than others, with numerous facilities that are contributing to learning curves and therefore improving the enabling environment for the next wave of CCS projects. Other countries have fewer projects but have relatively good policy support for CCS albeit not at the level needed to match deployment rates elsewhere.

The United States has the greatest level of deployment of large-scale facilities but has been deploying CCS since the 1970s. While the relatively recent introduction of the 45Q tax credit stimulated the industry, pre-existing CCS facilities were developed prior to government intervention. Investments in these pre-existing projects were driven mostly by the sale of CO_2 for EOR purposes, predating public grant capital funding and the 45Q tax credit. This led to a private sector driven deployment of the technology, setting a foundation for future projects that would be enabled through government GHG policies and the EOR market.

In the absence of such commercial arrangements, it is up to governments to create the drivers that lead to the development of the first wave of large-scale project. This is achieved through enabling policies that derisk private investments in CCS.

Some countries have been successful in initiating first wave projects through ad-hoc policy measures, such as the Gorgon project in Australia and Boundary Dam in Canada, which have come about as a result of regulatory measures that necessitate investment in CCS to initiate or continue operations respectively. Other countries have not yet finalized their respective policy frameworks to enable deployment. While all countries have medium to long term targets, the lack of first wave projects will likely impede progress towards these.

To overcome this, governments may consider appointing a delivery body – an independent, government-backed organisation with the purpose of delivering against a particular set of strategic objectives. Delivery bodies are useful because they can occupy a role between government and industry with the potential to deliver on the following:

- Coordination
- Advocacy
- Brokering
- Knowledge sharing
- Expertise outside of government

In the case of CCS, this can include the identification and recommendation of key policies, mechanisms and, in some cases, a delivery body can also undertake the operation of a component within the CCS supply chain that would otherwise have relied on the private sector to fulfil.

Delivery bodies have been used across numerous sectors in many different countries. In general terms, delivery bodies are non-departmental or non-ministerial, meaning they are kept at arm's length from ministers, although it tends to be the case that a particular department within government takes responsibility for the activities of a given delivery body. They tend to have to meet at least one of three basic requirements:

- They perform a technical function
- They are politically impartial
- They act independently

Historically speaking, CCS delivery bodies have been involved in projects in different capacities. While a more complete overview of delivery bodies is provided in the country sections of this document, below, are some examples of different ways in which delivery bodies have contributed towards the development of CCS projects:

Pilot Projects and technical advisory: In Japan, Japan CCS (JCCS), a company that responded to the Japanese government's call for development of CCS technology, has been involved in the implementation of the Tomakomai pilot project. In fact, JCCS was formed under a Japanese Government CCS policy to solely be responsible for the Tomakomai project and relevant CCS activities in Japan. It has 34 shareholders, including Japan Petroleum Exploration, a former subsidiary of the Japanese Government. While the shareholders' capital is US $2miliion, the remaining operational budget for the Tomakomai is in the order of several hundred million US dollars, provided for by the Japanese government through its Ministry of Economy, Trade and Industry (METI).

JCCS had previously taken on roles including numerous feasibility studies that would eventually lead to its direct involvement in the Tomakomai pilot. For each of these, it was directly contracted to and mandated by METI. In the context of the Tomakomai project itself, METI secures a budget and directly instructs JCCS to implement the project. This example demonstrates how a delivery body may have capacities beyond what is available within government and is given clear objectives to implement numerous activities throughout the development cycle of a pilot project. In this case, government sought technical guidance and expertise from JCCS.

Large scale projects and pilot projects and policy advisory: Gassnova is a state-owned enterprise established by the Norwegian government to further the development of technologies and knowledge related to CCS and also to serve as the advisor to the government on this issue. Gassnova is also tasked with the role of administering CLIMIT, a national programme for research, development and testing of technologies for CCS from industry and power production. CLIMIT's goal is to contribute to faster realisation of climate technologies. The CLIMIT programme ensures the follow-through of activities that would not have been realised without support from the state, or that would have been realized at a much smaller scale or over a much longer time span. Gassnova plays a crucial role in supporting the work to realise Europe's first industrial-scale CCS project. This project involves multiple capture facilities and a storage site. Gassnova's role in this is to coordinate the different components of the CCS chain, from capture to transport and storage. Initially CO_2 capture is planned at the Fortum Oslo Varme (FOV) waste to energy plant in Oslo and at Norcem's cement plant in Brevik. Simultaneously, Equinor and their partners, Total and Shell, are exploring how CO_2 from industrial plants from both Norway and Europe can be stored deep below the seabed in the North Sea. The selected site could potentially store carbon from multiple industry plants both in Norway and abroad. The goal is that the feasibility of the projects can show that capture and storage of CO_2 can be executed at large scale, and thus lower the barriers for future projects in other countries as well.

The above examples are representative of two organisations with slightly different roles. JCCS is more focused on understanding CCS technologies by implementing and operating a large pilot project, and reports back to government on technical progress. Gassnova has a broader role in that it, too, oversees technical developments at the industrial scale but at the same time it also functions as an advisor for policies and financing of pilot projects.

A third option for what kind of role can be played by delivery bodies is one that is less technically oriented, with a clearer objective towards advising on policies towards an enabling environment for CCS. In the context of a country developing its first large scale CCS project, prioritising a delivery body of this kind over a more technical one implies that other parties are better placed to address technical elements. For example, this approach might be used where Industrial emitters are already developing pilot capture projects on industrial plant. Instead, the aim may then be to implement a full chain CCS facility, to ensure that deployment occurs soon enough to contribute to meeting emissions targets. This requires a robust and well-defined policy framework to attract private investment. This, therefore, means that the major barriers to investments in CCS will have to be overcome by way of the following objectives:

A sufficient value has been placed on CO_2

- Hard to reduce risks have been sufficiently managed:

- Long term storage liability
    - The private sector is not liable for leakage of CO_2 occurring a predetermined time after injection has ceased;
    - Or the private sector is only responsible for a portion of the liability made possible through a risk capping mechanism
- Cross-chain or counterparty risk
    - The risk that arises from a single-source-single-sink model is diminished by spreading the risk across numerous emitters and storage operators through shared transportation and storage infrastructure

In such a case, the mandate given to the delivery body must be sufficiently comprehensive to deliver on at least one of these objectives. For such a delivery body to perform this function, it will have to have the capability to interface with the private sector, such that its understanding of business models and investment risks from the point of view of a variety of different sectors and industries are well understood. This will then allow it to make policy recommendations that, per its mandate, overcome the barriers to investment.

The fourth option for the use of a delivery body is in its provision of a service within the CCS supply chain. This is likely to be in the transport and storage operations that are to service multiple emitters. The value of the delivery body in this role is that most of the benefit of a diminished cross chain risk and economies of scale would be passed onto industrial organisations.

There are distinct advantages of utilising a delivery body, for example:

- The establishment of a delivery body signals a firm commitment to the deployment of CCS;
- In an advisory capacity, a delivery body can offer an independent and separate voice, act faster and with more urgency and focus than a government department with less expertise;
- A delivery body might be best placed to engage with regional emitters and help optimise the development and operation of a transport and storage network. This is something that local project proponents alone and indeed Government might otherwise struggle to achieve;
- Industrial organisations may not trust a service provider within the supply chain, for example, one that operates the transport and storage infrastructure for a CCS hub. If, however, a delivery body is mandated to undertake this task, industry will be more confident that the cost of services will be priced fairly.

And yet, there are also some important considerations:

- A delivery body comes at additional cost;
- Some of the activities which might be performed by CCS delivery bodies, are in many jurisdictions performed by other organisations;

3.0 REVIEW OF ENABLING ENVIRONMENTS FOR DEPLOYMENT OF CCS

The report focusses on five countries: United States; Canada; Japan; Norway; and Australia. For each country, it describes the policy mechanisms, institutions and organisations that have supported the deployment of CCS facilities. It is structured by theme, as shown in the table below.

Table 1: Categories and themes assessed for each country

CATEGORY	THEME
Policy mechanisms and regulation	• Financial incentives or mandatory requirements • Public finance support • Regulation of CO_2 transport • Regulation of CO_2 injection and post-injection site care and closure • Management of liabilities, including long-term storage liability • Other significant regulations
Institutions	• Public sector sponsored delivery bodies • Major research institutions focused on deployment
Capture	• Capture technology providers • Capture project investors and operators
Transport	• Pipeline infrastructure investors and operators
Storage	• Storage site appraisal • Storage site leasing arrangements • Storage site operators

4.0 UNITED STATES

	CATEGORY	DESCRIPTION
POLICY MECHANISMS AND REGULATION	Financial incentives or mandatory requirements	There are 10 large-scale CCS facilities in operation in the US. Most of the facilities that have come into operation since 2011 have benefitted from a combination of the 45Q tax credit and revenues from CO_2 Enhanced Oil Recovery (CO_2-EOR) which have placed a value on capturing CO_2 emissions. The 45Q tax credit was introduced under the Energy Improvement and Extension Act of 2008 and recently amended under the Bipartisan Budget Act in 2018. It provides capture operators with credits for each tonne of CO_2 stored or utilised, including for CO_2-EOR, which can be used to reduce the capture operator's tax liability. If a capture operator's tax liability is less than the value of the tax credits received, the capture operator can transfer the tax credits claimed to the storage operator or another qualifying organisation. Initially, the 45Q tax credit was worth \$20/tCO_2 for geological storage and \$10/tCO_2 for CO_2-EOR. Under the changes made in 2018, this has been increased to \$31/tCO_2 and \$19/tCO_2 respectively in 2019 for CO_2 stored in dedicated geological storage and injected for utilisation purposes, rising to \$50/tCO_2 and \$35/tCO_2 respectively in 2026. The Internal Revenue Service (IRS) is currently consulting on the guidance and regulations required to implement the changes made in 2018. Our understanding is that there are several projects in the US that plan to move ahead with feasibility studies and investment decisions once these changes have been implemented. The Century Plant, Air Products, Coffeyville, Lost Cabin and Petra Nova CCS facilities, all of which came onstream after the introduction of the 45Q tax credit, also benefit from the sale of CO_2 for CO_2 EOR. The price paid for CO_2 for EOR is generally linked to the price of oil. At oil prices of US\$70 per barrel the price of CO_2 is understood to be around US\$30/tCO_2. The California Low Carbon Fuel Standard (LCFS) provides another strong financial incentive for CCS. California has primacy to regulate GHG emissions under the Clean Air Act and in 2018 it amended its LCFS to allow CCS projects to qualify to generate credits. These changes came into effect in 2019. The scheme is administered by the California Air Resources Board. To qualify, the CCS project needs to be associated with the production of a transport fuel that is sold in California, except for direct air capture projects that can be located anywhere. The price of LCFS credits are currently trading at around \$200/tCO_2. We are aware of around half a dozen ethanol production facilities that are considering retrofitting CCS to qualify for the scheme.
	Public finance support	The American Recovery and Reinvestment Act of 2009 (ARRA) provided US\$3.4bn for CCS projects and activities between 2009 and 2015. Three of the large-scale CCS projects received grant funding under the program. These include: Petra Nova (US\$163m); Air Products SMR (US\$284m); and Illinois Industrial / Archer Daniels Midlands (US\$141m). The Department of Energy (DOE) also provides grant funding in the order of US\$50m for riskier stages of project development i.e. Front End Engineering and Design. Further, the US federal government also has support programmes that are implemented by DOE and the US Department of Agriculture (USDA), including direct loans and loan guarantees.

	CATEGORY	DESCRIPTION
POLICY MECHANISMS AND REGULATION	Regulation of CO_2 transport	The regulation of CO_2 pipelines is currently a joint responsibility of federal and state governments. The federal government regulates only CO_2 safety standards. State governments are largely responsible for the oversight of CO_2 transportation pipeline development and operation. Some states have begun to plan for and establish corridors for future CO_2 pipelines – in the case of Wyoming, this is done through its Pipeline Authority which is a State-public body defined in legislation. However, the development of a national CO_2 pipeline network capable of meeting proposed CO_2 emission goals may require a more organised approach and much closer cooperation among federal, state, and local governments than is currently in place. In the 1970s when US CO_2 pipelines were initially built, designs were based on meeting codes for natural gas pipelines rather than specific standards for CO_2 pipelines. These were later regulated under Code for Federal Regulations Title 49 Part 195, which prescribed safety standards and construction, operation and maintenance standards for CO_2 pipelines. The rules governing different pipeline systems in the US are not standardised. Each has its own CO_2 purity and operating conditions in place for example, partly due to the organic nature with which the industry evolved.
	Regulation of CO_2 injection and post-injection site care and closure	In the US, the Environmental Protection Agency (EPA) sets minimum standards for the construction, operation, permitting and closure of injection wells under the Underground Injection Control (UIC) program, created under the authority of the Safe Drinking Water Act ("SDWA"). There are six different well classifications under the UIC Program, with Class II and Class VI being most relevant in the context of CO_2 injection. Class II wells are those that are used to inject fluids associated with oil and gas operations, including wells used for enhanced recovery of oil and natural gas. Class VI wells are those used for the injection of CO_2 into geological formations, for the primary purpose of long-term storage. The Federal regulations for Class II wells have been in force since the 1980s and Class VI well regulations were later added in 2010. States can apply for primary enforcement authority, often called primacy, to regulate injection activities. For all other states, the EPA directly implements the Class II and Class VI program. Thirty-nine states have an approved primacy program for Class II wells and one state has an approved primacy program for Class VI wells. The injection sites for the large-scale CCS projects in the US that have Class II wells are located in the states of Oklahoma, Texas, Illinois, Montana, Wyoming and Colorado. Each of these states has an approved state-level primacy program for Class II wells which is implemented by the Oklahoma Department of Environmental Quality (Oklahoma), Texas Commission on Environmental Quality and the Railroad Commission of Texas (Texas), the Illinois Environmental Protection Agency and Illinois Department of Natural Resources (Illinois), Montana Board of Oil and Gas Conservation (Montana), Wyoming Oil and Gas Conservation Commission (Wyoming) and Colorado Oil and Gas Conservation Commission (Colorado). Most of the Class II primacy applications were granted between 1982 and 1990 and therefore these state-level regulators will have regulated the injection of CO_2 for most of the large-scale projects in the US. North Dakota is the only state with an approved state-level primacy program for Class VI wells. Speeding up these regulatory processes is priority for states that do not yet have Class VI well permits. These will be needed so that these states are aligned with the 45Q timeframe.
	Management of liabilities, including long-term storage liability	The management of liability is generally dealt with through State-level legislation and regulations. For example, the states of Montana, Texas and North Dakota have transfer liability provisions in place. The length of time before the state assumes liability varies - for example, in Texas (offshore) and Illinois (for the FutureGen project), the state takes on the liability from the point that the injection well has been closed. In North Dakota and Montana the period before liabilities can be transferred is longer, at between 10 and 15 years. In North Dakota, Montana and Texas all liabilities are transferrable.
	Other significant regulations	None listed.

	CATEGORY	DESCRIPTION
INSTITUTIONS	Public sector sponsored delivery bodies	There are some examples of public delivery bodies that support the deployment of CCS in the US at the State level. For example, in Wyoming the Wyoming Pipeline Authority actively promotes the development of intrastate and interstate pipeline infrastructure necessary to enhance natural resource development within Wyoming and encourage the export of the State's natural resources to the nation. In anticipation of the need for CO_2 pipeline infrastructure, the Wyoming Pipeline Authority has established the Wyoming Pipeline Corridor Initiative. This project will create corridors across State and Federal lands to assure coordination across different organisations which in turn should reduce permitting time. In addition, the Wyoming Infrastructure Authority, another body defined in state legislature, promotes and assists in the development of CCUS, mainly in the context of advanced coal power generation.
	Major research institutions focused on deployment	The US has a series of national labs that both provide research and are involved in CCS projects of different scales. The universities in the US, such as the universities in Montana, Wyoming and West Virginia, are also involved in CCS projects. The National Carbon Capture Center, which is sponsored by the US Department of Energy, is focused on finding breakthroughs in next generation CCS technologies.
CAPTURE	Capture technology providers	This information is not publicly available
	Capture project investors and operators	This information is not publicly available
TRANSPORT	Pipeline infrastructure investors and operators	Relative to the rest of the world, the US has significant experience in the development of CO_2 pipelines, with around 4,500 miles of CO_2 pipelines currently in use (as of 2015). Pipeline operators can be split into large-scale trunk-line operators and smaller-scale (in terms of capacity) distribution systems. Large-scale trunk-line providers include Kinder Morgan, Oxy Permian, ExxonMobil and Denbury Resources. Some of these have specialised in specific regions - for example, Denbury Resources operates all major CO_2 transportation pipelines in the Gulf Coast region. Some of the large-scale trunk-line providers also operate smaller-scale distribution networks. Other smaller-scale distribution system operators include Whiting, Chevron, Hess, Trinity CO_2, XTO, Apache, Anadarko, Merit, Devon, Chaparral Energy, Anadarko, TransPetco, Dakota Gasification and Core Energy.
STORAGE	Storage site appraisal	Most of the large-scale CCS projects in the US have utilised CO_2 for Enhanced Oil Recovery. A large proportion of the costs associated with appraising these sites will have already been incurred in the original appraisal of the oil reservoir, making them relatively low-cost storage sites to develop. All of the sites have been onshore, which again has lower costs. The US Department of Energy, along with the Office of Fossil Energy (FE) and National Energy Technology Laboratory (NETL) have also established the Regional Carbon Sequestration Partnership (RCSP) Initiative to support research into the best regional approaches for permanently storing carbon dioxide (CO_2) in geologic formations through characterisation and field projects. The partnerships include more than 400 distinct organisations, spanning 43 states and 4 Canadian provinces, have conducted 19 small-scale field projects building on research, and are developing the framework needed to validate geologic carbon storage technologies. There are several large-scale CO_2 tests (tests injecting at least 1 $MtCO_2$) currently being conducted or recently finished in the United States including in Mississippi, Alabama, Illinois, Montana, Texas and Michigan.
	Storage site leasing arrangements	The issue of the ownership and leasing of pore space in the US is complex as there is a mix of state regulatory systems that are not consistent. Several states, including Wyoming, Montana, North Dakota and Oklahoma, have defined pore space as private property in their statute. In these instances, land owners own the subsurface pore space and mineral rights and storage projects must obtain permission from the landowner to utilise the pore space. The mineral rights can be split from the surface estate and in some states, such as Texas, Kentucky and Kansas, case law may favour the mineral rights owner having ownership rights of the pore space over the landowner. In these circumstances the CO_2 storage project would need to get surface approval and then obtain the mineral rights from all of the relevant parties. The federal government also owns around 700 million acres of mineral rights in 22 states, providing for a different set of arrangements with regards to the leasing of the pore space.

	CATEGORY	DESCRIPTION
STORAGE	Storage site operators	The storage operators in the US are primarily EOR field operators. In some cases, such as the Century Plant project, the storage operator is vertically integrated with the capture and transport operations. In other cases, the storage operator is one or more organisations that purchase the CO_2 from the capture plant operator. Terrell: Occidental Petroleum Enid Fertiliser: Chaparral Energy and Merit Energy Shute Creek: Anardarko Petroleum, Chevron, Devon Energy, Memorial Production Partners and Denbury Resources Century Plant: Occidental Petroleum Air Products SMR: Denbury Resources Coffeyville: Chaparral Energy Lost Cabin: Denbury Resources Illinois Industrial: Illinois State Geological Survey under the Midwest Geological Sequestration Consortium, and The Illinois Industrial Carbon Capture and Storage CCS managed by NETL Petra Nova: Texas Coastal Ventures, a joint venture between Petra Nova Parish Holdings and Hilcorp Energy Company

5.0 CANADA

	CATEGORY	DESCRIPTION
POLICY MECHANISMS AND REGULATION	Financial incentives or mandatory requirements	There are 4 large scale CCS facilities in operation in Canada. In addition, there is one CO_2-EOR project in Canada that sources its CO_2 from the US. All but one of these projects utilise the CO_2 captured for CO_2-EOR. While it is not publicly available, the Institute's understanding is that the price paid for CO_2 for projects in Canada ranges from around US$12 to US$30 per tonne of CO_2. The Provinces of Alberta (under the Innovative Energy Technologies Program) and Saskatchewan also provide royalty relief for CO_2-EOR. The first major project (Great Plains) in Saskatchewan was supported by a specific set of regulations, given the uniqueness of the project, that was outside of the province's royalty regime. These regulations were set out in the Weyburn Unit CO_2 Crown Oil Royalty Regulations and The Weyburn Unit CO_2 Freehold Oil Production Tax Regulations. Alberta also provides, on a temporary basis, double offset credits under its carbon emissions offset programme for CCS projects where the capture occurs at a facility upgrading or refining bitumen. This provided an additional incentive for the Quest project. In 2012 the Canadian Government enacted the Reduction of Carbon Dioxide Emissions from Coal-Fired Generation of Electricity Regulations pursuant to The Canadian Environmental Protection Act. These regulations came into effect in 2015 and require all new and end-of-life conventional coal units to meet an emissions performance standard of 420gCO_2/kWh before 2030. Regulations require existing facilities to comply with the performance standard at their end of life. While the regulations came into effect after Unit 3 at Boundary Dam came into operation, they have been cited as a potential driver for deployment of CCS at the site. An equivalency agreement granted by the Federal Government in 2019 allows Boundary Dam to comply with the standard at the plant level, rather than individual unit level, such that retrofitting CCS on Unit 3 has enabled the temporary extension of the lifespan of Unit 4 and 5 to 2021 and 2024 respectively.
	Public finance support	Most of the large-scale projects in Canada have benefitted from a combination of Federal and State grant funding, mainly through the Government of Canada's Clean Energy Fund and the Government of Alberta's Carbon Capture and Storage Fund which funded a diverse set of CCS projects. This includes the Shell Quest project ($120m from Canadian Government, $745m from Alberta Government), Boundary Dam ($240m from Canadian Government) and the Alberta Carbon Trunk Line ($63m from Canadian Government, $495m from Alberta Government - $371m for the pipeline and storage, $124m for the capture facility). The Boundary Dam project also benefitted from investment by the plant operator, Sask Power, which is a State Owned Enterprise. Government funding was also provided to Project Pioneer ($342m from Canadian Government, $436m from Alberta Government) and Swan Hills Synfuels ($285m from Alberta Government). Both projects were later cancelled - the former due to uncertainties in pricing and offtake of CO_2, and the latter due to the persistent low cost of natural gas.
	Regulation of CO_2 transport	Canada has its own regulations for CO_2 pipelines, CSA standard Z662. Pipeline transport is regulated by each province, except where it crosses a provincial or international border where the federal government takes over authority. In Alberta, pipelines are regulated by the Alberta Energy Regulator (AER) under the Pipeline Act and Directive 056. These two sources of regulation cover elements of design such as: size, materials selection, design pressure, resistance to degradation, protection from damage, appropriate monitoring facilities, safety systems and siting considerations. One pipeline has been built and another is under construction adhering to these regulations.

	CATEGORY	DESCRIPTION
POLICY MECHANISMS AND REGULATION	Regulation of CO_2 injection and post-injection site care and closure	In Canada, the regulation of activities during the CCS project life cycle is not undertaken at the federal level. Instead, the primary authorities responsible for energy and natural resources in the provinces regulate activities such as CO_2 injection as per the provisions of the relevant provincial legal and regulatory framework. For example, in Alberta, the Alberta Energy Regulator (AER) is responsible for regulating CCS activities such as CO_2 injection as per Part 9 of the province's Mines and Minerals Act and accompanying Regulations. Project operators are required to obtain well licenses and approval under the Oil and Gas Conservation Act from the AER before drilling commences for CO_2 injection. The AER is also empowered to regulate and oversee related activities such as MMV and post-closure requirements. Examples of compliance requirements in this regard include submission of MMV plans, closure plans and reports on compliance with MMV plans. As an example, regulatory approval for CO_2 injection activities for the Shell Quest project was obtained from the AER, which conducts an Injection Certification Audit to confirm injected CO_2 volumes.
	Management of liabilities, including long-term storage liability	As specified above, regulatory developments, notably those concerned with the design and implementation of CCS-specific legislation, have principally occurred at the provincial level in Canada. Alberta's CCS-specific regime is perhaps the most comprehensive model among the Canadian states. The Carbon Capture and Storage Statutes Amendment Act, 2010 allows the government to assume long-term liability for storage sites. It also makes it mandatory for carbon capture and storage operators to contribute to the Post-Closure Stewardship Fund. The provincial government will use this fund for ongoing monitoring and any required maintenance and remediation. The Act also clarifies that the Government of Alberta is the owner of pore space but does not change ownership of mine and mineral resources in any way.
	Other significant regulations	None identified.
INSTITUTIONS	Public sector sponsored delivery bodies	None identified.
	Major research institutions focused on deployment	NRCan (through CanmetENERGY) provides research focused on capture technologies applied to coal-fired power. They operate a 5MW demonstration facility that is used to test oxy-combustion technologies as well as various small-scale pilot post capture solvents. Aquistore continues to provide technology assessment for monitoring of a deep saline aquifer. The program has recently conducted additional testing. Carbon Management Canada Research Institute (CMCRI) have two facilities set up to test and demonstrate CCS technologies. In Burnaby, BC the Carbon Capture and Conversion Institute is a place for technology companies to test their technology at a larger scale than lab. At the Containment and Monitoring Institute headquartered in Calgary, they have access to a Field Research Site (FRS) near Brooks, AB where they have set up a shallow demonstration site where companies and technologies can be tested to monitor the subsurface through several wellbores. The site is used for training on CCS.

	CATEGORY	DESCRIPTION
CAPTURE	Capture technology providers	This information is not publicly available
	Capture project investors and operators	This information is not publicly available
TRANSPORT	Pipeline infrastructure investors and operators	Canada currently has around 462 km of CO_2 pipelines in operation, and by the end of 2019 will have 702 km. These primarily link individual sources of CO_2 to EOR sites. The operators of these pipelines include: Great Plains: Cenovus (via Souris Valley pipeline) Boundary Dam: Cenovus (pipeline to Weyburn for EOR) and the Petroleum Technology Research Centre (3km pipeline to Aquistore project) Quest: Athabasca Oil Sands Project (AOSP), a joint venture with Shell Canada Energy, Chevron Canada Limited and Marathon Oil Canada Corporation ACTL: Wolf Carbon Solutions who are responsible for constructing, owning and operating the CO_2 capture and pipeline transportation assets The ACTL is unique in that it was developed with the aim of connecting multiple sources of emissions in Alberta's industrial heartland with aging oil reservoirs in central and southern Alberta for use in EOR. The pipeline has been oversized for the first phase of the project, such that the volume of CO_2 transported can increase over time as more emitters invest in capturing CO_2 and utilise the transportation network. At full capacity, the pipeline will be able to transport 14.6 $MtCO_2$ per year, making it the largest EOR project in the world. The oversizing of the pipeline has a number of benefits: i) when operated at full capacity it allows for the fixed costs of building the pipeline to be spread over many users, reducing the unit cost of transporting CO_2; ii) it helps to reduce the cross-chain risk to the capture plant as, subject to contractual agreements, the operator of the capture plant will be able to take final investment decisions in the knowledge they will have multiple customers to sell the CO_2 to; and iii) oversizing the pipeline provides an indirect signal to operators that the government is willing to support CCS over the longer-term, which may help to reduce the perceived policy risk of investing in CCS.
STORAGE	Storage site appraisal	Most of the large-scale CCS projects in Canada utilise CO_2 for Enhanced Oil Recovery. A large proportion of the costs associated with appraising these sites will have already been incurred in the original appraisal of the oil reservoir, making them relatively low-cost storage sites to develop. Saskatchewan and Alberta are land locked provinces and all sites are onshore, which again has lower costs. QUEST underwent extensive characterisation of their deep saline storage formation. Original scoping for dedicated saline formations was done by the Alberta Saline Aquifer Project (ASAP) and the Wabamun Aquifer Storage Project (WASP). Aquistore was initiated in December 2009. The project looked for a saline storage formation in Saskatchewan for a CO_2 source. The project directive was to increase understanding on saline storage and to identify a large storage reservoir for Saskatchewan's CO_2 emissions. Weyburn has been the site for extensive modelling, characterization and MMV. The site was host to the IEAGHG Monitoring study that conducted extensive surveys on the field to understand CCS monitoring requirements. Cenovus consulted with Schlumberger to build a complete static geological model and initialize dynamic reservoir simulation.
	Storage site leasing arrangements	Canada has a common law regime with a traditional approach to property rights attaching to oil and gas activities. It should be noted that the province of Alberta in its Carbon Capture and Storage Statutes Amendments Act 2010 clarified that the government of Alberta is the owner of the pore space in the province.

	CATEGORY	DESCRIPTION
STORAGE	Storage site operators	The storage operators for the large-scale projects in Canada include: Great Plains: Cenovus Boundary Dam: Cenovus (for the Weyburn Oil unit) and the Petroleum Technology Research Centre (for the Aquistore dedicated geological storage site project) Quest: Athabasca Oil Sands Project AOSP, a joint venture with Shell Canada Energy, Chevron Canada Limited and Marathon Oil Canada Corporation ACTL: Enhance Energy, who are the owner and operator of the CO_2 utilization and sequestration portion of the ACTL project through its EOR operations Between 2000 and 2012 the Government of Canada ($15m), Saskatchewan Government ($5m), US Government ($14m) and industry partners ($7m) funded the International Energy Agency Greenhouse Gas Weyburn-Midale CO_2 Monitoring and Storage Project. The project was used to develop best practice with respect to the design, implementation, monitoring and verification of CO_2 geological storage projects in the context of CO_2-EOR.

6.0 JAPAN

	CATEGORY	DESCRIPTION
POLICY MECHANISMS AND REGULATION	Financial incentives or mandatory requirements	There are currently no CCS-specific financial incentives or mandatory requirements in Japan.
	Public finance support	The Ministry of Economy, Trade and Industry (METI) has funded the Tomakomai CCS Demonstration Project. The objective is to demonstrate the viability of a full CCS system, from CO_2 capture to injection and storage. The implementation of this project is being led by Japan CCS Co., Ltd. (JCCS). METI also funded the Osaki Coolgen Project (IGCC project combined with carbon capture) from 2012 to 2016. From 2016, the project has been funded by the New Energy and Industrial Technology Development Organization (NEDO). The Ministry of Environment (MOE) has funded Mikawa CCS Demonstration Project and Saga CCU Project (supplying CO_2 captured from waste incineration plant to algae culture).
	Regulation of CO_2 transport	Under consideration by Japanese government
	Regulation of CO_2 injection and post-injection site care and closure	In Japan, the permitting provisions for underground storage of CO_2 are found in the Marine Pollution Protection Law and only cover offshore, sub-seabed storage. There are no provisions covering onshore geo-sequestration. Under the Marine Pollution Protection Law, the provisions applicable to the subsea bed storage of CO_2 are focused on protecting the marine environment from any adverse impacts of sub-seabed storage activities and are not specifically aimed at promoting CCS as a low-carbon technology. This reflects the fact that the CCS provisions were enacted in 2007 in order to comply with Japan's international obligations to implement the amendment to Annex I of the London Protocol that included CO_2 streams as wastes or other matter that may be considered for ocean dumping. For example, an application for sub-seabed CO_2 storage is made to the Minister of the Environment and is assessed, largely, from an environmental perspective. Re-permit is required every 5 years. Other than the regulations above, existing regulations are applied for METI's Tomakomai CCS Demonstration project operation but there is no regulation for post injection and closure.
	Management of liabilities, including long-term storage liability	Under consideration by Japanese government
	Other significant regulations	None identified

	CATEGORY	DESCRIPTION
INSTITUTIONS	Public sector sponsored delivery bodies	Japan hosts several industry-led partnerships supported by government funding that are responsible for operating CCS demonstration plants. Japan CCS Co. Ltd. (JCCS) is responsible for implementing the Tomakomai CCS Demonstration Project which is funded by METI. It has also conducted an assessment of CO_2 storage sites for METI and MOE. JCCS was established in 2008 by 24 industry stakeholders covering the oil, power generation, engineering, steel and chemical sectors. Its membership now stands at 34 as of July 2019. Its Board is formed of a mix of Japan CCS staff and stakeholder staff. Its objectives are to i) accomplish comprehensive investigations and demonstrations for CCS projects in Japan, ii) integrate the opinions of the private sector for the early establishment of laws and regulations, iii) promote CCS, iv) cooperate with foreign organisations for the deployment of CCS overseas, and v) collect and exchange information with overseas institutions. It has Y242m (C.£2m) in capital. A significant stakeholder of JCCS is Japan Petroleum Exploration Co. Ltd. - the main shareholder of which is METI who own a 34% equity share. The Osaki Coolgen Corporation is responsible for implementing the IGCC Project combined with carbon capture in Hiroshima funded by METI. The Osaki Coolgen Corporation was founded through joint funding by the Chugoku Electric Power Co., Inc. and Electric Power Development Co., Ltd. (J-POWER). Its aim is to achieve revolutionary low carbon coal-fired power generation in accordance with the government's clean coal policy - the Cool Gen Plan. It has around Y490m (c.£4m) in capital.
	Major research institutions focused on deployment	The Japanese Government also established the Research Institute of Innovative Technology for the Earth (RITE) to progress research on new technologies, with a focus on climate change mitigation. RITE is formed of 169 employees and has a budget of Y2.8bn (c.£21m) in FY2019. CO_2 storage is one of the 6 themes of its research laboratory.
CAPTURE	Capture technology providers	This information is not publicly available
	Capture project investors and operators	As explained above, all of the Japanese demonstration projects have been funded by the Japanese Government and operated by various industry partners.
TRANSPORT	Pipeline infrastructure investors and operators	The Japanese government has considered that CO_2 transportation by ship is more feasible than CO_2 transportation by pipeline. JGC corporation is in charge of reviewing the feasibility of CO_2 transportation by ship for the Mikawa CO_2 Capture Demonstration Project funded by Ministry of Environment (MOE). JGC corporation provides Engineering, Procurement and Construction (EPC) services for plants and other facilities to customers in Japan and over 80 overseas countries.
STORAGE	Storage site appraisal	For now, CO_2 storage has been conducted only at the site of Tomakomai CCS Demonstration project. The operation of this project, including site appraisal, has been led by Japan CCS Ltd.
	Storage site leasing arrangements	Given the emerging nature of CO_2 storage, the issue of storage site leasing arrangements has not been considered by the Japanese Government.
	Storage site operators	Japan CCS CO., Ltd. (JCCS), which is the operator of Tomakomai CCS Demonstration Project, has been the only storage site operator in Japan.

7.0 NORWAY

	CATEGORY	DESCRIPTION
POLICY MECHANISMS AND REGULATION	Financial incentives or mandatory requirements	There are two large scale CCS facilities in operation in Norway - the Sleipner and SnØhvit projects. In contrast to deployment in other countries, both of these projects store CO_2 at dedicated geological storage sites - Sleipner was the first project to store CO_2 offshore globally. The main driver for the development of these two projects was the introduction of a CO_2 tax in 1991. In 1996, at the time of the Sleipner project, the CO_2 tax on offshore petroleum production on the Norwegian continental shelf was around NOK 210 (33 USD) per tonne of CO_2, which was significantly higher than the estimated cost of injecting CO_2 (c.17 USD). The tax has since been increased and the current CO_2 tax on petroleum production stands at 500 NOK. CCS was also a mandatory requirement of the permit provided for the SnØhvit project.
	Public finance support	Both Sleipner and SnØhvit are operated by Equinor (previously Statoil). At the time the Sleipner project came into operation, Statoil was a wholly government owned entity. From 2001 Statoil was partially privatised and at the time the SnØhvit project came into operation the government held around a 71% stake in the company. While both projects did not receive any direct grant funding, the ownership by the state is likely to have enabled Statoil to borrow at lower rates than a privately owned organisation and to take a longer-term view on investments.
	Regulation of CO_2 transport	Norway did not have dedicated CCS legislation to provide permits for the Sleipner and Snøhvit projects. These successful experiences in CCS demonstrate that the permitting process substantially depends on the close co-operation between project developers and national authorities. The regulations were based on the Petroleum Act.
	Regulation of CO_2 injection and post-injection site care and closure	The EU CO_2 storage directive (Directive 2009/31/EC) was adopted in 2009. It regulates both the exploration of storage sites and the storage of CO_2 in Europe. As the directive is considered relevant to the European Economic Area (EEA), it had to be transposed into national law in Norway. This was done in 2014 through new regulations on the storage and transport of CO_2 on the NCS, as well as new chapters to the pollution regulations and to the petroleum regulations.
	Management of liabilities, including long-term storage liability	The management of CCS specific liabilities is contemplated within existing Norwegian petroleum legislation and wider EU energy legislation.
	Other significant regulations	None specified

	CATEGORY	DESCRIPTION
INSTITUTIONS	Public sector sponsored delivery bodies	In 2005, the Norwegian government established Gassnova, a state backed body whose mission is to realise CCS solutions, so the planet will be inhabitable for future generations. Gassnova reports to the Ministry of Petroleum and Energy, and receives its funding via the fiscal budget. It has around 40 employees and has three main focus areas: i) Technology development, ii) Full-scale CCS and iii) advice. It is responsible for the CLIMIT RD&D programme and manages the Norwegian State's interest in the Technology Centre Mongstad (TCM). It plays an active role in the development of the Full Scale Project in Norway currently under development and it acts as a technical advisor to Norwegian policymakers.
	Major research institutions focused on deployment	The Norwegian government supports research, development and demonstration of CCS technology through its CLIMIT Programme. The Programme is jointly administered by Gassnova and the Research Council of Norway, with Gassnova having overall responsibility for the Programme. Its objective is to: i) develop knowledge, expertise, technology and solutions that can contribute towards cost reductions and international deployment of CCS; and ii) leverage national advantages and develop new technology and service concepts with commercial and international potential. Norway is also the location of the Technology Centre Mongstad which provides a centre for testing and developing CCS technologies. The TCM is currently owned by the Norwegian State (77.5%),, together with Equinor (7.5%), Shell (7.5%), and Total (7.5%). Aker Solutions, GE (earlier Alstom), Can¬solv Technologies, Carbon Clean Solutions and ION Engineering have all tested their technologies at TCM. One of the world's largest engineering companies, Fluor, has signed an agreement with TCM to test its technology at the site.
CAPTURE	Capture technology providers	This information is not publicly available. Our understanding is that Aker Solutions is one of the capture technology providers for the existing large-scale projects in Norway.
	Capture project investors and operators	This information is not publicly available.
TRANSPORT	Pipeline infrastructure investors and operators	The Sleipner project involves direct injection of the CO_2 that is separated on the offshore platform and therefore does not transport the CO_2 via pipeline. SnØhvit seperates CO_2 onshore and then returns the CO_2 offshore for storage via pipeline. The pipelines are operated by Equinor
STORAGE	Storage site appraisal	The Norwegian Continental Shelf has seen significant exploration over the past 50 years. Many wells have been drilled and the geology is well known. To support future projects, the Norwegian Government has published a CO_2 Storage Atlas. The Atlas was prepared by the Norwegian Petroleum Directorate, on request by the Ministry of Petroleum and Energy. One of the key objectives for this atlas is to provide input on where it is possible to implement safe long-term storage of CO_2, and how much capacity there is for geological storage of CO_2. Other potential storage sites have been appraised as part of initial development of projects that did not come into operation. In 2006, Gassnova, Gassco, the Norwegian Petroleum Directorate, and the Norwegian Water Resources and Energy Directorate completed the investigations of two storage locations – the Johansen Formation and the Utsira Formation as part of the Mongstad and Kårstø CCS projects. It has been estimated that the Johansen Formation could store at least 160 Mt of CO_2. Further studies were completed in 2012 on the CO_2 storage potential for the Mongstad CCS project with the Troll Kystnær Formation as a potential CO_2 storage target.
	Storage site leasing arrangements	Norway's CCS activities are restricted to the offshore storage of CO_2 and accordingly, the Norwegian State retains rights over the pore space within the continental shelf. There is no ownership regime for subsurface storage under Norway's regulation.
	Storage site operators	The Sleipner project is operated by Equinor, but involves the following partners: ExxonMobil, Lotos E&P Norway AS and KUFPEC Norway AS. The SnØhvit project is also operated by Equinor, in partnership with Neptune Energy.

8.0 AUSTRALIA

	CATEGORY	DESCRIPTION
POLICY MECHANISMS AND REGULATION	Financial incentives or mandatory requirements	The Gorgon LNG project is the only operational large-scale CCS project in Australia. The injection of CO_2 was a mandatory requirement established as part of the permitting process for the LNG project.

	Public finance support	There have been numerous public funding bodies for CCS in Australia, mostly from the Federal Government. These include:
		• Low Emission Technologies for Fossil Fuels (LETFF) programs, which supported:
		  • CCS Flagships- originally AUD $2 billion; most withdrawn, AUD217M spent; CarbonNet Funding remaining
		  • Low Emissions Coal Initiative (NLECI): AUD 500M (AUD 233M spent), supports ANLEC R&D
		  • Low Emission Technology Demonstration Fund: Gorgon Project received AUD$60M
		• National CO_2 Infrastructure Plan (NCIP): AUD 30 million funded to develop storage sites and transport planning

	Regulation of CO_2 transport	See below
	Regulation of CO_2 injection and post-injection site care and closure	Australia has comprehensive CCS-specific legal and regulatory frameworks, at Federal and State levels. These sit within existing regulatory frameworks of petroleum legislation. CCS-specific legislation includes: • Offshore Petroleum and Greenhouse Gas Storage Act 2006 (Commonwealth) • National Greenhouse and Energy Reporting Act 2007 (Commonwealth) recognizes the amount of CO_2 avoided by subsurface injection. Offshore Petroleum and Greenhouse Gas Storage Act 2006 (Commonwealth) • Greenhouse Gas Geological Sequestration Act 2008 (Victoria) • Offshore Petroleum and Greenhouse Gas Storage Act 2010 (Victoria) • Greenhouse Gas Storage Act 2009 (Queensland) • Petroleum and Geothermal Energy Act 2000 (South Australia) • Barrow Island Act 2003 (Western Australia – 'Project-specific' legislation to regulate the Gorgon project)
	Management of liabilities, including long-term storage liability	The Commonwealth government retains sovereignty over territorial sea, EEZ and continental shelf. States own onshore formation, reservoirs and resources. Operators can transfer CO_2 plume liability to Federal Government after confirming demonstration of CO_2 plume behaving as predicted. Post closure transfer can occur after 20 years.
	Other significant regulations	None identified.

	CATEGORY	DESCRIPTION
INSTITUTIONS	Public sector sponsored delivery bodies	The Australian government created the Global CCS Institute (now privatised). Federal and State Geological Surveys complete storage basin evaluations. CarbonNet is managed by the Victorian Department of Economic Development, Jobs, Transport and Resources, and is jointly funded by the Australian and Victorian governments.
	Major research institutions focused on deployment	Major research institutions and initiatives include: • ANLEC R&D: seven-year progamme to support CCS Flagships. The coal industry matches the Australian Government contribution. • CO_2CRC: currently in Stage 3 drilling and monitoring programme, having injected 70,000 tonnes of CO_2 to date. • CSIRO/IHI Loy Yang A Power Station Capture test facility • Delta PCC pilot plant at Vales Point Power Station • Stanwell PCC Pilot Plant at tarong Power Station (ceased) • Callide Oxy-fuel demonstrated Oxy-fuel combustion at Callide 'A' power station (not ceased) • NGL: Laboratory for subsurface geological storage analysis, support South West Hub and other project • GippNet: supports the deployment of monitoring equipment for CarbonNet Project
CAPTURE	Capture technology providers	This information is not publicly available.
	Capture project investors and operators	This information is not publicly available.
TRANSPORT	Pipeline infrastructure investors and operators	National Carbon Storage Taskforce created a series of transport plans as part of national CCS Atlas. A specific and detailed review of pipelines required for the CarbonNet Project has been completed.
STORAGE	Storage site appraisal	Four phases of storage appraisal have been completed 1. National study to identify specific sites for storage (known as ESSCI) 2. National Carbon Storage Taskforce undertook prospectivity analysis on every Australian basin and completed storage evaluation and resource estimates on key basins 3. Specific site scale assessments completed in Gippsland, Bonaparte, Browse, Perth and Bowen/Surat 4. Specific appraisal studies underway/operations include Gorgon, Petrel (Northern Australia), Wandoan in Surat Basin (Queensland), CarbonNet, and Cooper CO_2-EOR
	Storage site leasing arrangements	Federal Government has the Offshore Petroleum and Greenhouse Gas Storage Act to permit exploration and development of storage activities. In Western Australian the project specific Barrow Island Act was enacted as part of the Gorgon CO_2 Injection Facility.
	Storage site operators	Only current large-scale storage facility is Gorgon. CO_2CRC is also an operator of a pilot injection project.

GET IN TOUCH

To find out more about the Global CCS Institute including Membership and our Consultancy services, visit globalccsinstitute.com or contact us.

AMERICAS

Washington DC, United States

americasoffice@globalccsinstitute.com

EUROPE & MIDDLE EAST

Brussels, Belgium

europeoffice@globalccsinstitute.com

AUSTRALIA

Melbourne, Australia

info@globalccsinstitute.com

UNITED KINGDOM

London, United Kingdom

ukoffice@globalccsinstitute.com

CHINA

Beijing, China

chinaoffice@globalccsinstitute.com

JAPAN

Tokyo, Japan

japanoffice@globalccsinstitute.com