GLOBAL CCS INSTITUTE

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POLICY PRIORITIES TO INCENTIVISE LARGE SCALE DEPLOYMENT OF CCS

ALEX ZAPANTIS
General Manager – Commercial

ALEX TOWNSEND
Senior Consultant – Economics

DOMINIC RASSOOL
Senior Consultant – Policy & Finance

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EXECUTIVE SUMMARY

Carbon capture and storage (CCS) prevents carbon dioxide (CO_2) from being released into the atmosphere. The technology involves capturing CO_2 produced by large industrial plants, compressing it for transportation and then injecting it deep into a rock formation at a carefully selected and safe site, where it is permanently stored.

CCS is essential to achieving climate change mitigation targets. It is the only feasible technology that can deliver deep emissions reductions in many industrial processes that are vital to the global economy, such as steel, cement and chemicals production. In combination with bioenergy used for power generation or biofuel production, it provides one of the few technologies that can deliver negative emissions at scale; unambiguously required to limit temperature rises to no more than 2°C. CCS can also be applied to coal and gas fired power plants, providing dispatchable generation capacity to complement the increased deployment of intermittent renewables, and in the production of low emissions hydrogen for heat and transport.

While the critical role of CCS has been demonstrated in many reports, the policies in place today are insufficient to ensure CCS deployment scales up at the rate required. This paper seeks to address the current policy gap by describing priorities for policymakers to support the transition from current to future rates of deployment of CCS. It starts by reviewing the barriers to investment in CCS and how these have been overcome for the eighteen large scale facilities currently in operation and five under construction. It then develops a framework to support the scaling up of CCS deployment. It concludes with recommendations for policymakers.

The assessment of barriers to CCS deployment is summarised as follows:

- In the absence of a well-designed policy framework that enables the creation of a self-sustaining market for CCS, the private sector will not deploy CCS at the scale required to meet climate change mitigation targets. This is because there are multiple market failures and broader barriers to investment in CCS.
- These market failures translate to risks, some of which are general project risks that can be mitigated over the course of deployment, whilst others are hard to reduce risks that will need to be allocated to government, at least in the short term.
- It is important to note that this does not mean that governments should take on all of the risks associated with CCS projects. Instead, risks should be allocated efficiently to the organisation that is best placed to manage them at the lowest cost. The private sector is well placed to manage general project risks, such as technical, construction and operational performance risks and this is common across many large infrastructure projects. However, the private sector has limited control over the occurrence and impact of the hard to reduce risks, so government would need to take on those risks, at least initially.
- Over time, as the market develops and there is more experience from successfully implementing CCS projects, those risks may reduce, disappear or become transferrable from government to the private sector. This relies on there being a stable policy framework in place to support that transition.

The paper also assessed the prevailing conditions that have enabled the eighteen large scale CCS facilities in operation as well as those under construction:

- These have been enabled through a mix of supportive policy and favourable project conditions and provide a valuable insight into how the barriers mentioned above have been overcome to make CCS a commercially viable proposition.
- While the specific mechanisms used to overcome the market failures have differed, there are common features that are reflected across a number of projects. CCS has been deployed in relatively few countries, mainly in North America, and has largely been reliant on the sale of CO_2 for enhanced oil recovery (EOR) to provide a revenue stream to incentivise the capture of CO_2. While this has enabled projects to get off the ground, the policies currently in place are insufficient to enable CCS deployment to scale-up at the rates required to meet global climate targets.
- Funding CCS projects is capital intensive, and so several projects have relied on grant support to bridge funding deficits. This is the case for many emerging energy technologies that are beset by the 'technology valley of death', where financing is difficult to obtain for innovations that are technically proven but not yet deployed at commercial scale. In the short term, other forms of capital funding can be considered, such as bonus capital depreciation.
- It has been widely reported that by addressing market failures, allocating risks efficiently, achieving economies of scale and learning by doing, the costs of CCS could be brought down significantly. This is critically dependent on the number of CCS facilities in operation.

The report also finds that, currently, there is an insufficient value on carbon, which is an essential part of any policy framework to support climate change mitigation:

- The United States is the only nation to put a significant value (up to US$50 per tonne by 2026) on carbon dioxide storage. Norway is the only nation that has implemented a carbon tax sufficient to support a business case for geological storage of CO_2 produced during gas production. Eighty per cent of global emissions are still not covered by carbon pricing[1] and half of current emissions covered by carbon pricing initiatives are priced at less than US$10 per tonne CO_2. This highlights an important gap in the existing policy framework and one that, if plugged in the short-term, could help move CCS up the deployment curve.
- While CCS is often erroneously referred to as being too expensive compared to other climate change mitigation technologies, a relatively low value on carbon could lead to a significant increase in deployment.

To reduce the overall cost of CCS, it was found that shared transport and storage networks are an essential component of both risk mitigation and operational cost reductions:

- This is because of the benefits of economies of scale and overall derisking related to storage liability as well as the cross-chain risk[2].
- A disaggregated transport and storage business model allows businesses to focus on their core competency and avoid the risk and cost that comes from extending into new activities. The net result is a significant reduction in unit cost of CO_2 storage through the realisation of economies of scale and risk reduction.
- Government has a leading role to play in early deployment of shared transport and storage infrastructure, either by development or by setting the regulatory framework within which networks can be developed cost effectively.

This paper concludes that investments in most CCS projects to date have been enabled through high proportions of grant funding, with little to no debt financing. To deploy CCS at the rate necessary to meet climate change targets, private sector investment must increase by orders of magnitude. To achieve this, banks have a critical role in providing debt financing to project developers:

- Currently project risks are perceived by banks as too high, which makes it difficult for them to qualify CCS projects for debt financing. Policy derisking, including establishing a sufficient value on carbon and enabling the deployment of shared transport and storage infrastructure, is essential to reducing risks such that debt financing can be secured for CCS projects.
- The cost of capital has a substantial implication for the sanction of CCS projects. As the number of CCS facilities increases, and through policy derisking, debt finance will become available for CCS projects.
- Establishing the incremental cost of individual risks can be achieved through structured interviews with banks and equity investors. It is suggested that this is undertaken to help policymakers prioritise policy instruments which will enable the necessary growth in CCS deployment.

[1] Carbon pricing in this context means the implementation of a carbon tax or emissions trading scheme (World Bank 2018); in this report we use the term 'value on carbon' to reflect a set of broader policies.

[2] The risk arising as a result of the interdependency between capture and storage operators, and other counterparties.

1.0 INTRODUCTION

Carbon capture and storage (CCS) prevents large amounts of carbon dioxide (CO_2) from being released into the atmosphere. The technology, first deployed at commercial scale in 1972 (Global CCS Institute, 2013), involves capturing CO_2 produced by large industrial plants, compressing it for transportation and then injecting it deep into a rock formation at a carefully selected and safe site, where it is permanently stored.

CCS is essential to achieving climate change mitigation targets at the lowest possible cost. It is the only feasible technology that can deliver deep emissions reductions in many industrial processes that are vital to the global economy, such as steel, cement and chemicals production. In combination with bioenergy used for power generation or biofuel production, it provides one of the few technologies that can deliver negative emissions at a relevant scale that will be crucial to limiting temperature rises to well below 2°C. CCS can also be applied to coal and gas fired power plants, providing dispatchable generation capacity to complement the increased deployment of intermittent renewables, and in the production of low emissions hydrogen for heat and transport.

Significant investment will be needed if CCS is to fulfil its potential, and global climate targets are to be met. To remain on track to meet the 1.5°C target, the rate of capture and storage of CO_2 will need to increase rapidly over the next two decades, from around 37 million tonnes of CO_2 per annum today to thousands of millions tonnes of CO_2 per annum by 2040 (International Energy Agency, 2019). This will require over 2,000 large scale CCS facilities to be built within that timeframe and hundreds of billions of dollars of investment.[3]

The scaling up of deployment will only be achieved if there is a clear commercial case to invest in CCS. In this context, the commercial case describes a situation where the unit cost of CCS (normally expressed in US$/tonne of CO_2 avoided) is less than the prevailing or expected future cost of CO_2 regulation. Governments have a pivotal role to play, by providing a clear, stable and supportive policy framework for CCS. While the policy landscape has improved in recent years, there remain gaps that are holding back investment in CCS, and therefore preventing the achievement of global climate targets.

This report seeks to address the current policy gap by describing a framework to support the transition from current to future rates of deployment of CCS. It starts by reviewing the barriers to investment in CCS and how these have been overcome for the eighteen large scale facilities currently in operation and five under construction. It then develops a framework to support the scaling up of CCS deployment. It concludes with recommendations for policymakers.

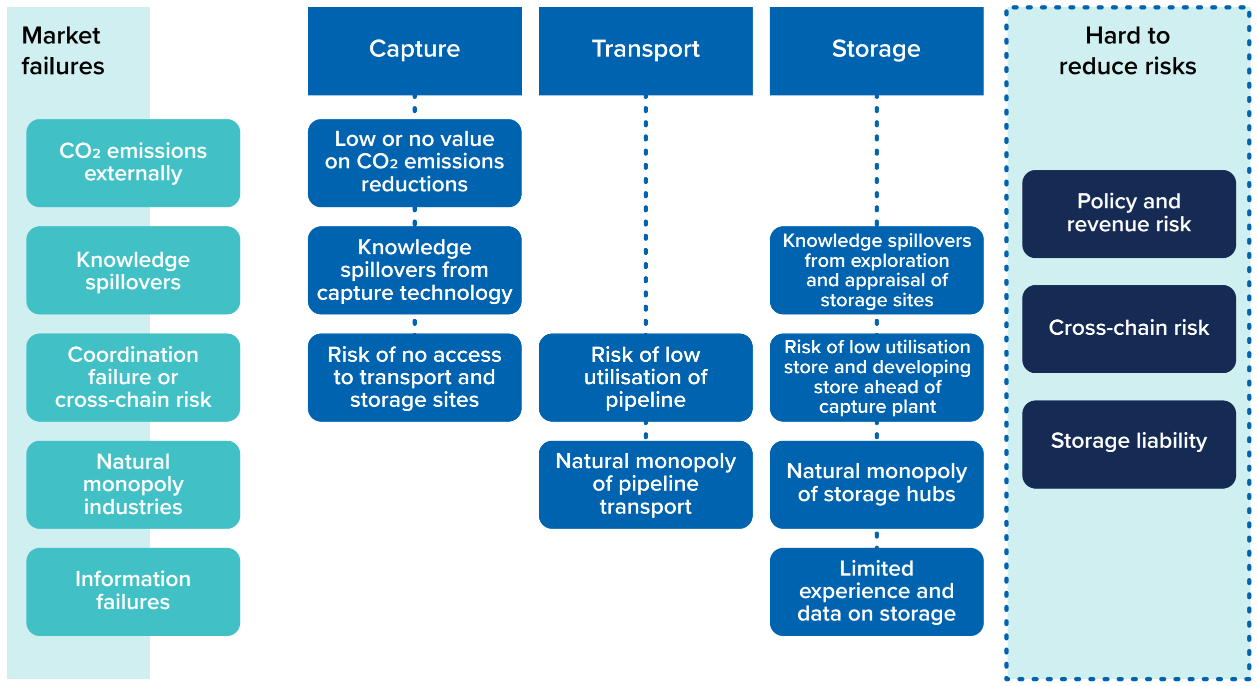
[3] Based on the assumption that the average CCS facility has a capture rate of ~1.5MtCO_2 per annum.

2.0 BARRIERS TO CCS DEPLOYMENT

In the absence of well-designed policy, the private sector will not deploy CCS at the scale required to meet climate change mitigation targets. This is because there are several market failures and broader barriers to investment[4] that have led to the absence of a CCS market. These market failures directly affect the business case for CCS by reducing the expected return from projects relative to alternative options, including not investing in emissions reductions altogether. They give rise to a series of hard to reduce risks[5] that the private sector is unwilling or unable to take on at an appropriate price, at least during the early stages of deployment.

The market failures differ across the CCS supply chain (Figure 1). For a potential capture plant developer, the main impediment to investment is often the lack of a definitive price signal that places a sufficient value on emissions reductions. Without this, there is no incentive for a developer to incur the costs of constructing and operating the capture plant, even though it may be beneficial from a broader societal perspective in helping to meet climate targets cost effectively. This results in there being a 'missing market' for the capture, transport and storage of CO_2.

Figure 1: Market failures across the CCS supply chain



[4] Market failures occur when the operation of the free market leads to an inefficient allocation of goods and services from society's perspective. For example, rational decisions made by individual firms to maximise financial performance may not in the best interests of broader society.

[5] Risks that are not possible to mitigate or can only be partially mitigated.

Early developers of capture plants also create knowledge that can be used by other developers, at no additional cost, to improve the design and operation of future capture plants. While these knowledge spillovers help to reduce the unit costs of CCS over the longer-term, they increase the risk of asset stranding. To illustrate, a capture facility may become uncompetitive following the construction of newer facilities that achieve performance and cost improvements through the adoption of design or operational innovations learned from earlier facilities. This encourages a 'wait and see' approach in anticipation of being able to achieve better value for money by learning from the success and failures of others. Without projects going ahead though, there are limited opportunities to learn from other projects to improve future plant design, perpetuating the status quo. A similar issue arises for storage developers, where there are knowledge spillovers from the exploration of storage sites.

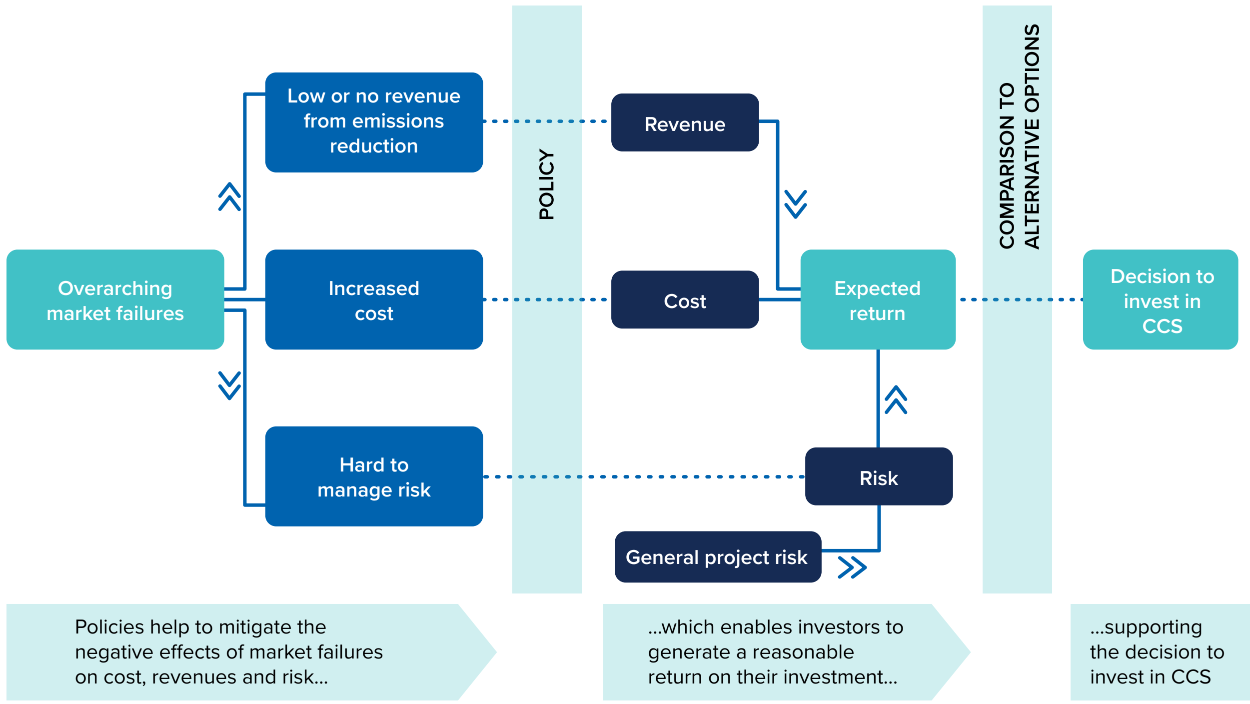
CCS projects require the coordination of multiple investment decisions, each with long lead times, leading to cross-chain risk. This arises as the decisions to develop each element of the CCS chain are taken before there is full certainty that the capture plant will have access to transport and storage infrastructure, and the transport and storage infrastructure will be sufficiently utilised. Once projects are operational the interdependency remains, as the failure of one of the components to deliver on their obligations may affect the costs and revenues of others and prevent the value chain performing as a whole.

The cost structure of transport and storage projects potentially introduces additional economic barriers for capture developers too. Transport and storage projects involve high upfront costs such that it is cheaper for one firm to provide the transport or storage infrastructure than two or more competing firms due to the cost of replicating infrastructure. Transport and storage providers can use this natural monopoly advantage to charge a high fee for using their infrastructure, knowing that a competitor cannot provide the service at a lower cost. If priced inefficiently, this would add to the costs of the capture plant operator who must pay for CO_2 transport services, and so act to erode the business case for investment.

The CCS industry also suffers from several information failures, largely driven by the limited experience to date in deploying large scale facilities relative to the numbers needed. As a result, the market has relatively little experience in the application and effectiveness of different competing CCS technologies and business models. While the capture and safe storage of CO_2 has been technically proven over many decades, banks and insurance companies need to price in a high risk premium on lending or providing insurance to CCS projects due to the lack of operational data compared to mature industries (Karmali, 2019).

A general rule of thumb of policymaking is that there needs to be one policy per market failure. The presence of multiple market failures highlights the need for a comprehensive policy framework that is tailored to address the specific barriers to investment in CCS. Well-designed policy can set the conditions that make CCS a commercially viable proposition, by minimising costs, supporting stable revenues and allocating risks efficiently. This ultimately enables the CCS market to operate more efficiently and help to deliver climate mitigation targets at least cost (Figure 2).

Figure 2: Illustration of how market failures, policy and risks influence the business case to invest in CCS



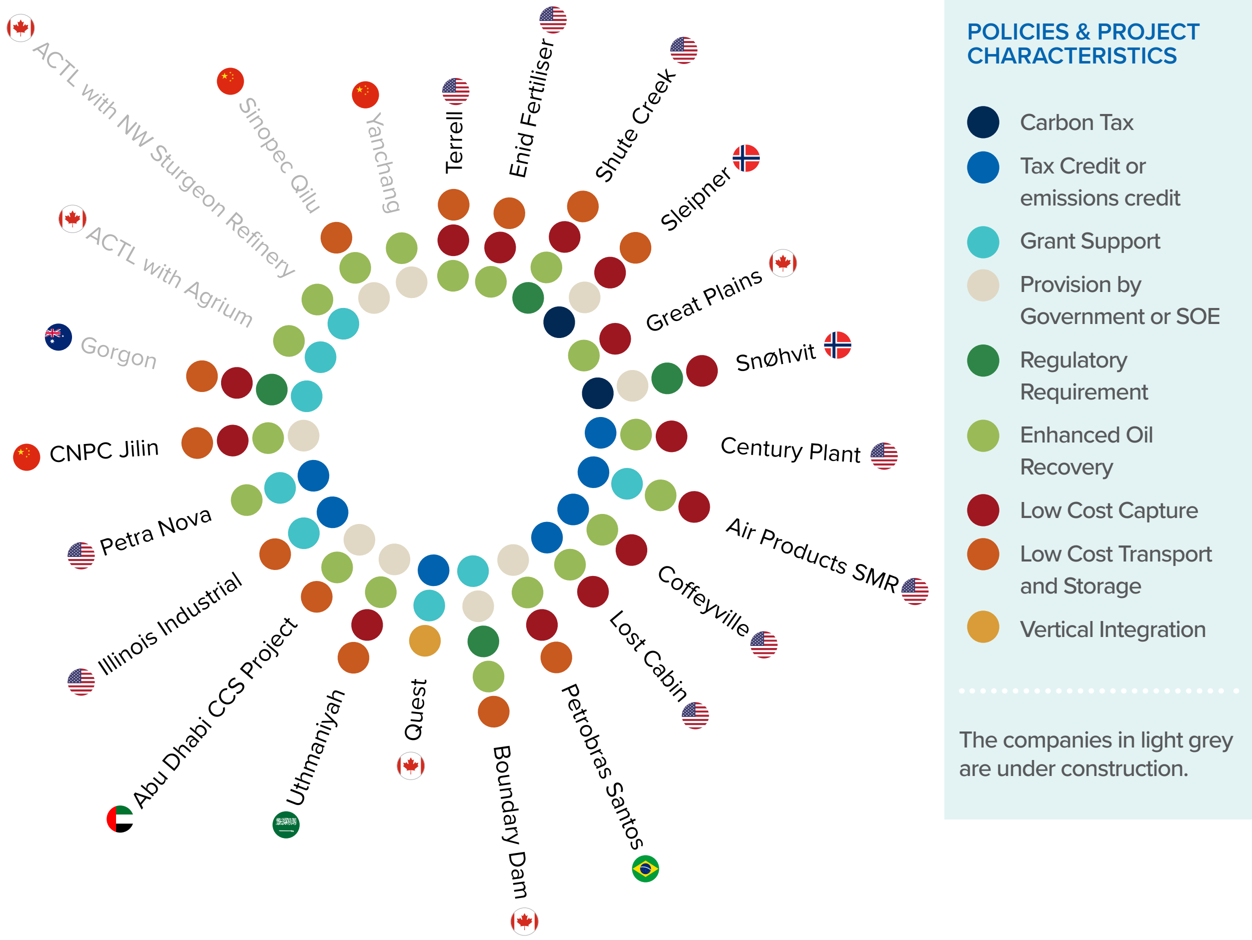
It is important to note that this does not mean that governments should take on all of the risks associated with CCS projects. Instead, risks should be allocated efficiently to the organisation that is best placed to manage them at the lowest cost. The private sector is well placed to manage general project risks, such as technical, construction and operational performance risks, and this is common across many large infrastructure projects.

However, the private sector has limited control over the occurrence and impact of the hard to manage risks, so government needs to take on those risks, at least initially. Over time, as the market develops and there is more experience from successfully implementing many CCS projects, those risks may reduce, disappear or be transferable from government to the private sector. This relies on there being a stable policy framework in place to support that transition.

3.0 LESSONS FROM CURRENT POLICIES AND PROJECTS

While no country has yet put in place a comprehensive framework to support the scaling-up of CCS that is consistent with meeting climate targets agreed in Paris, there are today eighteen large scale CCS facilities in operation and five under construction. These have been enabled through a mix of supportive policy and favourable project conditions, and provide a valuable insight into how the barriers described above have been overcome to make CCS a commercially viable proposition. While the specific mechanisms used to overcome the market failures have differed, there are common features that are reflected across a number of projects (Figure 3).

Figure 3: The main policies and project characteristics that have overcome the barriers to investment in CCS[6]



[6] While some projects in the US will have been eligible for 45Q tax credits, these may have only been partially claimed. Similarly, some CO_2-EOR projects in the 1980s may have benefited from an exemption to the Windfall Production Tax, but data is not publicly available to confirm this. CO_2-EOR projects in the 1980s may have benefited from an exemption to the Windfall Production Tax, but data is not publicly available to confirm this.

Enhanced Oil Recovery

The main way through which a value has been placed on capturing CO_2 has been in its use for Enhanced Oil Recovery (EOR) rather than through any individual policy mechanism. Of the eighteen projects currently in operation, thirteen sell CO_2 for EOR, a process where CO_2 is injected into oil reservoirs to improve flow properties and increase oil production. While not publicly available, the price of CO_2 for EOR is understood to be linked to the price of oil. For example, the cost of CO_2 is around US$30/t$CO_2$ at oil prices of US$70 per barrel (Bliss, et al., 2010). At these prices the revenue from the sale of CO_2 for EOR alone may be sufficient to cover the costs of capturing and transporting CO_2 in sectors where the cost of capturing CO_2 is relatively low, such as natural gas processing, fertiliser and bioethanol production. This was the case at the Terrell, Enid Fertiliser and Great Plains CCS facilities. This combination of favourable project costs and revenues from the sale of CO_2 for EOR has been the main driver of early CCS projects in the US.

Tax credits

More recently, tax credits in the US have supplemented the revenues for CO_2-EOR projects and have also provided an incentive for the geological storage of CO_2. This has been widely recognised as an important enabler of the six large-scale facilities in the US that have come on stream since 2011, including some in higher cost capture sectors such as Petra Nova (coal fired power generation). Under the current arrangements, 45Q provides tax credits worth US$18/t$CO_2$ for CO_2 used for EOR and US$29/t$CO_2$ for CO_2 stored through dedicated geological storage, rising linearly to US$35/t$CO_2$ and US$50/t$CO_2$ by 2026 respectively (Clear Air Task Force , 2017). The credits can be used to reduce a company's tax liability or, if they have no tax liability, transferred to the company that disposes of the CO_2 or traded on the tax equity market (Martin, 2018). Tax credits have the benefit of being well established in the context of climate change mitigation in the region, having been used to drive significant investment in renewables over the past two decades.

Carbon pricing

An alternative approach to placing a value on emissions reduction would be to introduce a 'stick', such as a carbon tax. A carbon tax introduced in Norway in 1991 has been successful in incentivising the development of the Sleipner and Snøhvit CCS projects. At US$17/t$CO_2$, the cost of injecting and storing CO_2 for the Sleipner project was much less than the US$50/t$CO_2$ tax penalty at the time for CO_2 vented to the atmosphere (Massachusetts Institute of Technology, 2016) (Herzog, 2016). This was complemented by a commercial need to separate the CO_2 from natural gas to meet market requirements and provided a clear business case to invest in CCS. The current level of the tax is higher than the level when it was introduced, making the business case for CCS at Sleipner even stronger (Price, 2014).

Regulation of emissions

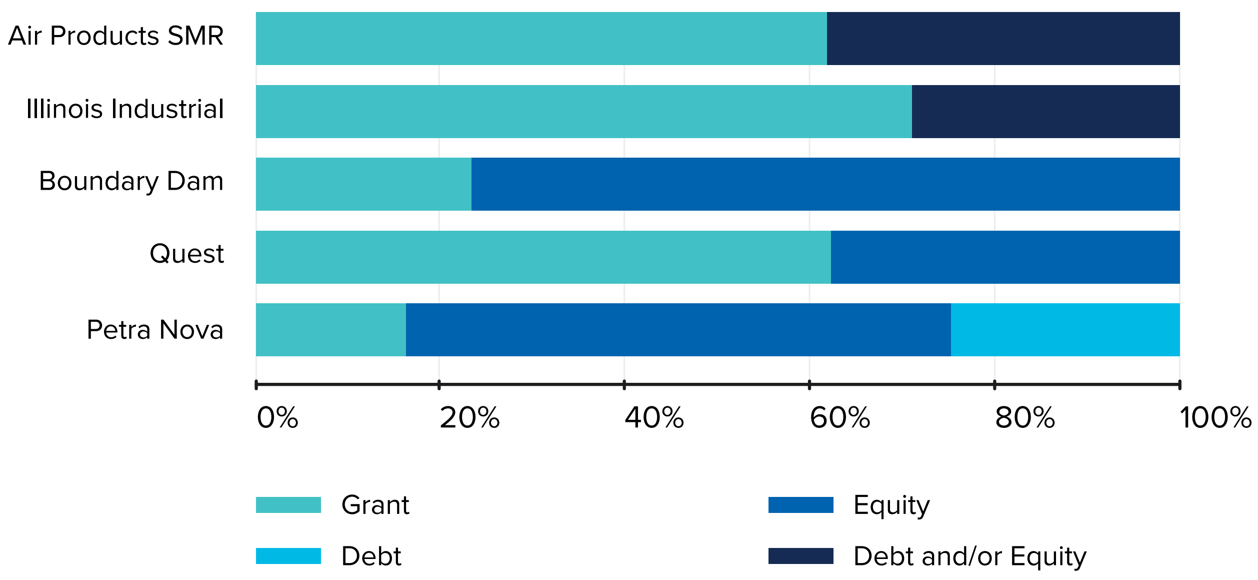
Regulation has also played a role in supporting the deployment of CCS by placing an implicit value on emissions. A mandatory condition for the approval of the Gorgon project in Australia was the injection of at least 80 per cent of the CO_2 released by the gas processing operations. As one of the largest natural gas projects in the world, the additional costs of compressing and storing CO_2 were manageable in the context of the project as a whole, adding less than five per cent to the total project costs. Once launched, the project is projected to be the world's largest dedicated CO_2 storage facility with the ability to store up to 4 million tonnes of CO_2 per year (Chevron, 2018). The expectation of a future tax on carbon has also been raised as a reason for CCS being adopted for the Gorgon project (Price, 2014). This highlights an important point, that it is not just current policies but also expected future policies that determine an investors decision to support a CCS project.

Other regulatory requirements that have been adopted include emissions performance standards, which place a cap on the emissions intensity of power stations. One drawback of an emissions performance standard is that it drives decision making only on the basis of generation technology attributes. It does not consider the total cost of electricity supply which includes the cost of engineering requirements to ensure demand can always be met and the grid is resilient to planned and unplanned events. Intermittent generation technologies incur system-level costs and risks that are ultimately met by the consumer and are generally beyond the scope of emission performance standards. Having said that, the introduction of a federal emissions standard in 2011 in Saskatchewan has been identified as a driver of the development of the Boundary Dam CCS facility. When partnered with other supporting measures, the cost of electricity after the retrofit was expected to be similar to building a new NGCC power plant, which would have been an alternative option to meeting the standard (Herzog, 2016).

Capital grants

Information on capital structure is not always publicly available, and in the instances when it is, there can be a lack of clarity over the proportions of debt and equity in relation to grant funding. Figure 4, below, shows the capital structure of a selection of operating CCS facilities. Facilities for which there are unknown amounts of equity or debt, the chart identifies these with dark-blue bars to indicate their combined proportions. Several facilities have received capital grant support from governments to bridge funding deficits. It is well understood that bringing new energy technologies to market is challenging because they are beset by the 'technology valley of death' where financing is difficult to obtain for innovations that are technically proven but not yet deployed at commercial scale (Murphy & Edwards, 2003). Grant funding helps to address this, first by rewarding early investments for the knowledge they create that can be used by future project developers, and second by making investments more attractive to private sector investors, helping to increase investment, bring down the cost of finance and build confidence in the technology.

Figure 4: Proportion of grant funding provided to selected projects



Grant support has also been used to fund the construction of transport and storage networks, to address the cross-chain risk that capture plant developers are exposed to. This is the approach that has been adopted for the Alberta Carbon Trunk Line currently under construction, which has received CAN$558M from the Alberta and Canadian governments for the CAN$1.2B project (Natural Resources Canada, 2013). The 240km pipeline will connect emitters 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 (Enhance Energy, 2018).

The oversizing of the pipeline has a number of benefits. Firstly, 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. Around 75-95 per cent of the costs of a pipeline are fixed capital costs associated with building it, so there are large economies of scale from building a pipeline that can serve multiple users (Zero Emissions Platform, 2011). Secondly, 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. Finally, 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.

Other approaches to addressing elements of the cross-chain risk have included the funding of storage appraisal and the vertical integration of projects. In the case of the former, funding provided by government for the early appraisal of the Illinois Industrial project storage resource and the Boundary Dam Aquistore helped to move those projects forward, reducing the time and cost of project development and making them bankable. In general, nations that have long-term, clear CCS policy frameworks have the most developed storage resources and are best placed to convert the technically available resources into bankable projects.

State ownership of CCS facilities

Rather than providing a direct 'carrot', some governments have overcome the barriers to private sector investment by supporting the construction of CCS facilities through State Owned Enterprises (SOEs). In effect, the governments of Saudi Arabia and the UAE have adopted a strategy of state ownership of CCS facilities to supply CO_2 for enhanced oil recovery, at least in the early stages of deployment, rather than establishing policy environments to encourage private sector investment. China has similarly supported CCS through the state-owned CNPC for the Jilin project, but has also implemented other policy measures to support CCS deployment over the longer-term.

Sponsoring projects through SOEs has several advantages for these countries. State ownership is a way of directly supporting the development of infant industries like CCS, particularly in countries that have less developed regulatory frameworks or where outsourcing to the private sector is difficult (Kowalski, et al., 2013). Stable governments can borrow at relatively low interest rates, helping to bring down the effective cost of capital of projects. Some elements of CCS also lend themselves well to state ownership due to their natural monopoly characteristics, such as the development of transport and storage infrastructure.

4.0 PRIORITIES FOR POLICYMAKERS TO SUPPORT THE SCALING UP OF CCS DEPLOYMENT

WHY SHOULD GOVERNMENT INVEST IN CCS?

Whilst private sector investment in any business venture, including CCS, is driven by expectations of financial return, government has other objectives and incentives for investment. The role of government is to ensure the provision of public goods to their constituents. Public goods include such things as public health and welfare, education, security, public infrastructure and a clean environment. A stable climate is an example of a public good. Thus, it is right and proper for governments to fail to achieve financial returns on investments as long as those investments are efficiently contributing towards the delivery of public goods. It is in this context that government support of CCS and other climate mitigation technologies is justified.

It also introduces the concept of government support actually being an investment which delivers returns in the form of public goods, rather than financial profits. This is an important concept with respect to opportunities for government to attract private sector investments in CCS by taking on certain costs and risks during the early stages of deployment.

Another important concept to recognise is that government alone will not solve the challenge of climate change. The solutions (and there are many) will be developed, commercialised and deployed by the private sector which has enormous resources and capabilities. All that is required are the incentives to mobilise private capital, and the creation of those incentives is entirely within purview of government.

The experience from projects deployed to date demonstrates that CCS is technically proven across several sectors. However, as noted, CCS has only been deployed in relatively few countries, mainly in North America, and has largely been reliant on the sale of CO_2 for EOR to provide a revenue stream to incentivise the capture of CO_2. While this has enabled projects to get off the ground, the policies currently in place are insufficient to enable CCS deployment to scale-up at the rates required to meet global climate targets. This presents an opportunity for policymakers to work collaboratively with the private sector to identify priority areas where additional policy is needed.

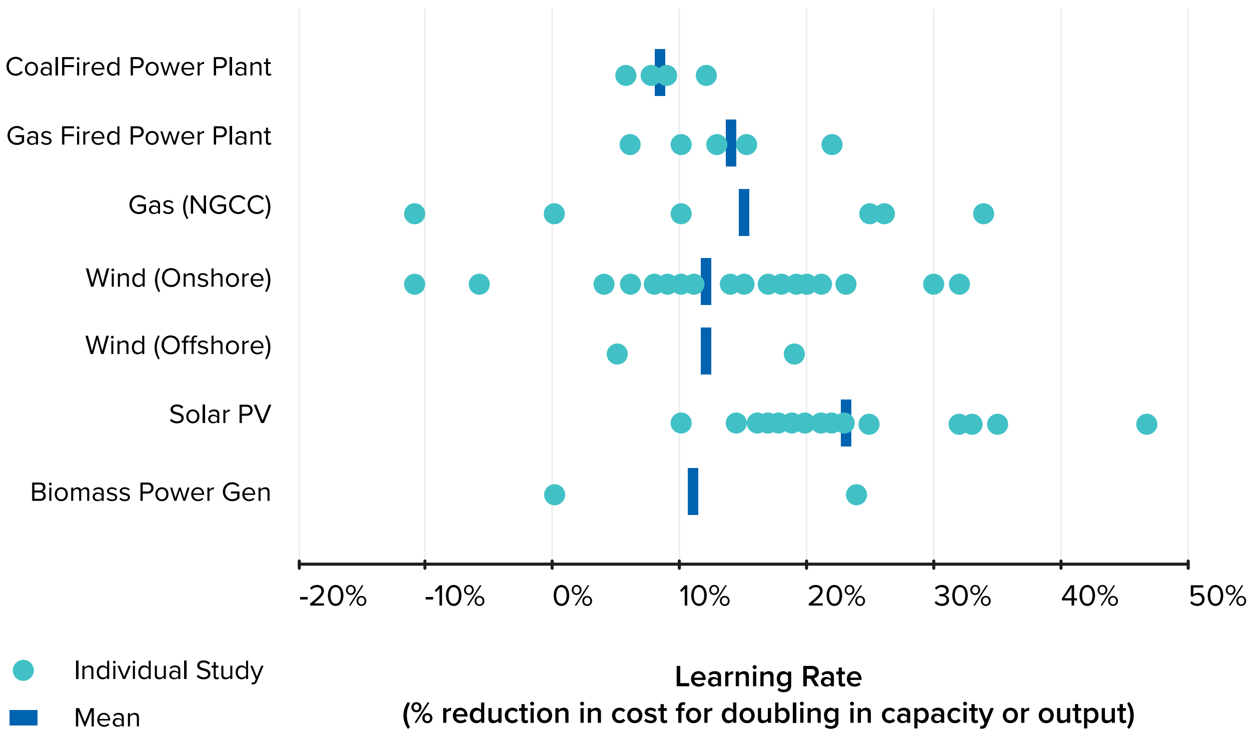
It has been widely reported that by addressing market failures, allocating risks efficiently, achieving economies of scale and learning by doing, the costs of CCS could be brought down significantly. This is critically dependent on the number of CCS projects deployed at a given point in time.

The concept of achieving lower costs as the number of operating facilities increases is not new. That has certainly been the experience with renewable technologies which have benefited from strong and sustained policy support throughout this century.

Evidence from empirical studies of learning rates, which show the percentage reduction in costs for every doubling of capacity or output, support this. While there is a lot of variation across the studies due to the different location, timing and approach adopted, most electricity generation technologies have experienced an average learning rate of between 8 per cent and 15 per cent (Figure 5). As an illustration, if an 8 per cent learning rate was applied to the deployment of CCS then the rise of the number of facilities from tens to thousands by the middle of this century (as is required to meet climate change targets) would result in a the cost of capturing CO_2 falling by around a half[7]. This may be a conservative estimate of the possible reduction in cost given the capital cost reduction per unit capture capacity already observed between the Boundary Dam and Petra Nova power plants of approximately 20 per cent implies a learning rate of 15 per cent [8].

Achieving these levels of cost reductions in the longer-term requires immediate action today. Here we set out some of the priorities for governments that, if addressed sufficiently, should support that scale-up.

Figure 5: Learning rates for selected electricity generation technologies[9]



[7] Assumes 8% cost reduction for every doubling of installed capacity, and a 100-fold increase in installed capacity.

[8] Increase in installed capacity from 1Mtpa to 2.4Mtpa. Capital cost per Mtpa CO_2 capture capacity of Boundary Dam was approximately AU$750 million. Capital cost per Mtpa CO_2 capture capacity of Petra Nova was approximately AU$593 million.

[9] Source: Based on (Rubin,et al, 2015; EPRI, 2013)

Placing a value on emissions reductions

A fundamental part of any policy framework to support climate change mitigation more broadly is the presence of a sufficient value on carbon. Without this, there is no incentive to reduce emissions. Governments have a wide range of policy options to choose from when putting a value on carbon, including carbon taxes, emissions trading and tax credits or payments linked to delivered emission reductions. Each option has very different effects in terms of its efficiency, ability to leverage finance and distributional impacts. The option that policymakers choose will ultimately depend on the particular context in which it is being implemented, as illustrated by the support that has been provided to CCS projects in different countries to date. While CCS is often erroneously referred to as being too expensive compared to other climate change mitigation technologies, a relatively low value on carbon could lead to a significant increase in deployment. For example, the International Energy Agency has estimated that as much as 450 $MtCO_2$ could be captured, utilised and stored globally with a commercial incentive as low as US$40 per tonne of CO_2 by deploying CCS on the many low-cost opportunities available (OECD-IEA-UNIDO, 2011). This value is at the bottom end of the US$40-80 range of carbon prices that the High-Level Commission on Carbon Prices recommended would be needed by 2020 to drive transformational change consistent with meeting Paris Agreement targets (Carbon Pricing Leadership Coalition, 2017). (World Bank Group, 2018) Harnessing these low-cost opportunities could provide a solid foundation for scaling up CCS deployment.

For some CCS applications that are part of the cost-effective mix of measures needed to meet Paris targets, the value on carbon would need to be higher than US$40 per tonne of CO_2. Given the long lead-in times for CCS investments, it is critical that policy frameworks are designed in a way that gives potential project developers sight of how the future value on carbon is expected to evolve, and the eligibility requirements for accessing it.

While there has been promising progress in putting a value on carbon, it remains the case that this is not widespread. For example, the United States of America is the only jurisdiction that offers a significant tax credit of up to US$50 per tonne (by 2026) for geological storage of carbon dioxide.

Norway is the only nation that has implemented a carbon tax sufficient to support a business case for geological storage of CO_2 produced during gas production. Eighty per cent of global emissions are still not covered by carbon pricing and half of current emissions covered by carbon pricing[10] initiatives are priced at less than US$10 per tonne CO_2 (World Bank Group, 2018). This highlights a gap in the existing policy framework and one that, if plugged in the short-term, could help move CCS and other low emission technologies, up the deployment curve.

Providing capital support

More recently, tax credits in the US have supplemented the revenues for CO_2-EOR projects and have also provided an incentive for the geological storage of CO_2. In the early stages of deployment, capital support from government is likely to be necessary to mobilise private capital in the majority of cases. This is, in part, due to the relatively high cost of capital that applies to CCS investments because of their perceived risk, as will be discussed later in this report. Capital support may take the form of grants, tax credits, concessional loans, or accelerated depreciation on CCS assets. Direct equity investment in CCS facilities is another option that may be considered by government. Over time, as the value on CO_2 increases, and the cost of CCS decreases, the requirement for capital support will reduce until the business case for investment in CCS is created by normal market forces. Until that time, to deliver the public good of a stable climate, government should enable private investment in CCS by providing capital support where required.

Facilitating the development of transport and storage networks

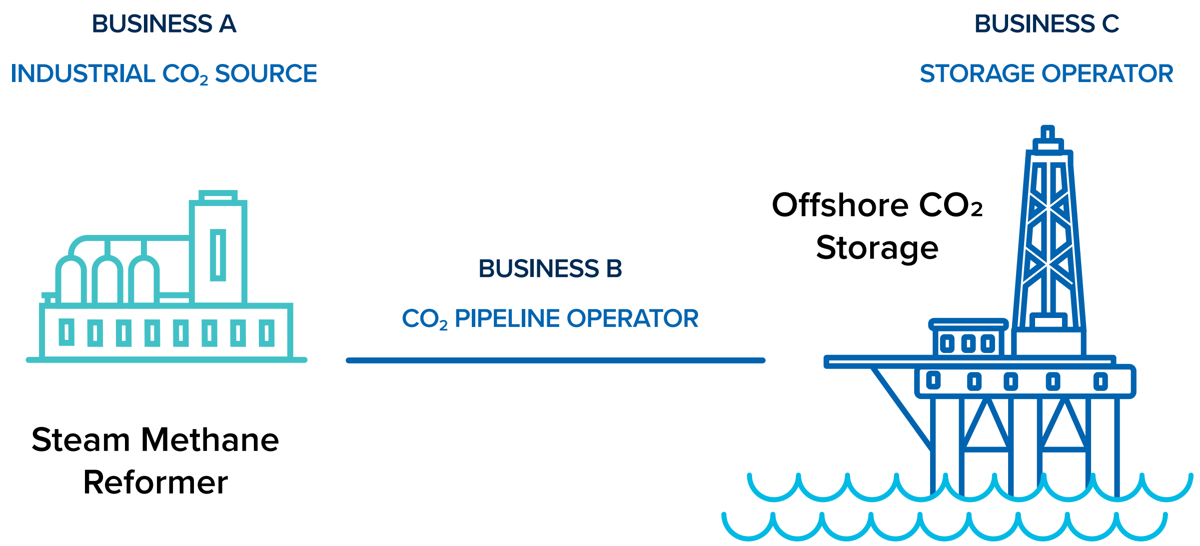
Placing a value on carbon dioxide goes a long way towards incentivising investment in CCS, however Governments should also consider how to contribute towards reducing the overall cost of CCS to deliver even lower cost abatement. A shared transport and storage network can significantly improve the economics of CCS facilities. This is because of the benefits of economies of scale and overall derisking (related to storage liability as well as the cross-chain risk) that can emerge from a shared and reliable network.

[10] Carbon pricing in this context means the implementation of a carbon tax or emissions trading scheme; in this report we use the term 'value on carbon' to reflect a set of broader policies.

Managing cross-chain risk

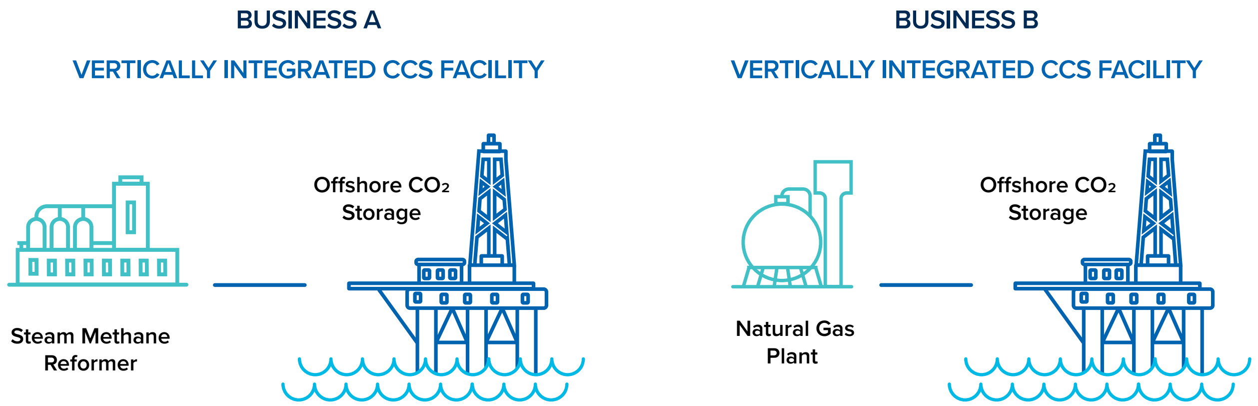
CCS facilities may involve one source, one sink, and one pipeline. In a disaggregated business model, there is significant cross-chain risk for all members of the value chain. For example, if the industrial source of CO_2 ceases operation, both the pipeline operator and the storage operator will have no customers and no revenue. This risk is a significant barrier to investment, and manifests, ultimately, as a higher cost of capital and higher project costs.

Figure 6: Single source, single sink, disaggregated business model



Alternatively, CCS facilities may adopt a vertically integrated full-chain business model rather than a disaggregated model. This allows the operator to optimise the entire CCS value chain but requires the operator to be competent across a broad range of activities which increases risk and thus cost. For example, steel or cement makers typically do not have expertise in geological storage of CO_2. Further, this model does nothing to reduce the dependence of the CO_2 source on a single CO_2 transport and storage operation and vice versa. If one facility is unavailable, the others will not operate reducing overall asset utilisation, and increasing the unit cost of storage.

Figure 7: Single source, single sink, vertically integrated business model

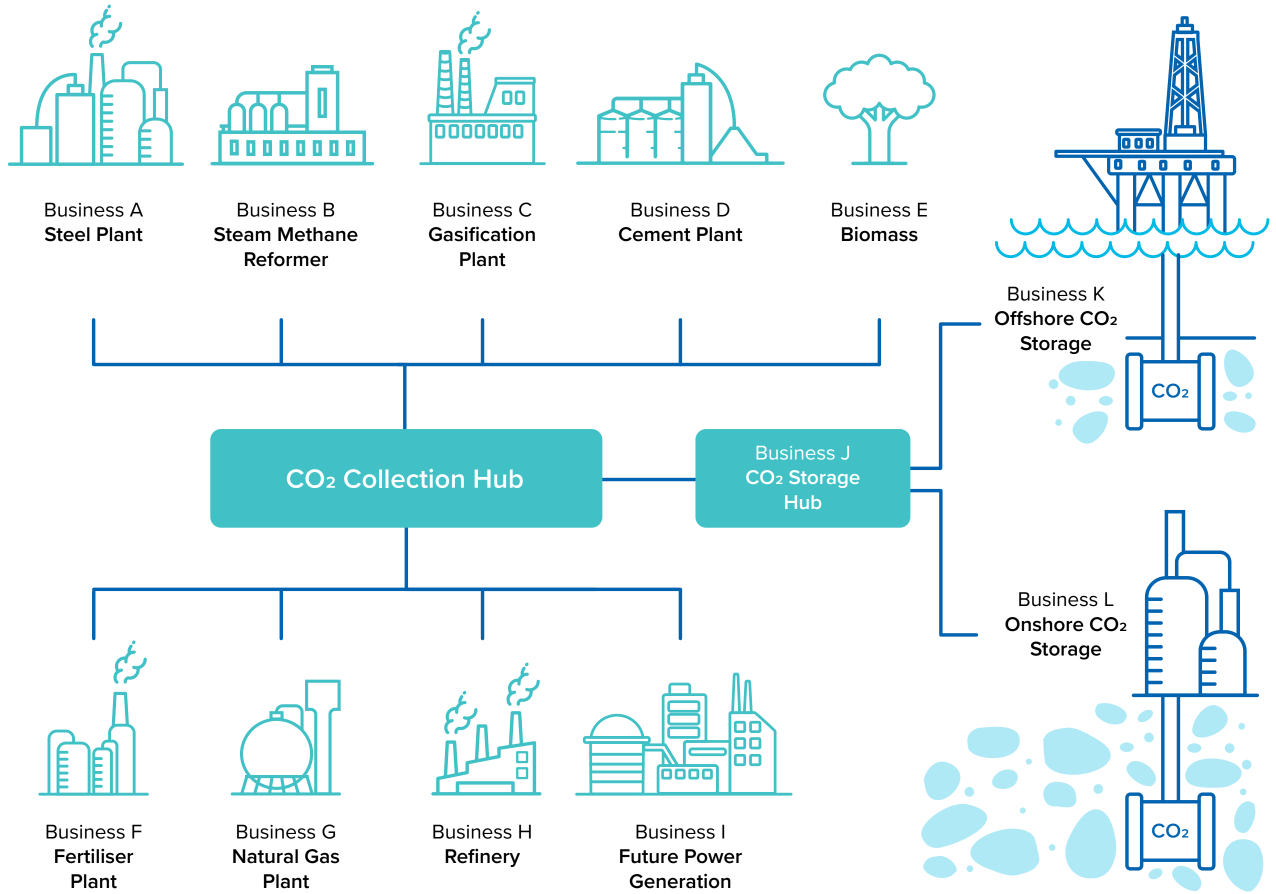


An option which is superior to the single source - single sink model is a hub and cluster model which utilises a transport and storage (T&S) network. Emissions intense industries such as steel, cement and fertiliser production often exist in clusters due to the local availability of necessary resources such as fossil fuel feedstocks, a skilled workforce or infrastructure such as port and rail. These industrial clusters provide an opportunity to create CO_2 transport and storage networks allowing multiple CO_2 sources access to common CO_2 transport and injection infrastructure. This significantly reduces the unit cost of carbon dioxide storage as the capital cost of building the pipeline is spread across more tonnes of stored CO_2. Transport and storage networks also reduce cross-chain risk by creating multiple customers for the operators of the CO_2 transport and injection business and multiple CO_2 storage service providers for industrial CO_2 sources. They offer much greater levels of operational flexibility than dedicated single source – single sink facilities, and therefore help to reduce operational risk.

For example, the flexibility they offer allows switching between storage sites as and when necessary, for example, during planned or unplanned maintenance. As will be discussed later, risk directly increases the overall cost of capturing and storing CO_2.

Further, a disaggregated business model allows businesses to focus on their core competency and avoid the risk and cost that comes from extending into new activities. The net result of all these advantages is a significant reduction in unit cost of CO_2 storage through the realisation of economies of scale and risk reduction. However, investing in T&S networks can be challenging for the private sector. Storage operators may have significantly different balance sheet strengths, and tolerances to risk compared to capture plant operators. For example, one party may be a large corporation with a very strong balance sheet and a strategic interest in CCS, justifying the acceptance of a higher level of risk. Other parties may not have the same incentives or balance sheet strength and may be more risk averse.

Figure 8: Hub and cluster disaggregated business model



Further, the first investors in a new T&S network will face all the costs and risks of a single source – single sink business model until others join the network which exposes them to cross-chain risks, as previously described. Put simply, businesses prefer not to be the first investor in a new CCS hub and cluster; they prefer to invest in a mature network. This is a significant barrier to the initial investments in the hub and cluster model, unless guarantees are provided for revenue during the early stages of development.

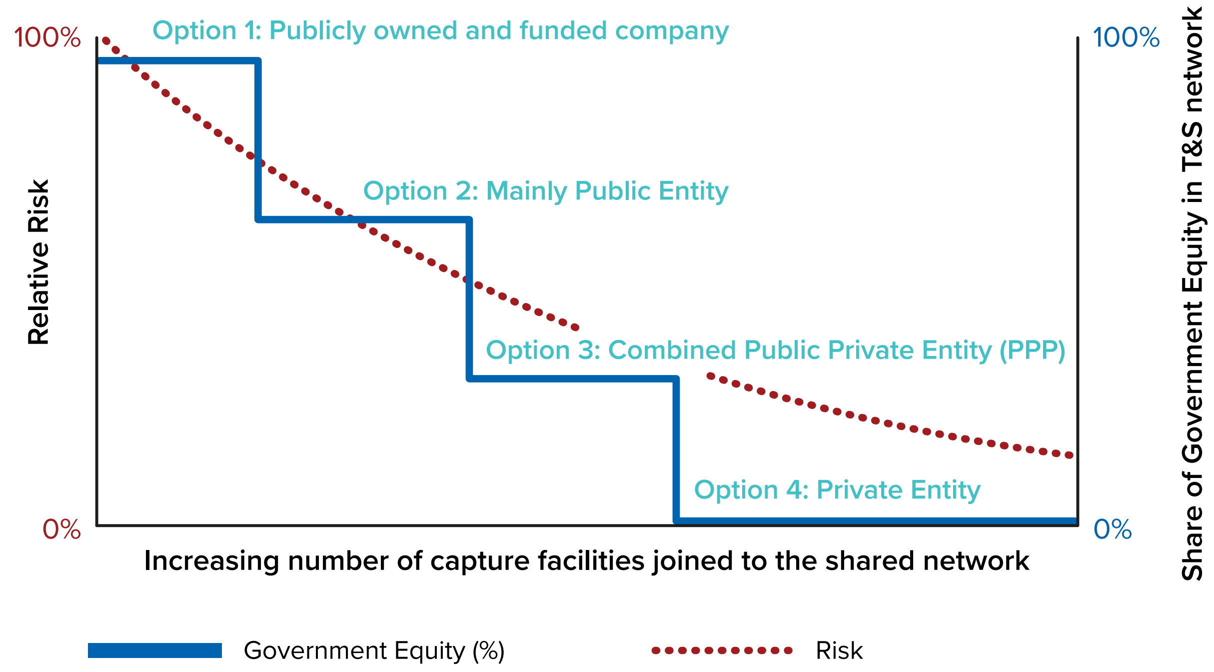
In some regions, the Regulated Asset Base (RAB) model has been used to enable private investment in infrastructure. RABs utilise a legally binding license with periodical regulatory review of long-term tariffs. In this setup, all investments made are valued and costs are recovered from consumers under regulation. The consumers effectively cover the risks, which in turn shelters investors from exposure to these, making it possible for them to invest (Pale Blue Dot, 2018). In the UK, where the RAB model has been employed in utilities and other infrastructure-based sectors since the nineteen nineties, it has become the de facto underpinning of investor expectations for investments in infrastructure.

Where the balance of risk and return is insufficient to initiate private sector investment in a CO_2 transport and storage network, government can play the role of first investor. Government could make the initial investment establishing transport and storage infrastructure for an anchor customer and then expand the network to service growing demand.

This hub would attract further investment from other emissions intense industries seeking to establish operations in precincts that offer carbon dioxide storage services. In this way, Government can kickstart a hub and cluster development with the option of privatising the business after it has recruited sufficient customers (CO_2 emitters requiring CO_2 transport and storage services) to deliver sound financial performance.

Initial government investment could represent any level of equity up to 100 per cent. The determining factor should be the minimum public sector investment necessary to establish and operate the infrastructure. This model of government making the initial investment in infrastructure followed by later privatization is proven in other sectors such as road and rail transport, power generation and transmission and telecommunication. Alternatively, governments could invest in establishing a regulatory framework that provides the private sector with the right incentives to invest in transport and storage networks. This may be preferable in regions where this is already common among infrastructure providers and where government is restricted in funding transport and storage networks.

Figure 9: T&S ownership models, Business ownership model vs Diminishing risk



Managing long-term liability

Another significant barrier to investment in CO_2 storage is risk associated with long term storage liability. Whilst the risk of leakage from an appropriately selected storage resource is diminishingly small, it is not zero. If there are no limitations on liability, the storage operator will be liable for any leakage that occurs at any time in the future. That liability may include the cost of actions to stop the leakage, any damages claimed by any parties as a consequence of the leakage, and any fines or sanctions applied under legislation including the cost of purchasing emission allowances at the price in effect at that time. Today, carbon prices are generally absent or very low, however that cannot be assumed into the future. In fact, it is common for large companies with long planning horizons to assume a rising carbon price when assessing potential investments. It is very difficult for private sector investors to accept essentially unlimited and perpetual liabilities, particularly in emerging industries like CCS where experience is limited.

To mitigate this risk, it is critical for governments to implement a well-characterised legal and regulatory framework that clarifies operators' potential liabilities. A remedy, where the storage operator bears the risk of short-term liability during the operational period of the project and for a specified post-closure period, has been implemented by the Australian Government. This is described below.

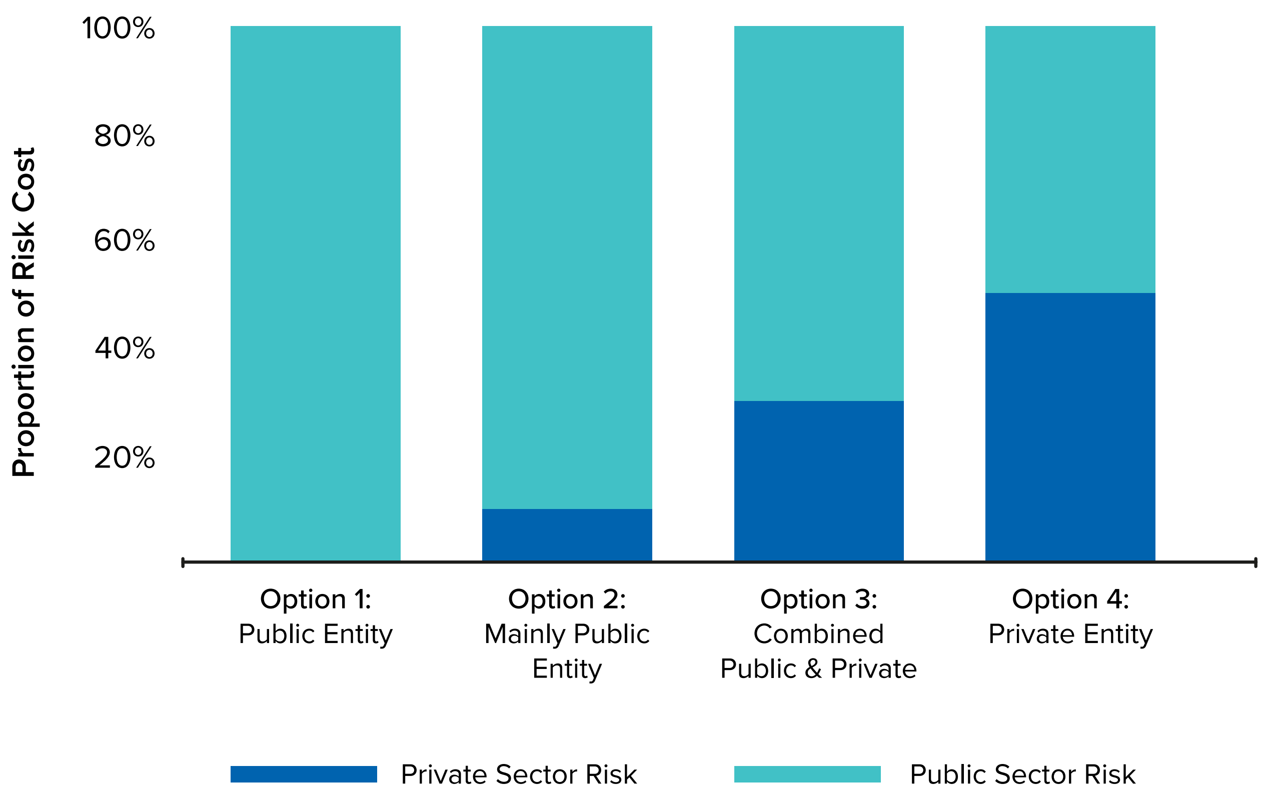
"Following the completion of a period of at least 15 years, from the issue of the Site Closure Certificate, the title-holder may apply to the Minister for a declaration confirming the end of the "Closure Assurance Period". A declaration at the end of this period concludes the title-holder's liability for the storage site. Importantly, the Offshore Petroleum and Greenhouse Gas Storage Act also provides the former title-holder with an indemnity from the Commonwealth Government for any liability accrued after the Closure Assurance Period (Havercroft, et al., 2015)."

This approach has been replicated in a number of other jurisdictions including the Australian States of Victoria and Queensland, the European Union and the Canadian Province of Alberta. It recognises that the risk of leakage from a geological storage resource is highest during injection of CO_2, reduces immediately upon cessation of injection, and continues to reduce with time. Consequently, the risk ultimately accepted by Government is very small, and continues to get smaller during the post-closure period.

Another option that has been proposed is that Government bear a proportion of the risk during storage operations. If accepted, this could be implemented through a risk capping mechanism. Under this arrangement, the private sector operator would be responsible for risks incurred below a cap, whilst Government would take responsibility for all additional risks above a cap (Pale Blue Dot, 2018). The value of the cap could be a function of the balance of public and private equity in the storage operation, with higher private equity translating to a higher cap. Note that all risks, not just long-term liability risks, are subject to risk sharing under this model.

Similar to placing a value on CO_2, there are many potential ways by which government could address this barrier to investment. Each government will choose the path that best suits its particular circumstances. Ultimately, success will be defined by the effectiveness of the approach in reducing long term liability risk to levels that allow private sector investment to proceed.

Figure 10: Risk Capping[11]



Accessing affordable debt financing

To date, investments in most CCS projects have been enabled through high proportions of grant funding, with little to no debt financing. To deploy CCS at the rate necessary to meet climate targets, private sector investment must increase by orders of magnitude. To achieve this, banks have a critical role in providing debt financing to project developers.

To qualify projects for debt financing, however, banks will first need to be assured that key risks are sufficiently mitigated, and that hard to manage risks are allocated to government, at least in the short term. Existing examples where banks have lent to projects include Petra Nova and Lake Charles, both of which have been funded with significant proportions of debt financing. These projects, however, depend heavily on revenues from the sale of CO_2 for EOR (Lake Charles) or from the direct use of CO_2 for EOR (Petra Nova) to meet revenue targets. Deployment of CCS at the scale necessary to mitigate climate change will have to rely on a policy framework that reflects the value of CO_2 in the context of emissions reductions targets.

Risk plays a key role in determining the cost of capital. Banks determine the interest they charge on loans after considering the risk of default. Loans to higher risk business ventures incur higher interest rates. Equity investors require higher rates of return on higher risk investments. For capital intensive investments, such as CCS facilities, the cost of debt and equity can have a material impact on the total cost of the project, and its financial viability. Different financial instruments can be applied to projects to address risks, for example mezzanine financing or loan guarantees.

[11] Risk cost is the cost associated with the occurrence of a risk

Types of financiers

The table below describes the different types of financial instruments and their providers. Project financiers will typically utilise a suite of financial instruments to reduce the risk exposure of projects. At this point, this should lower the return expectations of equity investors and attract additional commercial debt financing. Guarantees and risk sharing arrangements (e.g. political risk guarantees, counterparty risk guarantees, and public first loss investments (Deutsche Bank, 2011) can allow the financial sector to provide more equity and lend more money to CCS projects.

Table 3: Financial Institutions and Financial Instruments

Source	Description	Advantages	Disadvantages
Commercial Debt	Asset-backed loans that can be secured over the medium to long-term. Commercial debt has been an important source of finance for both fossil fuel and renewable energy projects.	Flexible and capable of providing a significant proportion of funding (high liquidity)	Time consuming and execution uncertainty; Not attracted to new technologies and will tend to perceive these as risky
Green Banks	Banks specifically targeting green or low-carbon investments	Deep liquidity; Able to provide policy and technical support	Limited in scope and may not have support for CCS; Region specific
Investment Insurance Agency or Export Credit Agencies	Government or private financial institutions that can offer financing to domestic companies' international operations. They help to resolve risks such as export and political risks of overseas investments	Reduces risks	Backed by assets; requires a well-defined strategy employed during the early stage of project design
Multi-Lateral Banks / International Financial Institutions	This includes multilateral development banks (serving developing countries) and multilateral financial institutions (specialising in types of projects rather than regions). They play a significant role in Climate Finance as many of them serve as accredited entities to the Green Climate Fund. They have a long history of providing direct lending to projects.	Deep liquidity; Typically better than commercial bank's lending conditions as they are often able to provide concessional financing; Able to provide substantial technical and policy support	Region specific and may not support CCS based on eligibility criteria

Some of these institutions specialise in high risk environments, specifically, developing countries. Currently, CCS is still in an 'early market' development phase in developed countries, so its growth in developing countries is not likely to occur at the same rate. This having been said, if the international community targets greater rates of deployment, multi-lateral banks will have a leading role to play in supporting CCS projects in developing countries.

If both policy and financial derisking steps still lead to projects not meeting investors' hurdle rates, then direct financial incentives, such as grants – which can come from vertical funds – can be utilised to 'top up' investments so that the hurdle rate can be met. Placing this step at the end effectively reduces the amount of grant funding required from government or multi-lateral funds, thereby promoting cost-effectiveness.

CASE STUDY

THE ROLE OF DEBT FINANCE IN THE PETRA NOVA CCS FACILITY

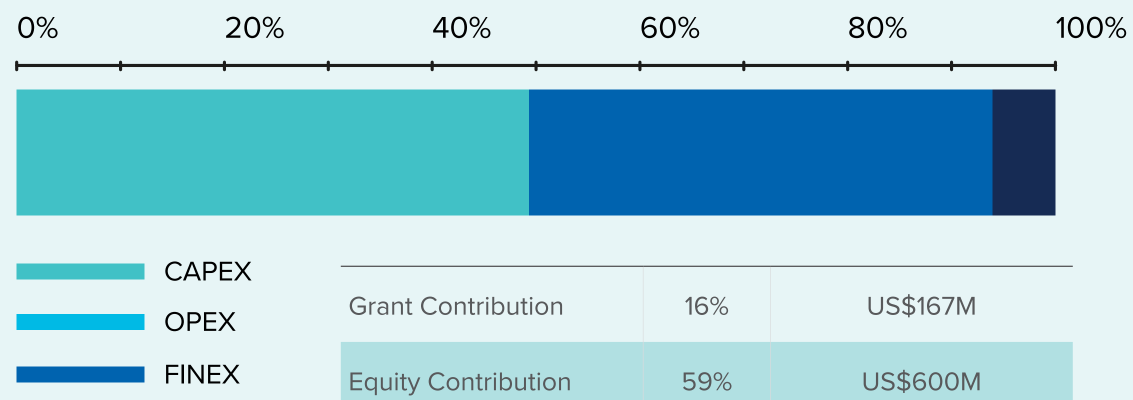
Petra Nova is a post-combustion retrofit project utilising amine-based post-combustion CO_2 capture technology. The capture unit is attached to the WA Parish coal fired power station owned by NRG in Texas, USA. At 240MW, Petra Nova is the world's largest power-based CCS facility, capturing and storing 1.4 million tonnes of CO_2 per year.

The project is the result of a joint venture between NRG and JX Nippon, a Japanese oil and gas company. Together, they invested in the CCS facility as well as buying a 50 per cent stake in an aged oil field, West Ranch, 130 km away from the capture facility (Jenkins, 2015). This makes the design of the project unique because, unlike other post-combustion capture projects, Petra Nova makes direct use of CO_2 for EOR rather than selling it to a third party.

Typically, CO_2 sold for EOR is priced at US$10-35 per tonne (OECD-IEA-UNIDO, 2011). The value of the CO_2 is actually greater than this because it was projected that its use would enable the extraction of an additional US$150-300 worth of oil for each tonne of CO_2 delivered to West Ranch. The economics of the project are, therefore, centred on the additional oil production from the well.

Although the CCS component of the project creates revenue through avoided costs of US$10-35 per tonne through the generation of tax credits under the 45Q, its value to the overall venture is far greater. This effectively justified investment in the plant, especially given there would be an element of grant funding from the DOE as well as debt financing.

Proportion of Levelised Cost



Grant Contribution	16%	US$167M
Equity Contribution	59%	US$600M
Loan Contribution	25%	US$250M
Total Capital (CAPEX)	100%	US$1,017M

GRANT FUNDING

The project obtained US$167M of grant funding from the US Department of Energy's Clean Coal Power Initiative (Shimokata, 2018). This was for the first 60MW of the CCS facility and represents approximately 16 per cent of the overall CCS facility's costs. Along with other aspects of the project, this element of grant funding will have reduced costs that will have otherwise been borne by the project developers.

EQUITY & DEBT FINANCING

A total of US$600 million, equally split between NRG and JX Nippon, was the amount of equity raised for the project. Commercial banks found the complexity of the project to be a first-of a-kind risk, so the developers had to source debt financing from alternative sources. The presence of JX Nippon in this venture played an essential role in securing US$250M in loans from Japanese export credit agencies, JBIC and NEXI.

Since their objective is to advance the competitiveness of the Japanese economy overseas, JBIC and NEXI were willing to cover the project's risks. NEXI insured a US$75M loan provided by Mizuho, a Japanese bank, whilst JBIC provided US$175m in debt financing in exchange for US$90M of preferred shares of JX Nippon's stake in the project.

LESSONS LEARNT

The Petra Nova project is an example of how CCS has been utilised as a key component of a broader objective: to extract oil from a depleted oil field. In this case, the value of CCS far outweighs its cost, which is something the project developers and their financiers will have established early in the project's design.

Although revenue and operating costs for the project were not possible to obtain, it is widely known that the Petra Nova project increased the production of oil at the West Ranch oil field from 300 barrels a day to 4,000 barrels a day. The precedence set by this project is that risk tolerant financiers, such as JBIC and NEXI, were willing to provide debt financing to a full chain CCS project so long as long term and sufficient revenue from a reliable source was assured. Capture technology, therefore, was not considered to be as great a risk as revenue uncertainty by the financiers that provided debt financing for Petra Nova.

Table 1 shows how different elements of risk may be valued by a financier, and in turn how each of these combine to raise the cost of debt from a low risk lending rate to a high risk lending rate based upon reasonable assumptions and experience in capital raising for climate related projects. The table should be considered as illustrative, not absolute. Nonetheless, this simple analysis shows how risks perceived by a financier will have a material impact on lending rates; in this case, increasing the interest charged from 4 per cent (low risk lending rate) to 15 per cent (high risk lending rate). Capital intensive projects like CCS require hundreds of millions of dollars in debt financing. This interest rate increase would increase the annual cost of servicing debt by tens of millions of dollars which comes straight off the bottom line, and severely impairs the profitability, and hence the investability of the project.

Breaking down the components of risk and the cost of debt allows the development and prioritisation of policies to reduce risks that deliver the greatest cost reductions. This would require the calibration of the risk model. In practice, the impact of each risk on lending rate could be determined through structured interviews with equity and debt financiers, who would each make their own assessment. By repeating this process with several banks and investors, it would be possible to quantify the impact different policies (used to address risks) would have on the cost of capital, informing policy formulation.

Table 1: Relationship between perceived risk and the cost of debt[12]

	(A) RISK TYPE Hard to reduce or General Project Risk	(B) PROBABILITY Low = 1 High = 5	(C) CONSEQUENCE Low = 1 High = 5	(D) RISK RATING (BxC)	(E) RISK PREMIUM (G-F) x (D/ΣD)
LOW RISK LENDING RATE (F)					4%
Cross-chain	HTR	5	5	25	2.7%
Policy and revenue	HTR	4	5	20	2.2%
Storage liability	HTR	2	5	10	1.1%
Leakage	GPR	2	5	10	1.1%
Standed asset	GPR	2	5	10	1.1%
Project financing	GPR	1	4	4	0.4%
Political risk	GPR	2	3	6	0.7%
Market design & regulatory	GPR	1	3	3	0.3%
Social acceptance	GPR	1	3	3	0.3%
Construction	GPR	1	2	2	0.2%
Operating and performance	GPR	1	3	3	0.3%
Legal system	GPR	1	3	3	0.3%
Administrative risk	GPR	1	2	2	0.2%
HIGH RISK LENDING RATE (G)					15%
RISK PREMIUM	11%				

[12] GPR and IR denote general project risk and hard to reduce risk respectively

It is important to understand that the mitigation of some risks will be dependent on the number of facilities in operation at any given time. As the number of operating facilities increases, business models mature and industry experience grows, perceived risks will decrease resulting in a concomitant reduction in the risk premium and cost of capital.

Fig. 10 shows an illustrative financing cost waterfall for the cost of debt for a CCS project across three different periods in time. It is important to note that this is intended to illustrate the risks as perceived by debt financiers. To calculate this, several CCS and non-CCS related risks were identified, and their pro-rated contributions to the difference in lending rates were established (see Table 1 for how this is calculated).

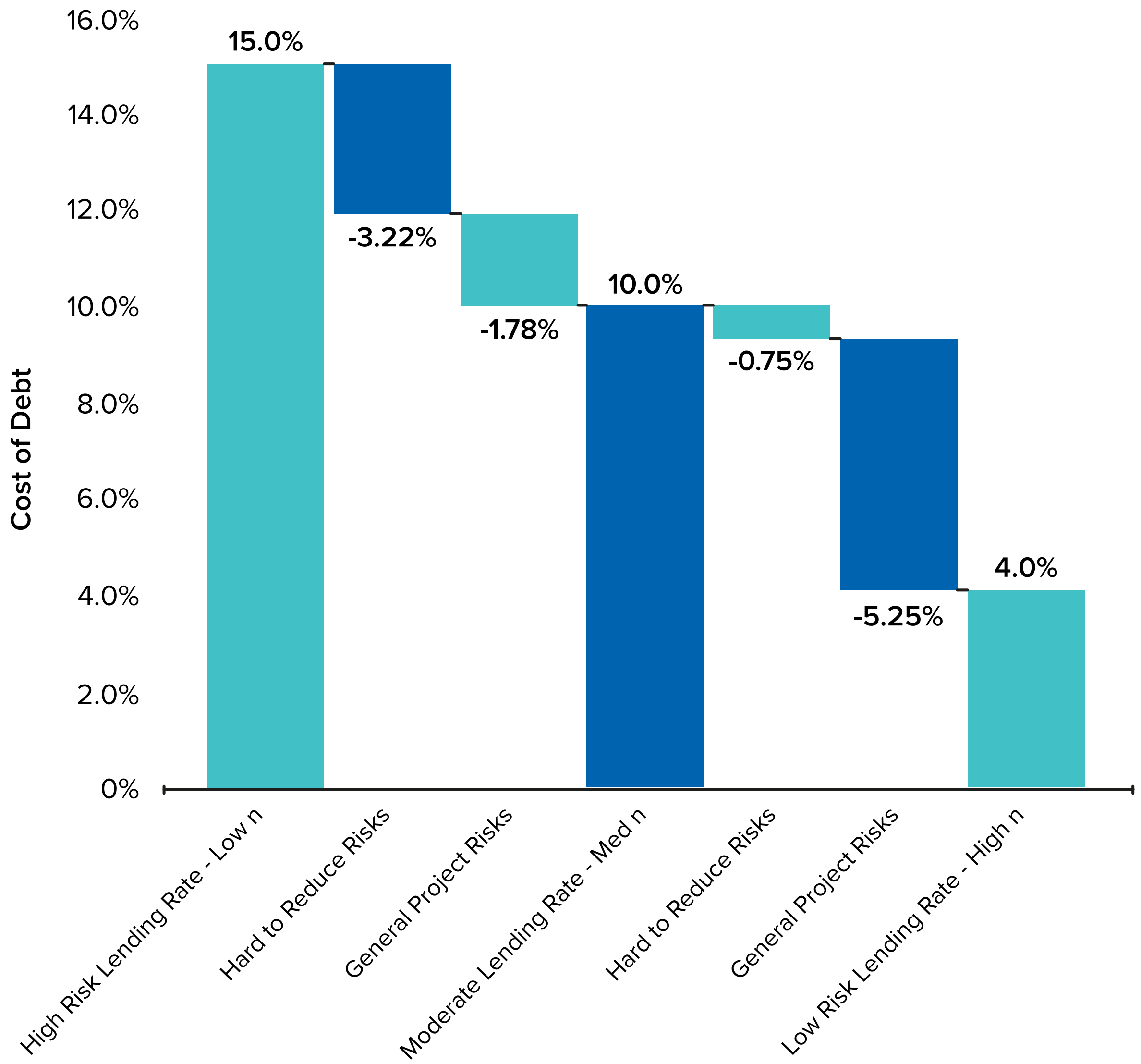
Initially ('risk premium lending rate'), CCS facilities are developed under 'high risk' conditions, due to the existence of a weak policy framework and very few operational CCS facilities. In this scenario, the cost of capital is at its highest.

As more facilities enter operation ('moderate lending rate'), policy derisking focusing primarily on hard to reduce risks leads to a reduction in the cost of capital. For example, long term liability risks may have been transferred to government through government ownership of shared T&S infrastructure. General project risks, such as the performance risk, are reduced through learning by doing. As a result, the overall cost of capital is reduced, leading to a moderate lending rate.

When the industry matures ('low risk lending rate'), risks are further reduced through additional policy measures and increased confidence by investors in CCS, reducing the cost of capital. Also, cost reductions achieved through learning, technology development, and new business models increases the competitiveness and profitability of CCS facilities increasing the return on investment.

This progression from high debt financing costs to low debt financing costs is one of the mechanisms that deliver overall cost reductions as deployment increases. The role of government policy is strongest early in this process where the risks and costs would otherwise prevent the initial investments.

Figure 11: Cost of Debt Waterfall



The cost of equity

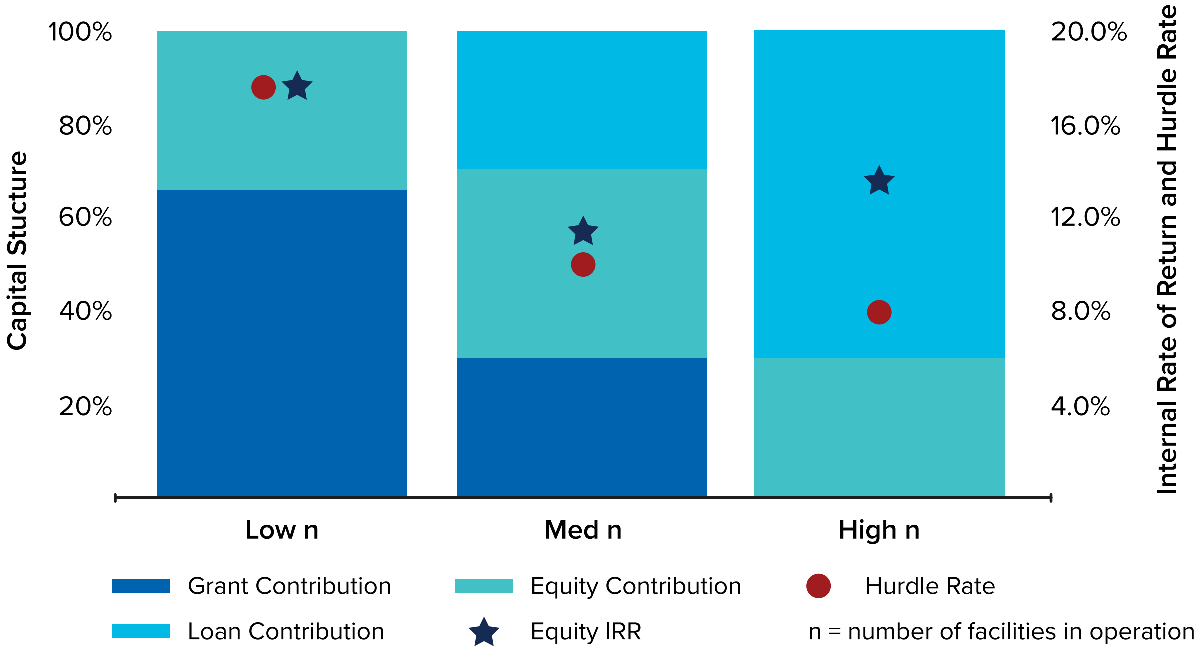
The previous discussion focussed mostly on the cost of debt, i.e., the interest rate charged by lenders. The cost of equity is also affected by risk. In general terms, an investment will only be made if the expected Internal Rate of Return (IRR)[13] is equal to or greater than the required rate of return, that is, the hurdle rate. The hurdle rate is usually equal to the Weighted Average Cost of Capital (i.e. weighted average of interest on debt and required return on equity) modified for risk. Higher risk investments will generally have a higher hurdle rate.

In the case of immature industries like CCS, this represents a challenge because risks are perceived to be high. Further, unless there is a significant value on carbon dioxide, CCS will generally not generate sufficient revenue nor avoided costs to be profitable. The result is an investment opportunity with a low or negative internal rate of return and a high hurdle rate and thus the investment is not made. To overcome this barrier, capital grants of one form or another have been provided by government.

As more CCS facilities come online and the industry matures, the relationship between IRR, hurdle rate and the requirement for policy support (i.e. capital grants) is expected to change. This is illustrated in Figure 12, which shows the results of a simplified financial model of three scenarios using the lending rates obtained from the cost waterfall in Figure 11.

[13] The internal rate of return (IRR) is the discount rate that, when applied to project's cash flows, will lead to a net present value (the sum of all discounted cash flows) equal to zero. Project developers favour projects with higher IRRs. Projects with debt financing use a modified version of the IRR called the leveraged or equity IRR.

Figure 12: Capital structure and varying routes of return



Each scenario is described below:

Baseline scenario – Low value of n: Investors are generally attracted to projects due to long term, strategic benefits rather than commercial ones. Project costs are offset through significant grant funding, whilst revenues are generated from the sale of CO_2 for EOR or through avoided costs such as minimum emissions standards. Latter projects attract small proportions of debt financing through reduced technological costs and innovative business models. Because of the presence of grant funding, the equity IRR is equal to the hurdle rate.

Improved policy framework – Medium value of n: The presence of a sufficient value placed on CO_2, along with other derisking policies, such as shared transport and storage networks, allow some CCS facilities to become commercially viable without relying on the sale of CO_2 for EOR. At this point, capital and operating costs will have also been reduced through learning by doing and economies of scale. This relatively derisked environment attracts debt finance at acceptable lending rates and also reduces reliance on grant funding. Notwithstanding the reduced proportion of grant funding, the equity IRR remains above the hurdle rate due to the value of CO_2 as well as acceptable lending rates.

Robust policy framework – High value of n: Costs will have been greatly reduced in comparison to the baseline scenario, at which point banks begin to offer more competitive, low-risk, lending rates. At the same time, grant funding is no longer required to deliver attractive rates of return.

The financial model helps to illustrate the overall trend that is expected across the global CCS industry, and highlights the important relationships at play between concessions, deployment and financeability. The conclusions from this modelling are that:

- Project finance costs are influenced significantly by risk, with higher risks resulting in a higher cost of capital. This is apparent in the first stage, whereby perceived risks are high and banks are unwilling to lend to projects. This represents the current status of CCS deployment.
- As an industry matures, risk reduces making lower cost finance easier to obtain, which in turn reduces the cost of investments. This trend begins in the second scenario, in which banks begin to lend to projects, but in relatively small proportions and at high lending rates. Importantly, this displaces some grant funding.
- In the final stage, projects tend to comprise exclusively of equity and debt capital. This represents a mature sector, for which risks are well understood and lending rates and returns are comparable to other industries. At this point, private incentives and public good incentives for investment are aligned, and private capital will be mobilised towards the broadscale deployment of CCS. This represents success.

Table 2 summarises the assumptions made for each scenario.

Table 2: Summary of financial model assumptions

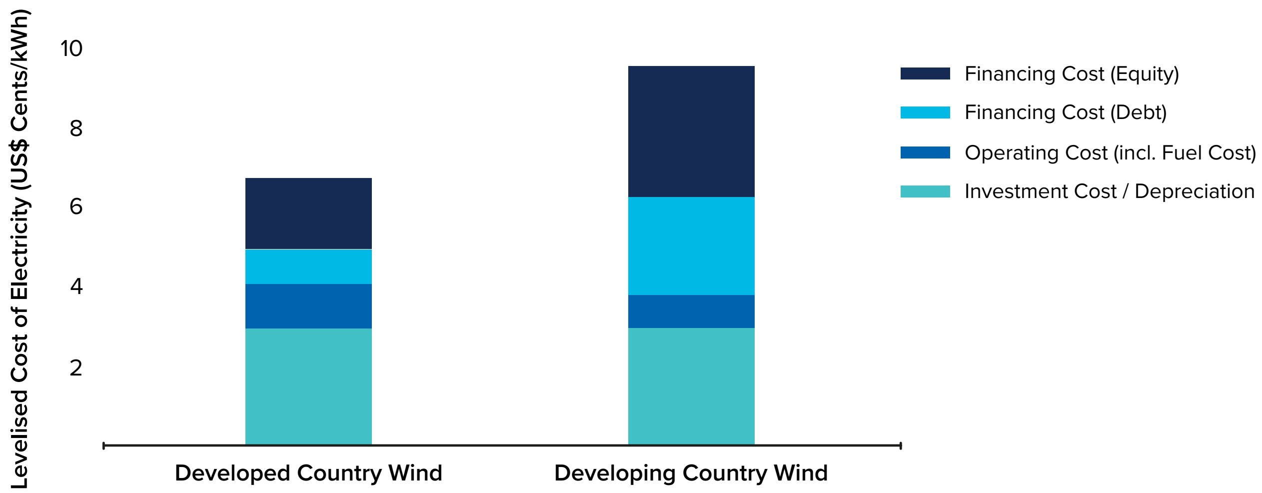
	Low n	Med n	High n
Capital cost (USD M)	800	600	500
Grant contribution	65%	30%	0%
Equity contribution	35%	40%	30%
Debt contribution	0%	30%	70%
Cost of debt	14%	10%	4%
Hurdle rate	17.5%	10%	8%
Cost of transport and storage (US$/t$CO_2$)	20 (single sink, single source)	12 (network exists but not fully utilised)	5 (mature network, full utilisation)

The link between risk and cost examined in the modelling described above is demonstrated by data collected by the United Nations Development Programme (UNDP), that compared the cost of electricity produced from onshore wind facilities in developed and developing countries (see Figure 13).

The key observations from this data are:

- Developing countries present greater investment risks than developed countries resulting in a doubling of the cost of capital in this case (combined equity and debt)
- The higher cost of capital translates to a 40 per cent increase in the total cost of production of wind generation, even after slightly lower operating costs are taken in to account.

Figure 13: Levelised cost of electricity for wind in developed and developing countries[14]



A 40 per cent increase in the cost of production for any business can have a material impact on its viability making a potentially profitable business loss-making and making investment impossible. For wind generation, the increase in cost in developing countries compared to developed countries was entirely due to higher risks driving a higher cost of capital. According to the UNDP study, this difference was due to a lack of a supportive policy framework to derisk investments in wind energy.

CCS, like wind, is capital intensive so the cost of capital has a very large impact on the total project cost. Further, CCS, like wind, also requires a supportive policy framework to derisk investments during early stages of deployment.

[14] Source: United Nations Development Programme, 2011

5.0 CONCLUSION & RECOMMENDATIONS

Accelerating the rate of deployment of CCS is essential to meeting global emissions reductions targets. While progress has been made in recent years, there remain gaps in the policy frameworks across all countries, such that no country has yet to implement a framework that would be consistent with meeting Paris targets.

This report reviewed the conditions that enabled current investments in large scale CCS facilities. Investments have predominantly relied on supportive policies, revenue from Enhanced Oil Recovery and low cost capture, transport and storage opportunities. This coincidence of circumstances has enabled a positive financial investment decision on 23 large scale facilities to date which has proven the technology over almost five decades of operational experience.

However, for CCS to be deployed at the rate required to meet emissions reductions targets, governments must implement policy frameworks that align private and public good investment incentives to drive private capital into CCS at a much greater scale. This report identifies areas where policymakers should focus their efforts in the near-term, and in doing so, derisk investments in CCS projects.

The main priority areas for policymakers are:

- To establish a material value on CO_2 to establish a financial incentive for investing in carbon dioxide capture and storage.
- For government to play the critical role of enabling the development of shared transport and storage infrastructure. It can do this by investing directly in transport and storage infrastructure or by setting the regulatory framework within which networks can be developed cost effectively. This will serve to reduce operational costs through economies of scale as well as to address cross-chain risks.
- To implement a well-characterised legal and regulatory framework that clarifies carbon dioxide storage operators' liabilities such that long term liability risk does not prevent private sector investment.
- To provide capital support where required, in the form of grants, accelerated depreciation, concessional loans, or other mechanisms to attract private capital to CCS investments, until the business case for investment in CCS is created by market forces.
- To identify and consider additional policy interventions designed to reduce specific risks perceived by financiers and equity investors in order to bring down the cost of capital and enhance the financial viability of future CCS investments.
  - This process should be informed by research to quantify the impact of each class of risk on the cost of debt and equity to ensure the efficiency and effectiveness of policy interventions.

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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