JULY 2021

CCS IN THE CIRCULAR CARBON ECONOMY: POLICY & REGULATORY RECOMMENDATIONS

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Acknowledgements

This research was overseen by an Advisory Committee of eminent individuals from government, academia and industry with deep expertise across technology, policy, economics and finance relevant to climate change. The guidance of the Advisory Committee has been invaluable in developing this work.
Thanks are also due to the Center for Global Energy Policy at Columbia University SIPA for their review and input to this report.

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THE CIRCULAR CARBON ECONOMY: KEYSTONE TO GLOBAL SUSTAINABILITY SERIES assesses the opportunities and limits associated with transition toward more resilient, sustainable energy systems that address climate change, increase access to energy, and spark innovation for a thriving global economy.

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1.0 INTRODUCTION

Stopping global warming requires net greenhouse gas emissions to fall to zero and remain at zero thereafter. Put simply, all emissions must either cease, or be completely offset by the permanent removal of greenhouse gases (particularly carbon dioxide - CO_2) from the atmosphere. The time taken to reduce net emissions to zero, and thus the total mass of greenhouse gases in the atmosphere, will determine the final equilibrium temperature of the Earth. Almost all analysis concludes that reducing emissions rapidly enough to remain within a 1.5°Celsius carbon budget is practically impossible. Consequently, to limit global warming to 1.5°Celsius above pre-industrial times, greenhouse gas emissions must be reduced to net-zero as soon as possible, and then CO_2 must be permanently removed from the atmosphere to bring the total mass of greenhouse gases in the atmosphere below the 1.5° Celsius carbon budget.

This task is as immense as it is urgent. A conclusion that may be drawn from credible analysis and modelling of pathways to achieve net-zero emissions is that the lowest cost and risk approach will embrace the broadest portfolio of technologies and strategies, sometimes colloquially referred to as an "all of the above" approach. The King Abdullah Petroleum Studies and Research Center (KAPSARC) in the Kingdom of Saudi Arabia developed the Circular Carbon Economy (CCE) framework to more precisely describe this approach. This framework recognizes and values all emission reduction options (Williams 2019). The CCE builds upon the well-established Circular Economy concept, which consists of the "three Rs" which are Reduce, Reuse and Recycle. The Circular Economy is effective in describing an approach to sustainability considering the efficient utilization of resources and wastes however it is not sufficient to describe a wholistic approach to mitigating greenhouse gas emissions. This is because it does not explicitly make provision for the removal of carbon dioxide from the atmosphere (Carbon Direct Removal or CDR) or the prevention of carbon dioxide, once produced, from entering the atmosphere using carbon capture and storage (CCS). Rigorous analysis by the Intergovernmental Panel on Climate Change, the International Energy Agency, and many others all conclude that CCS and CDR, alongside all other mitigation measures, are essential to achieve climate targets.

The Circular Carbon Economy adds a fourth "R" to the "three Rs" of the Circular Economy; Remove. Remove includes measures which remove CO_2 from atmosphere or prevent it from entering the atmosphere after it has been produced such as carbon capture and storage (CCS) at industrial and energy facilities, bio-energy with CCS (BECCS), Direct Air Capture (DAC) with geological storage, and afforestation.

This report describes the essential contribution of carbon capture and storage to achieving net-zero emissions, summarises policy and legal factors that have a material impact on the investability of CCS projects, and makes high level recommendations on how governments may facilitate greater private sector investment in CCS.

1.1 Urgency

The mathematics of climate change are unforgiving. Every tonne of carbon dioxide that enters the atmosphere increases the ultimate equilibrium temperature of the atmosphere. The longer it takes to achieve net-zero emissions, the more global warming that will ultimately occur. Every day that emissions continue to rise increases the rate at which they must reduce in the future for any given climate outcome. The Report on Global Warming of 1.5 ° Celsius published in 2018 by the Intergovernmental Panel on Climate Change (IPCC) reviewed the scientific literature to develop an authoritative projection of the impacts of global warming of 1.5 ° Celsius and charted possible pathways to that climate outcome. The four illustrative pathways developed by the IPCC, which show how global anthropogenic emissions must change over the remainder of this century to achieve a 1.5 ° Celsius climate outcome, all show a rapid decrease in emissions to net-zero by the middle of this century (Intergovernmental Panel on Climate Change (IPCC)

2018). Achieving net zero emissions in the middle of this century requires a rapid and profound departure from the current global emissions trajectory, which continues to rise.

Further, the IPCC estimates that 5-10Gt of CO_2 must be removed from the atmosphere each year in the second half of this century:

- to offset the residual emissions that are very difficult to abate – Hard to Avoid Emissions such as from agriculture and air travel; and
- to reduce the total load of greenhouse gases in the atmosphere to below the carbon budget for 1.5 ° Celsius of global warming – correcting for the Overshoot.

The climate change discourse has rapidly evolved since the signing of the Paris Agreement. Growing recognition of the severity of impacts of unmitigated climate change, demonstrated through recent extreme weather events and quantified through recent analysis, has amplified calls from civil society for effective and urgent action. This groundswell of voices has become ever louder in the halls of government as well as in board rooms and Annual General Meetings. And they have been heard. The International Energy Agency reports that as of late April 2021, 44 countries plus the European Union have announced net-zero emission targets. Ten have promulgated net zero targets in legislation, 8 propose to make it a legal obligation and the remainder have pledged net zero targets in government policy documents. These commitments cover approximately 70% of global CO_2 emissions (Net Zero by 2050 A Roadmap for the Global Energy Sector 2021). The Climate Ambition Alliance, which brings together countries, regions, cities, businesses and investors to work towards achieving net-zero emissions by 2050 has almost 4000 participants, including 121 countries, 2357 companies and 700 cities ('Climate Ambition Alliance:Net Zero 2050' 2021). The leaders of all these organisations have pledged to reach net-zero emissions by mid-century. Whilst the bar for participation in the Climate Ambition Alliance is relatively low, it illustrates the breadth of in-principle support for net zero emissions which may be expected to convert to firm commitments and action in the future.

Figure 1 Illustrative Representation of Emissions Trajectory for 1.5 Celsius (Adapted from (Friedmann, Zapantis & Page 2020; Intergovernmental Panel on Climate Change (IPCC) 2018)

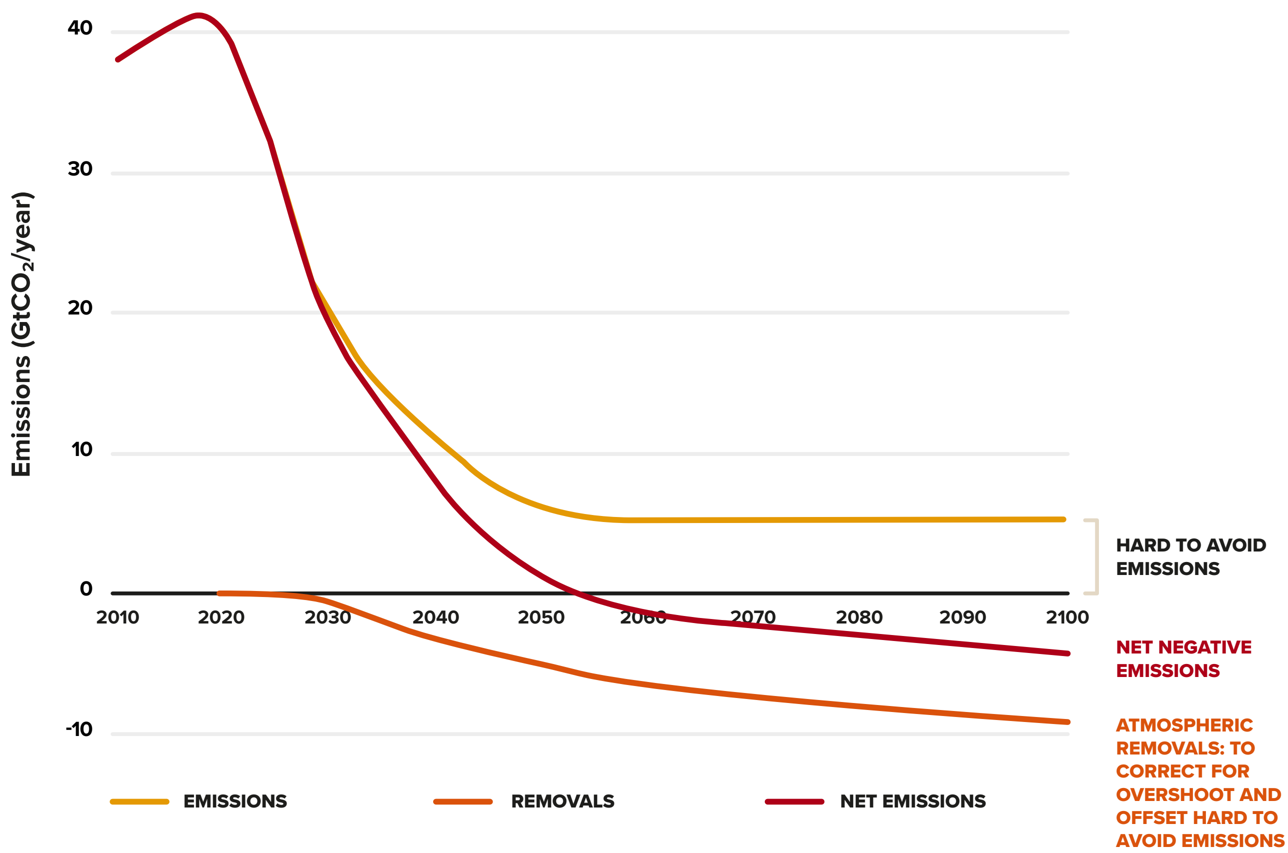


Table 1. Participants of the Climate Ambition Alliance ('Climate Ambition Alliance:Net Zero 2050' 2021)

CATEGORY OF PARTICIPANT	NUMBER OF PARTICIPANTS
Regions	28
Countries	121
Investors	163
Organisations	624
Cities	700
Companies	2357
Total Participants	3993

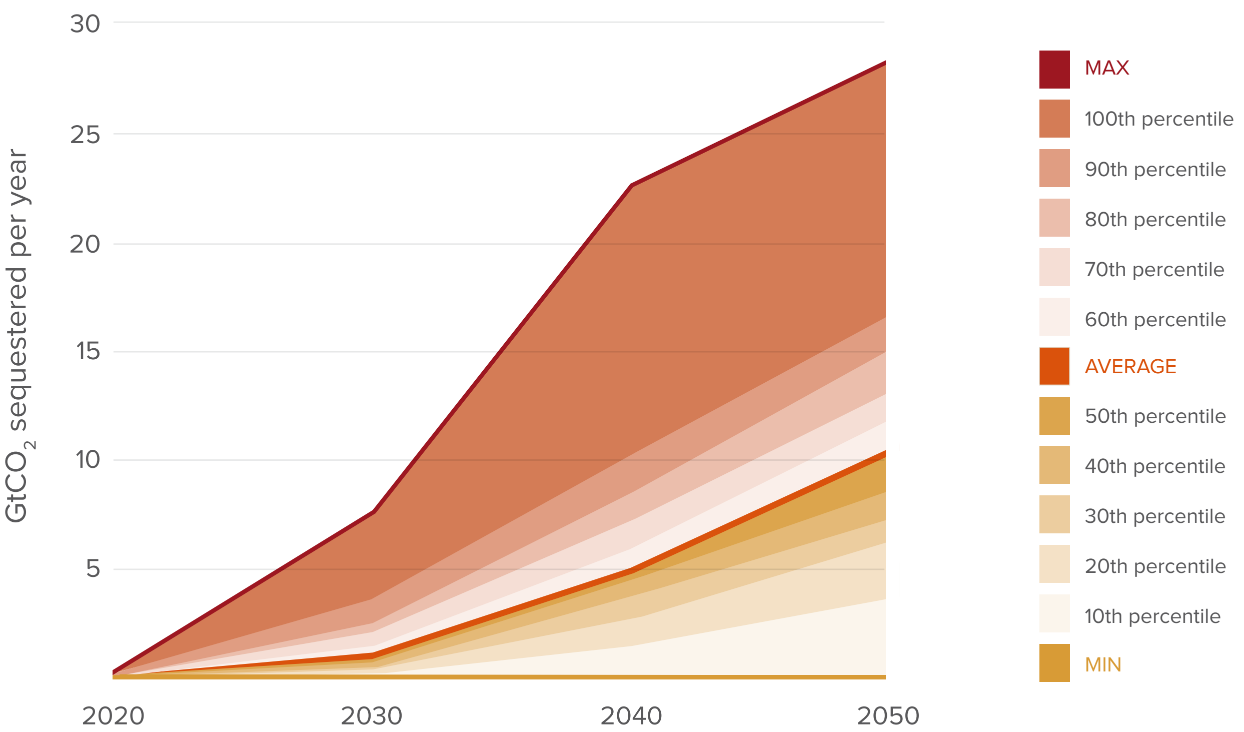
However, the rush to set net-zero targets has not been matched by the investment required for their delivery. Whilst climate considerations are beginning to have an impact on capital allocation, private investment incentives are not yet sufficiently well aligned with climate imperatives to stop the rise in global greenhouse gas emissions, let alone affect their rapid retreat.

1.2 CCS, An Essential Part of the Circular Carbon Economy

Achieving an emissions trajectory as shown in figure 1 will require action in every sector and in every country. A common finding of authoritative modelling going back to Socolow and Pacala (Pacala & Socolow 2004), and reiterated numerous times by the International Energy Agency and many others is that a broad portfolio of approaches and technologies is required to deliver significant emission reductions.

CCS is one of many climate mitigating technologies that is mature, commercially available, and absolutely necessary to achieve a stable climate. The IPCC reviewed 90 scenarios, each describing a possible pathway to limiting global warming to 1.5 °Celsius. The average mass of CO_2 permanently stored through CCS in the year 2050 across all scenarios reviewed by the IPCC was approximately 10Gt. The cumulative mass of CO_2 stored to the year 2100 in three of the four illustrative pathways developed by the IPCC was between 348Gt and 1,218 (Intergovernmental Panel on Climate Change (IPCC) 2018).

Figure 2. Annual CO_2 sequestration in the 90 1.5°C consistent scenarios used by IPCC[1]



[1] Global CCS Institute Analysis of IIASA 1.5C Scenario Explorer (Huppmann et al. 2019)

More recent modelling by the International Energy Agency is consistent with the findings of the IPCC; the optimal approach to stabilising the global climate involves CCS at the multi giga tonne scale in the middle of this century, with approximately 95% of captured CO_2 being geologically stored and the remaining 5% being utilised (Net Zero by 2050 A Roadmap for the Global Energy Sector 2021).

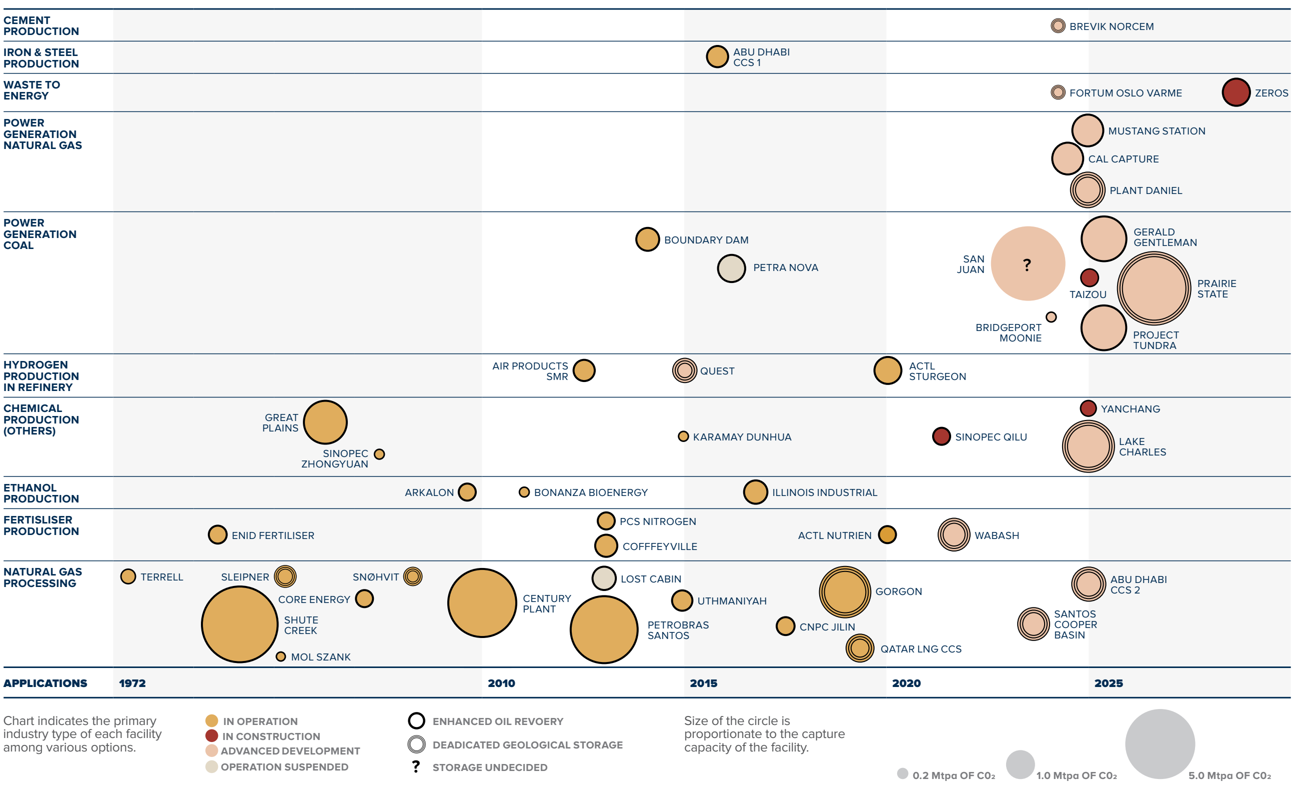
There are an infinite number of potential pathways to achieve net-zero emissions, and care must be exercised to understand that models such as those reviewed by the IPCC or developed by the IEA, are based on assumptions and scenarios, and are not predictions of the future. However, a common theme of such models is that deployment of CCS at the scale described by the IPCC and the IEA (and many others) is necessary in addition to all other measures which form part of a Circular Carbon Economy. The failure to fully apply any option increases the cost and difficulty of mitigating climate change with the remaining options. Further, the more ambitious the climate target, the sooner net zero emissions must be achieved, and the larger the contribution of CCS to emission abatement is required.

1.3 Versatility of CCS

A particular virtue of CCS is its versatility. CCS is not one technology. CCS describes a family of technologies which can be applied to almost any significant source of carbon dioxide, to capture, transport and permanently store CO_2 in geological formations. A description of CCS technologies, their costs and cost drivers may be found in another report in the Circular Carbon Economy: Keystone to Global Sustainability Series: Technology Readiness and Costs of CCS (Kearns, Liu & Consoli 2021).

Over the past 50 years, CCS has been applied in multiple industries. Figure 2 shows all commercial CCS facilities that are operating, in construction, or in advanced development, the industry in which it has been applied, and the year in which operation commenced or is expected to commence.

Figure 3. Commercial CCS Facilities (May 2021)



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Many of these industries produce CO_2 as a process emission, regardless of the source of energy that they utilise. In these processes, the production of CO_2 is unavoidable and the only option for mitigating emissions is to capture and permanently store the CO_2. For example, 65% of emissions from the production of cement arise from the chemical reaction in which calcium carbonate (limestone) is converted to calcium oxide (lime). It is not possible to avoid the production of CO_2 in cement production.

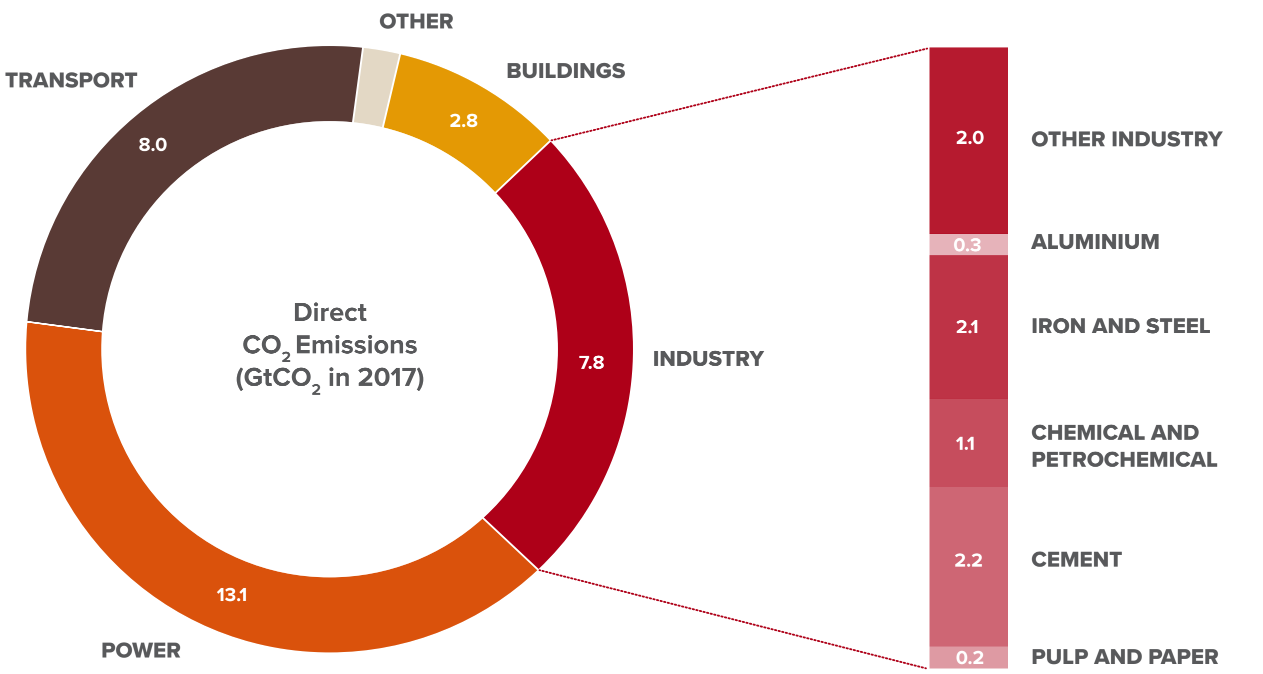
Other examples of industrial processes with significant process CO_2 emissions are natural gas processing, iron and steel production, fertiliser production, biofuel production, and various petrochemical processes that produce hydrogen, chemicals, plastics and fibers. Industrial sectors currently produce about 8 billion tonnes of direct CO_2 emissions annually. If indirect emissions (i.e. from electricity or heat supply) are considered, then industry accounts for almost 40% of global anthropogenic CO_2 emissions (International Energy Agency (IEA) 2019).

Without further mitigation measures, annual carbon dioxide emissions from industry are expected to approach 10 billion tonnes by the year 2060 (International Energy Agency (IEA) 2019). Various measures including CCS, fuel switching, improvements in energy efficiency, and the deployment of current best available technologies are required to mitigate those emissions. CCS will have the largest role in the cement, iron and steel and chemical sectors which currently constitute about 70% of direct emissions from industry.

CCS also enables the production of clean hydrogen. Clean hydrogen, produced from fossil fuels with CCS (known as blue hydrogen), or from biomass, or from electrolysers powered by renewable electricity (known as green hydrogen) or nuclear power, could deliver multi-gigatonne per annum abatement when used in various industries, transport and stationary energy. The Hydrogen Council estimates that demand for hydrogen could exceed 500Mt by 2050, delivering up to 6Gt per annum of abatement (Hydrogen Council 2017). Achieving this level of abatement requires demand and supply of clean hydrogen to increase from less than 1 million tonnes per annum in 2021 to hundreds of millions of tonnes per annum by 2050. Consequently, two critical success factors in realising the emissions abatement opportunity offered by clean hydrogen are scale and cost. Production cost must be low enough to be competitive with fossil fuels, taking into account the extant policy environment, to create demand for clean hydrogen. Production scale must be able to increase rapidly to meet that demand.

Blue hydrogen is very well positioned with respect to scale and cost. Blue hydrogen has been produced at commercial scale (hundreds to over 1000 tonnes per day per facility) since 1982. There are currently seven commercial facilities producing hydrogen from fossil fuels with CCS in operation with a total combined production capacity of 1.3 to 1.5Mtpa (depending on assumed availability).

Figure 4. Global Direct CO_2 Emissions by Sector[2]



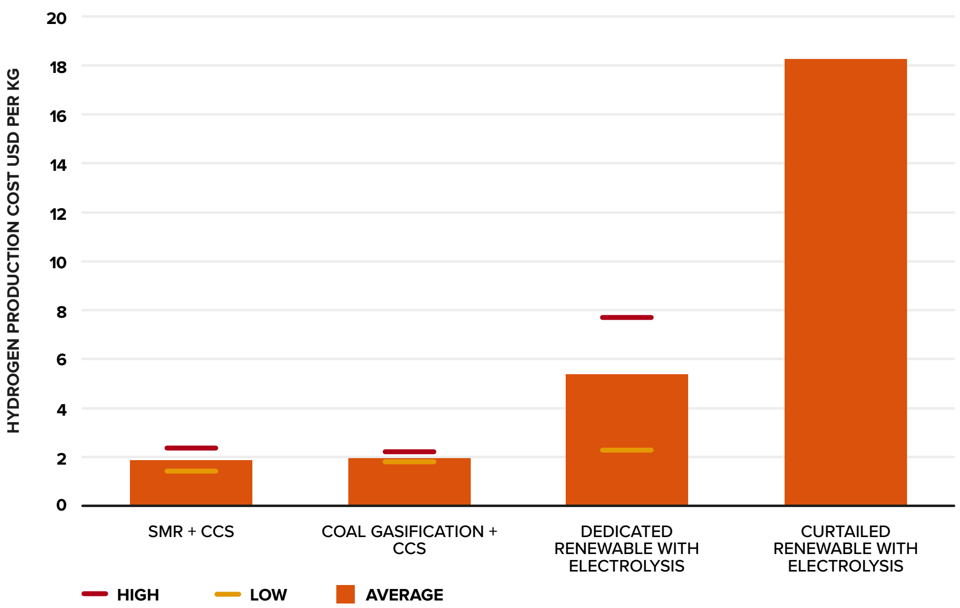
[2] Global CCS Institute analysis of IEA data

Table 2. Hydrogen Production from Fossil Fuels with CCS

FACILITY	H_2 PRODUCTION CAPACITY	H_2 PRODUCTION PROCESS	HYDROGEN USE	OPERATIONAL COMMENCEMENT
Enid Fertiliser	200 tonnes per day of H_2 in syngas	Methane reformation	Fertiliser production	1982
Great Plains Synfuel	1,300 tonnes per day of H_2 in syngas	Coal gasification	Synthetic natural gas production	2000
Air Products	500 tonnes H_2 per day	Methane reformation	Petroleum refining	2013
Coffeyville	200 tonnes H_2 per day	Petroleum coke gasification	Fertiliser production	2013
Quest	900 tonnes H_2 per day	Methane reformation	Bitumen upgrading (synthetic oil production)	2015
Alberta Carbon Trunk Line - Sturgeon	240 tonnes H_2 per day	Asphaltene residue gasification	Bitumen upgrading (synthetic oil production)	2020
Alberta Carbon Trunk Line - Nutrien	800 tonnes H_2 per day	Methane reformation	Fertiliser production	2020
Sinopec Qilu	100 tonnes H_2 per day (estimated)	Coal/Coke gasification	Fertiliser production	Expected 2021

Blue hydrogen is also lower cost to produce than green hydrogen. A review of recent reports published by Australia's Commonwealth Scientific and Industrial Research Organisation, the International Renewable Energy Agency, the International Energy Agency and the Hydrogen Council indicate blue hydrogen production costs around USD2/kg and green hydrogen production costs around USD5/kg (Bruce et al. 2018; International Energy Agency (IEA) 2020; International Renewable Energy Agency 2019; Hydrogen Council 2020)

Figure 5. Simple average and range of estimated current cost of clean hydrogen production from recently published reports.(International Energy Agency (IEA) 2020 2020b)(International Renewable Energy Agency 2019)(Hydrogen Council 2020)(Bruce et al. 2018). SMR = steam methane reformation. CCS = carbon capture & storage



1.4 Economic and Social Value of CCS

The versatility of CCS underpins its economic and social value. Emissions intense industries often develop in clusters due to the availability of necessary feedstocks, access to necessary infrastructure such as port and rail, the presence of a skilled workforce and a critical mass of specialist suppliers of engineering and other goods and services. It is common for local communities to rely upon a cluster of industries for a significant proportion of their employment and local economy. These communities would suffer severe economic and social dislocation if the emissions intense industries on which they rely were shut down or relocated elsewhere. CCS can contribute to transforming high emissions intensity industries into near-zero emissions industries, allowing them to continue to support economic prosperity whilst also supporting climate imperatives. In summary, CCS protects existing jobs in these industries and communities.

CCS also creates new high value jobs. CCS facilities are large engineering and construction projects taking years to plan, design, construct and commission. Like all large infrastructure projects, CCS projects require a significant development and construction workforce. Construction of the Boundary Dam CCS facility in Canada employed a construction workforce of 1700 people at its peak. Similarly, up to 2000 people were employed in the construction of the Alberta Carbon Trunk Line, a CO_2 pipeline project. Following the construction phase, a small number of ongoing direct jobs are created to operate and maintain the CCS facilities. A commercial CO_2 capture facility may require around 20 operators and maintainers (Townsend, Raji & Zapantis 2020).

Looking forwards, the global CCS industry must grow by more than a factor of 100 by the year 2050 to achieve Paris Agreement climate targets. This will require the construction of 70 to 100 facilities per year, creating up to 100,000 construction jobs, and 30,000 to 40,000 operators and maintainers (Townsend, Raji & Zapantis 2020).

By protecting and creating jobs, CCS builds support for strong climate action in communities that would otherwise perceive it as a threat to their economic security. Sustained community support is essential in the political economy of climate change. Without it, governments are unable to implement strong and effective policies that will survive the next change of government.

2.0 INVESTMENT IN CCS

Investment in CCS has grown year on year since 2017. The total capacity of all CCS facilities (operating, in construction and in development) grew by one third between 2019 and 2020. Whilst this is encouraging, much more rapid deployment of CCS is necessary to achieve climate targets. The total installed CCS capacity must increase from around 40Mtpa today to 5635Mtpa[3] by 2050 to limit global warming to 2° Celsius above pre-industrial times, according to the International Energy Agency Sustainable Development Scenario (International Energy Agency 2020). Building the 70 to 100 new CCS facilities per year between now and 2050 to achieve this installed capacity will require a total capital investment of between US$655 billion and US$1.28 trillion[4] (Rassool 2021).

This figure may appear daunting, but it is well within the capacity of the private sector to deliver. The private sector has enormous financial resources, as well as the requisite expertise and experience to develop projects. In 2018, total investment in the energy sector was approximately US$ 1.85 trillion (International Energy Agency 2019). Building 100 commercial CCS facilities per year would require only a small proportion of private sector investment, around 2% based on the total capital invested in 2018, and probably significantly less than 2% in reality given the expected growth in investment to decarbonise the global energy system. Further, in response to the rising expectations of stakeholders and shareholders, the private sector is actively looking for opportunities to invest in assets that serve climate mitigation outcomes. All that is needed to unlock the necessary capital is a business case.

2.1 Barriers to investment

Private investment requires an appropriate risk-weighted return. This is especially true for investments in long-lived capital intense assets like carbon dioxide capture facilities or pipelines. To date, investment in CCS has not been sufficient to meet climate objectives due to a number of market failures that prevent investors from achieving the necessary return in most circumstances. A brief description of those barriers follows.

Figure 6. CCS market failures and how these lead to hard to reduce risks

MARKET FAILURES	CAPTURE	TRANSPORT	STORAGE	HARD TO REDUCE RISKS
CO_2 emissions externally	Low or no value on CO_2 emission reductions			Policy and Revenue risk
Knowledge spillovers	Knowledge spillovers from capture technology		Knowledge spillovers from exploration and appraisal of storage sites	
Coordination failure or cross-chain risk	Risk of no access to transport and storage sites	Risk of low utilisation of pipeline	Risk of low utilisation store and developing store ahead of capture plant	Cross-chain risk
Natural monopoly industries		Natural monopoly of pipeline transport	Natural monopoly of storage hubs	
Information failures			Limited experience and data on storage	Storage liability

[3] 5266Mtpa geologically stored and 369Mtpa utilized.

[4] Lower figure assumes 20% learning rate. Higher figure assumes 10% learning rate)

No Value on CO_2

CCS delivers one service; emissions abatement. Similar to many other climate mitigation investment opportunities, the value of that service (emissions abatement) is generally insufficient to generate an appropriate risk-weighted return without government intervention through policy. For a potential capture plant developer, the main impediment to investment is the lack of 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. In economic terms, CO_2 emissions are an externality.

First Mover Penalty

Whilst capture technologies are well developed and proven, their application in most industries has been very limited and investment to date, for the most part, has been by first movers. First movers incur additional costs through the application of conservative engineering to ensure the successful integration of the capture plant with the host plant. The developers of the Boundary Dam and Petra Nova CCS facilities have both stated that the capital cost of building their plant again could be reduced by at least 20% simply by applying what was learned the first time. In fact, an approximate 20% reduction in capital cost per unit CO_2 capture capacity was observed between Boundary Dam in 2014 and Petra Nova in 2017.

First movers are also the first to test business models and regulations, especially if the project is in a jurisdiction in which CCS has not previously been undertaken. This particularly applies to geological storage resource operators who must navigate geological storage regulations or find a way to manage access to pore space, compliance and liability risk if the regulation is absent or unclear. The second operator in a jurisdiction will have the benefit of precedent and a more informed and confident regulator not enjoyed by the first. Fast followers can take advantage of the learnings for which first movers have paid. These knowledge spillovers create an incentive to delay investment in CCS projects until there is greater experience on which to base business decisions.

Cross-Chain Risk

The CCS value chain requires a broad range of skills and knowledge. Perhaps with the exception of natural gas separation, competencies required for the handling and transport of dense phase gases or the appraisal and operation of geological storage facilities are beyond the capture plant operator. Similarly, CO_2 separation and capture is often well beyond the competence of the host plant operator. For example, a cement manufacturer has no expertise in CO_2 capture, transport or geological storage. Thus in most circumstances, the most efficient value chain will involve multiple parties each specializing in one component of the value chain and the CCS project will require coordination of multiple investment decisions which all have long lead times. Once the CCS project is operating, the interdependency between value chain actors remains. The storage operator relies upon the capture operator to supply CO_2 and vice versa. If any element of the chain fails, the whole chain fails. This creates cross-chain risk.

Natural Monopolies

The transport and storage elements of a CCS value chain will in many if not most cases be natural monopolies which creates a risk of price gouging for the services they offer. In the absence of competitors, they are able to set their price at the highest level that their customers can bear, eroding the business case for investing in a capture project.

Information Failures

There are also information failures arising from the limited experience in developing and operating CCS value chains. One example relates to geological storage of CO_2. Whilst geological storage of CO_2 is well understood and has been proven through decades of experience and a massive body of scientific study, there is still only a very small pool of commercial operational data compared to other industries. This translates to an increased perception of risk amongst financiers and investors.

Hard to Reduce Risks

Capital intensive investments like CCS are exposed to many classes of risk. Most of these risks are best managed by the value chain actors. Project operators are best placed to manage operational and safety risks for example, as is the case across mature heavy industries. There are also ‘hard to manage’ risks that the private sector is unwilling or unable to take on at an appropriate price. These risks are usually managed through government policy and regulation.

For example, corporate law provides a general framework for undertaking business that significantly reduces the risk of undetected dishonest behavior by counterparties. For CCS, which is an immature industry, there are three specific hard to manage risks:

- Policy and revenue risk
- Cross chain risk
- CO_2 storage liability risk

The policy and revenue risk arises because there is no natural market for the storage of CO_2. Policy or regulation is required to correct the CO_2 externality to support revenue generation (or the avoidance of costs) essential to the business case for investment. The cross chain risk is linked to the immaturity of the CCS industry and the lack of confidence that exists in business models and between counterparties compared to mature industries.[5] The CO_2 storage liability risk is related to potential perpetual liability for regulatory enforcement action, exposure to future carbon pricing and civil claims for damages arising from leakage of CO_2 from geological storage facilities. Whilst the probability of leakage from an appropriately selected and operated geological storage facility is diminishingly small, it is not zero. Taken together, these 'hard to reduce risks' can be insurmountable barriers to investment. It is appropriate that government act to mitigate these hard-to-reduce risks because the resulting investment is necessary for the efficient delivery of an essential public good, a stable climate.

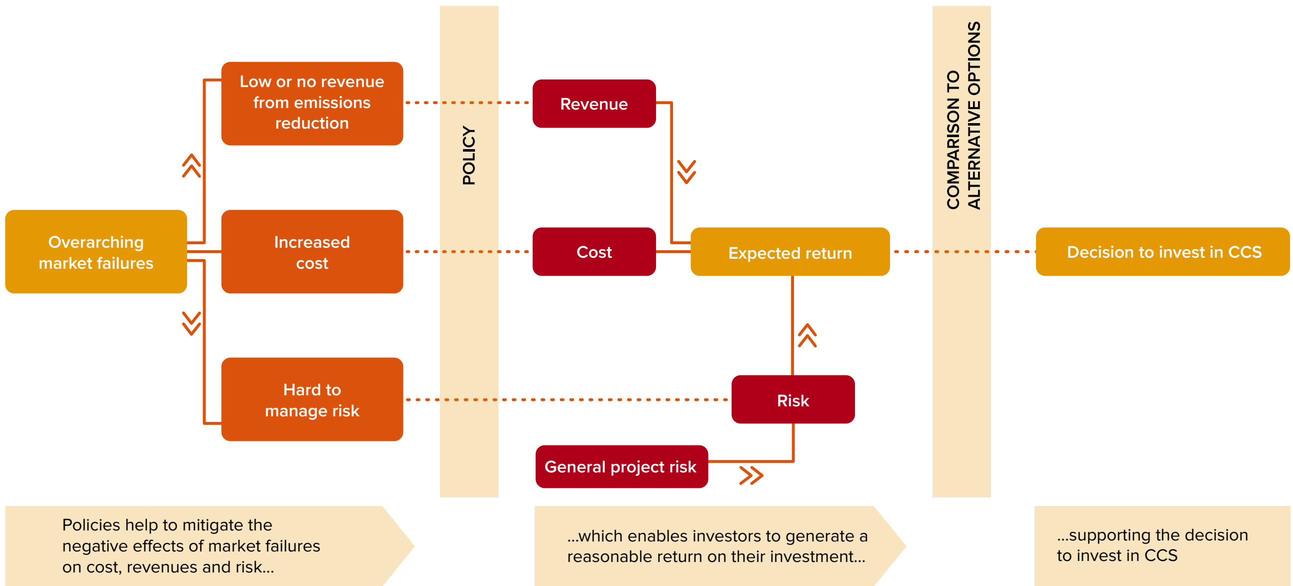
The difference in the cost of capital (debt and equity) between an investment that is perceived to have low risk versus an investment that is perceived to have high risk can be 10% or more. That risk premium can add several tens of millions of dollars to the annual cost of servicing debt for a CCS project, impairing the investability of the project.

Overall, the well-established and familiar business models, structures and practices that exist in mature industries and play a significant role in reducing perceived investment risk have generally not yet developed for CCS. In the large majority of cases, the market does not provide sufficient reward for CCS to achieve required rates of return on investment – and the required rate of return is usually elevated due to the perceived risk associated with the investment making financing difficult.

All things considered, it is clear that the primary barrier to the deployment of CCS at the rate and scale necessary to achieve climate targets is the difficulty in developing a project that delivers a sufficiently high risk-weighted return on investment to attract private capital.

The presence of multiple market failures highlights the need for a comprehensive policy framework for CCS that is tailored to address the specific barriers to investment. Well-designed policy is necessary to make CCS investable, by minimising costs, supporting stable revenues and allocating risks efficiently. This will ultimately enable the CCS market to operate more efficiently and help to deliver climate mitigation targets cost effectively. The way in which policies can overcome market failures and in turn enable CCS investments is illustrated in Figure 7.

Figure 7. How policies can incentivise CCS investments



[5] Note that the supply of CO_2 for enhanced oil recovery is a mature business in the USA.

2.2 Enablers of Investment in CCS

While the policy mechanisms that governments may choose can vary significantly, they all serve the same objective: to create a business case for investing in CCS. It is useful to review the existing fleet of commercial CCS facilities to understand what enabled those investments.

Figure 8. Commercial CCS facilities in operation, their location, and general characteristics (as of May 2021)

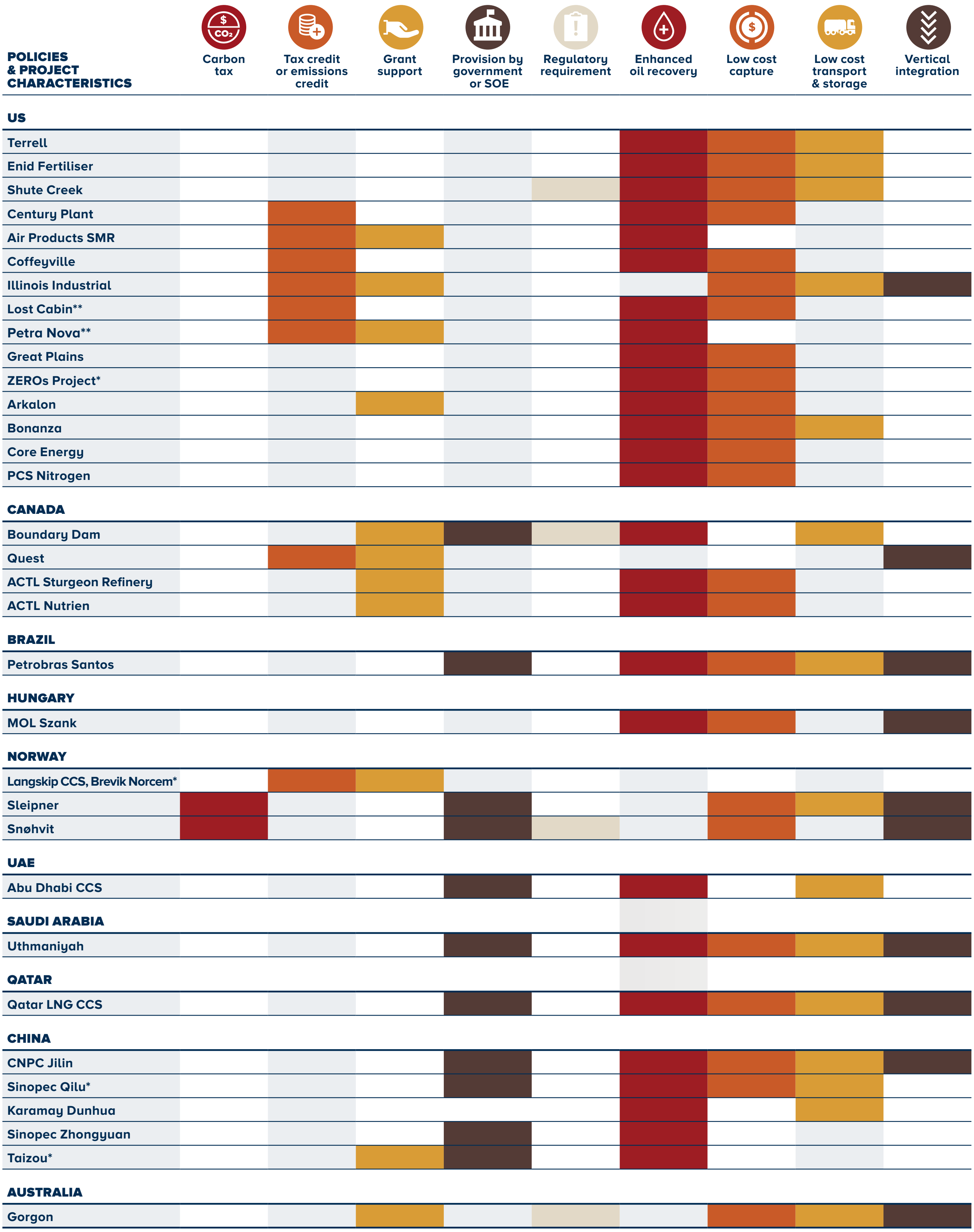


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Figure 8 shows that CCS investments have been incentivised through combinations of different mechanisms and characteristics. While specific circumstances may differ, the following features are common:

Low CO_2 Capture Cost Opportunities

As may be seen from Figure 3, CCS deployment has occurred chiefly across low-cost capture opportunities. These are in industries such as natural gas processing, where high concentration CO_2 gas streams are already available and the incremental cost of capture is extremely low. This effectively reduces CCS costs to compression, transport and storage. However, also evident from Figure 3 is that as time has progressed, proportionally more projects in industries with higher capture costs such as in power generation have entered the pipeline. This is a direct consequence of strengthening policy.

Low-Cost Geological Storage Appraisal

Appraising a geological storage structure requires the collection and analysis of three dimensional seismic data, drilling exploration wells, analysis of cores and ultimately CO_2 injection tests. This may cost tens of millions of dollars for on-shore resources and over one hundred million dollars for offshore resources. This expenditure is at-risk, as there is no guarantee at the outset that any particular geological structure will prove to be a suitable CO_2 storage resource. Unlike hydrocarbon exploration, there is not yet a well established relationship between investment in exploration and return from discovered resources. Consequently, almost all operating CCS facilities store CO_2 in geological structures with significant pre-existing geological data collected for the purpose of hydrocarbon exploration or production, greatly reducing the cost of data acquisition and analysis required for site appraisal.

A Value on CO_2 Emission Reduction – Financial Reward

Of the 26 commercial CCS facilities currently in operation, 20 sell or utilise CO_2 for EOR. The sale of CO_2 or utilisation for EOR provides a stable and predictable long-term source of revenue. That revenue stream may be sufficient to cover the costs of capturing and transporting CO_2 where capture costs are low, such as in natural gas processing, fertiliser and bioethanol production. This was the case at the Terrell, Enid Fertiliser and Great Plains CCS facilities. CO_2-EOR has proven to be a significant value driver and enabler of investment in CCS, however to meet climate objectives other value drivers not dependant upon EOR are essential. There is evidence that other value drivers are starting to have an influence. Figure 3 shows that proportionally more projects that do not rely on EOR are entering the CCS project pipeline.

One proven example of a policy that provides a financial reward for CCS is tax credits, which have been an important enabler of the seven commercial CCS facilities that have commenced operation in the USA since 2011.[6] In the USA, tax credits are issued under section 45Q of the Internal Revenue Code. The credits can be used to reduce a company's tax liability or, if they have no tax liability, can be transferred to the company that stores the CO_2 or can be traded on the tax equity market. Tax credits have the benefit of being well established in the context of climate change mitigation in the USA, having been used to drive significant investment in renewables over the past two decades. They provide a predictable effective revenue stream for each tonne of CO_2 stored (or utilized).

[6] Note that two of these facilities have since suspended operations

Figure 9. The 45Q Tax Credit[7]

TYPE OF CO_2 STORAGE/USE	MINIMUM SIZE OF ELIGIBLE CARBON CAPTURE PLANT BY SIZE ($KtCO_2$/YR)			RELEVANT LEVEL OF TAX CREDIT GIVEN IN OPERATIONAL YEAR (USD/tCO_2)									
	POWER PLANT	OTHER INDUSTRIAL FACILITY	DIRECT AIR CAPTURE	2018	2019	2020	2021	2022	2023	2024	2025	2026	LATER
DEDICATED GEOLOGICAL STORAGE	500	100	100	28	31	34	36	39	42	45	47	50	
STORAGE VIA EOR	500	100	100	17	19	22	24	26	28	31	33	35	INDEX LINKED
OTHER UTILISATION PROCESSES*	25	25	25	17	19	22	24	26	28	31	33	35	

*Each CO_2 source cannot be greater than 500 $ktCO_2$/yr. Any credit will only apply to the portion of the converted CO_2 that can be shown to reduce overall emissions.

A Value on CO_2 Emission Reduction – Financial Penalty

An alternative approach to placing a value on each tonne of CO_2 stored is to establish a financial penalty for each tonne of CO_2 emitted. For example, a carbon tax introduced in Norway in 1991 incentivised the development of the Sleipner and SnØhvit CCS projects.

Regulation has played a role in incentivising investment in CCS by proscribing emissions above a certain level, which is effectively a financial penalty for emitting CO_2 equal to the total present value of the project. Chevron recognised the need to reduce CO_2 emissions from its Gorgon LNG project in Australia and included CCS in its Environmental Impact Statement. The approval of the project by the Western Australian Government subsequently included a mandatory condition to inject at least 80% of the reservoir CO_2 produced by the gas processing operations. Gorgon is the world's largest dedicated CO_2 storage facility with a design-capacity of 4 million tonnes of CO_2 per year (Chevron 2019).

The introduction of an emissions performance standard (EPS) for power generation in 2011 in Saskatchewan was a driver of the development of the Boundary Dam CCS facility. Without CCS, the Boundary Dam coal unit would have been required to close and be replaced by a natural gas combined cycle plant (NGCC).

Financial penalties and regulation must be applied with caution to prevent perverse outcomes such as the movement of production capacity, and its associated emissions, to another jurisdiction with less stringent climate policy. Financial penalties and regulation must meet the following two criteria to be successful:

- any financial penalty must be set materially higher than the cost to the regulated facility of capturing and storing CO_2, and
- the cost to the regulated facility of capturing and storing CO_2 must not threaten the commercial viability of the facility

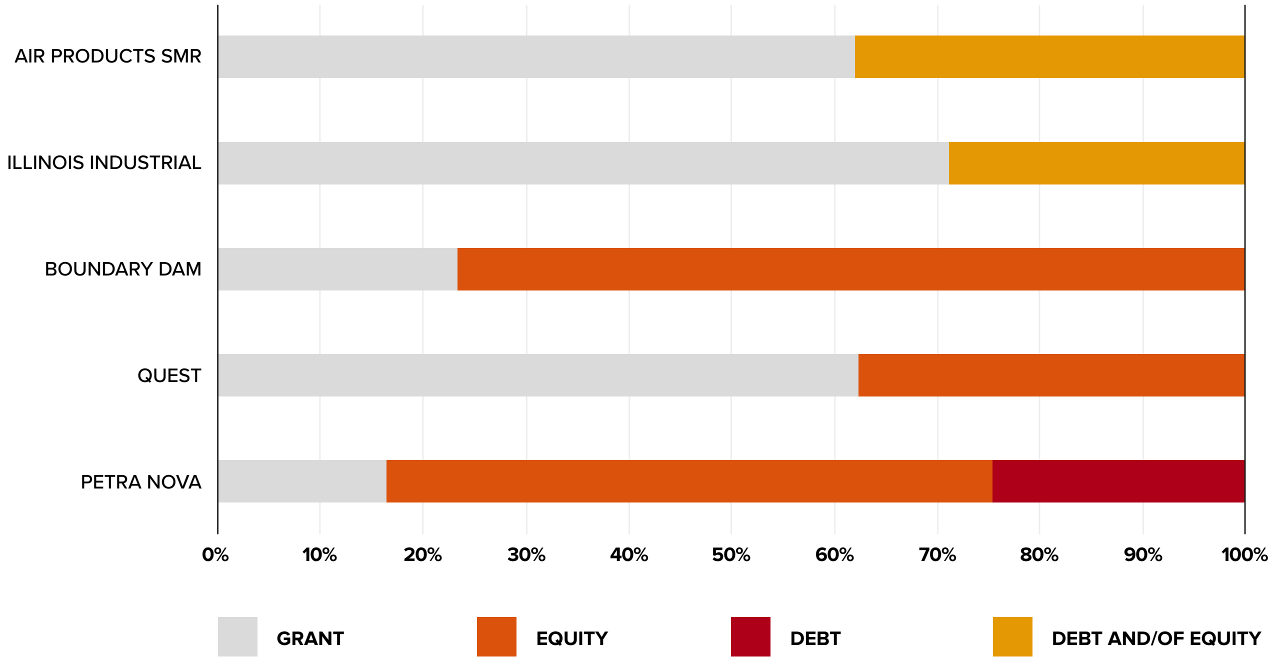
These conditions were met in the three examples provided. At \$17/tCO_2, the cost of injecting and storing CO_2 for the Sleipner project was much less than the \$33/tCO_2 tax penalty at the time for CO_2 vented to the atmosphere (Herzog 2016) ('Sleipner Fact Sheet: Carbon Dioxide Capture and Storage Project' 2016). At Gorgon, the additional capital costs of compressing and storing CO_2 were manageable in the context of the project as a whole, adding less than 5% to total project costs. At Boundary dam, the risk and cost of exposure to natural gas prices, which were much higher and expected to remain so at the time, made refurbishment and application of CCS to the coal unit the commercially rational decision.

Capital Grants

Bringing new 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 commercialised (Murphy & Edwards 2003). Grant funding reduces the private capital requirement and thereby increases the return on private capital enabling investment. It also mitigates the disincentive to be a first mover by rewarding them for the knowledge they create that is available to future project developers. Figure 10 shows the contribution of grant funding to the capital structure of a selection of CCS facilities.

[7] Adapted from (Bennett & Stanley 2018).

Figure 10. Capital Structure of Selected CCS Facilities (Zapantis, Townsend & Rassool 2019)



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 that commenced operation in 2020, which has received CAN$558M from the Alberta and Canadian governments for the CAN$1.2B project ('Alberta Carbon Trunk Line (ACTL)' 2016). The 240km pipeline connects 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. The pipeline has a capacity of 14.6 $MtCO_2$ per year.

Facilitating CO_2 Transport and Storage Infrastructure

There are many examples where government support, or direct investment was required to de-risk and initiate the development of new industries including road, rail, telecommunications, electricity generation and distribution, space exploitation and more recently, renewable energy. As those industries have matured and become commercial, government intervention has been replaced by increased levels of private sector investment. The equivalent opportunity for CCS is to support the establishment of CO_2 transport and storage networks that can service industrial CCS hubs.

CCS hubs significantly reduce the unit cost of CO_2 storage through economies of scale and offer commercial synergies that reduce the risk of investment. The colocation of industries and firms within a region creates an industrial ecosystem that benefits all firms. CCS hubs reduce counterparty or cross chain risks as they provide capture and storage operators with multiple customers/suppliers.

A CCS hub requires a geological storage resource for CO_2. Identifying and characterizing a storage resource requires the investment of tens to hundreds of millions of dollars, all of which is at-risk as there is no guarantee of success. Unlike mineral or hydrocarbon exploration, in which billions of dollars of at-risk capital are invested annually, the return on investment for exploration for pore space does not generally justify investment. Government can assist in overcoming this barrier by supporting the collection of geological data and making it available. The current fleet of CCS facilities have benefitted from pre-existing geological data collected in the course of oil or gas exploration and/or from government funded programmes.

Establishing a CCS hub also requires that CO_2 transport infrastructure initially be oversized to accommodate future demand. This is a difficult proposition for the private sector as it involves knowingly investing in a capital-intensive asset that will have low utilization, and in a business that initially has high cross chain risk (until other businesses join the hub). Government can overcome these barriers to investment by co-investing in CO_2 transport infrastructure with the private sector to establish the CCS hub. Over time, other businesses will join the hub increasing the utilization of the infrastructure. When the hub is well established, government has the option of selling its equity to recoup its initial investment. The end result is a commercially sustainable CCS hub delivering material CO_2 emissions abatement whilst protecting and creating high value jobs and delivering economic and social benefits to host communities.

A recent report by the Center on Global Energy Policy at the Columbia University illustrates the potential for CCS hubs to create jobs. It finds that the deployment of CCS, incentivised by tax credits issued by the United States Government, could create 60,000 jobs before 2035 in the industrial sector alone (Friedmann, Agrawal & Bhardwaj 2021).

Establishing Transparent Regulation of CO_2 Storage and Long-Term Liability

Transparent and predictable regulation of access to pore space for the geological storage of CO_2 is essential. Investors must be confident that they can secure the right to exploit geological storage resources and manage compliance risk associated with CO_2 storage operations.

Further, it is critical for governments to implement a well-characterized legal and regulatory framework that clarifies operators' potential liabilities. An excellent example, 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 & Dixon 2015)*

The absence of transparent and predictable regulation of the geological storage of CO_2 will preclude investment in CCS in the large majority of cases. Regulation is described in more detail in Section 4 of this report.

Access to Low-Cost Capital

The cost of debt and equity has a material impact on the total project cost and financial viability of capital intensive investments, such as CCS facilities. Governments can reduce the cost of capital to CCS developments through various measures other than capital grants including:

- provision of low-cost loans and convertible loans
- loan guarantees
- direct investment (taking equity)

This is a proven strategy for attracting private capital to investments that would not otherwise meet hurdle rates. An example is the Clean Energy Finance Corporation (CEFC) established and capitalised by the Australian Government. The CEFC provides low cost finance to renewable energy and other sustainable economy related projects, and has attracted AUD26B of private sector investment through the provision of AUD5.5B of CEFC capital ('Clean Energy Finance Corporation' 2019).

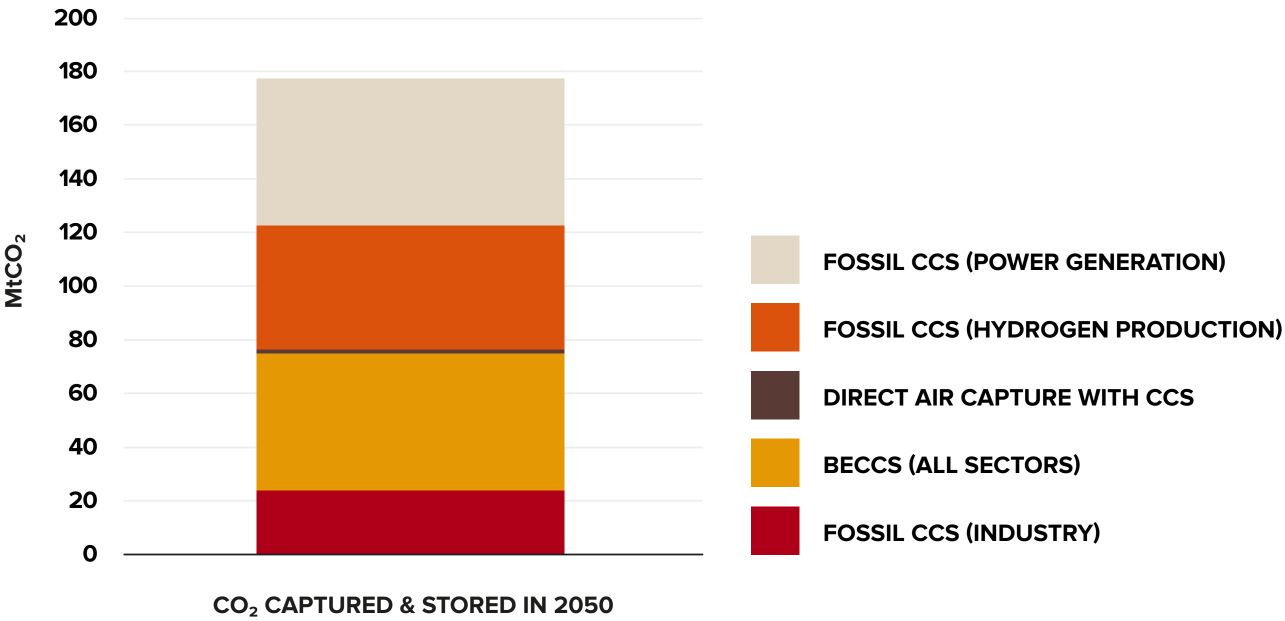
Building Confidence and Public Support

Public confidence in and understanding of the necessity of CCS in meeting climate targets is essential. The public discourse on climate change and CCS is sometimes marred by misinformation, misunderstanding and ignorance. This undermines investor confidence, community support and the ability of governments to allocate scarce fiscal and political capital to CCS, and if remains unchecked, will prevent achievement of climate targets. It is absolutely essential that governments do the rigorous analysis necessary to clearly define the role of CCS in meeting their national emission reduction targets and communicate that to industry and the public. This has two objectives. The first is to signal the government's intentions very clearly so that industry and the private sector has time to consider CCS as an investment option. The second is to build public understanding, confidence and ultimately political support for government policy that incentivises investment in CCS. Public and political

support is essential to the establishment of sustainable and effective climate policy.

The United Kingdom Committee on Climate Change provides an excellent example. In May 2019, the committee published its report; *Net Zero, The UK's contribution to stopping global warming*. This report describes how the UK can achieve net-zero emissions by 2050. Their analysis demonstrates the need for every possible low emissions and energy efficiency technology and identifies the need for CCS to mitigate emissions from industry, power generation, hydrogen production and also through BECCS and DACS. The report identifies 179Mt of CO_2 must be captured and stored in 2050 (Committee on Climate Change 2019).

Figure 11. CO_2 Captured and Stored in 2050 to Achieve Net-zero Emissions in the United Kingdom[8]



[8] Adapted from (Committe on Climate Change 2019)

3.0 FINANCING CCS

After policy settings and the commercial environment have set the general threshold for investment in climate mitigation assets, the final critical step towards FID is securing appropriate finance.

To date, most CCS facilities have been developed on the books of large corporations and state-owned enterprises (SOEs). These organisations have tended to have deep knowledge of the technologies and practices that underpin CCS. Alongside their capacity to absorb project costs, this has established them as primary candidates for investment in the first wave of CCS projects. From a financing perspective, this has led to the predominance of the corporate financing structure in the CCS investment landscape. This means that large corporations and SOEs finance the projects directly and bear the full cost of risks if they materialise, avoiding or limiting the need to consult their lenders when developing a CCS project.

In summary, the enablers for the existing CCS facilities have been effective for early and niche CCS deployment, necessary for derisking purposes. However, wide-scale deployment at a rate consistent with meeting climate targets cannot be achieved this way because:

- The opportunities for commercial sale of CO_2 will be limited. Further, there are logistical barriers to selling CO_2 since not all offtake opportunities will be within proximity of large emitters. This means that value drivers beyond the sale of CO_2 must be made available to project developers.
- The cost of capture will vary significantly depending on the industry and the type of CCS technology being applied (Kearns, Liu & Consoli 2021). The large majority of facilities constructed so far have taken advantage of low-cost capture opportunities whilst future application is required across a broader range of industries, including those with higher capture costs.
- Relatively few companies with a high need for CCS have the financial strength needed for on-balance sheet financing of CCS projects. This means that many projects, especially for smaller companies, must come to rely on alternative means of financing.

To meet these challenges, new projects must be driven primarily by climate policies without having to rely on revenue generated through the sale of CO_2. Crucially, most future projects will originate from a more diverse group of smaller companies. Since they have much smaller and more constrained balance sheets, these companies will not have the same financial capabilities as the large corporations that have been responsible for most of the CCS investments to date. Smaller companies will instead have to rely on debt financing from banks through project finance. This need has implications for the type of support that smaller companies will require to obtain debt financing from commercial lenders.

3.1 Corporate finance

The corporate finance model involves a single corporation that develops the project and finances all costs. The corporation may choose to implement the project through a subsidiary, which would then be consolidated into the corporate's financial accounts. Since it has full ownership of the subsidiary, the corporation reaps all the benefits of the project. The corporation is, however, also exposed to all of the risks and liabilities of the project, which can in turn affect the corporation's credit rating should the project not perform as expected. Such an arrangement makes it possible to raise debt at the corporate level, with the lenders having recourse to all the corporate's assets in the event of default. This significantly reduces the interest rate applied to debt, making the latter relatively cheaper. Also, since all project management is internalised, this makes the corporate finance process attractive in terms of cost of capital and speed of implementation. However, not all companies are large enough to develop projects in this way. A single CCS project for a large corporation may have little impact on their balance sheet, whilst the same project could pose a significant investment risk to a smaller company. So, while corporate finance is efficient, it cannot deliver the volume of investments in CCS required to achieve climate targets.

3.2 Project Finance

Project finance allows multiple equity investors to participate in a single project, and unlike corporate finance that is used by larger companies, the financiers have no recourse to the assets of project owners. Therefore, debt provided through project finance is charged at higher interest rates than corporate debt.

Under project finance, the project is set up through a standalone company, known as a special purpose vehicle (SPV), with each investor having an equity stake. Capital for the project is raised based on future cashflows, so both equity and debt investors are exposed to any uncertainty in the project's performance, thereby increasing the investment risk and subsequently the cost of debt. The ratio of debt to equity – also known as the gearing – in project finance can vary significantly and will be dependent on the project specifics, availability of capital and risk profile of the project owners. Some projects may have very high gearing of up to 85% debt, whilst others will be much lower, at around 50% debt. Each project is unique, and its gearing can depend on a wide range of variables, from the amount of equity available to the number and nature of risks and how they are managed. Since debt raised for project finance is secured entirely on the basis of the future cashflows, a lot of analysis is required before these types of projects can secure funding.

Large companies, such as utilities, will find that corporate finance suits their needs better than project finance. This is because large corporations have two distinct advantages: their ability to use cash flows from other operating activities and use their general creditworthiness to borrow money to fund projects.

Smaller companies which do not have the large balance sheets of corporations will find the project finance structure to be the more attractive and accessible option for funding CCS projects. Key to their participation in the project finance model will be their capacity to partner up with other investors. Project owners will need to form consortia to raise equity, whereas lenders will come together to provide syndicated project loans on the debt side. Figure 12 shows the interrelation between different parties within a simplified illustration of a project finance structure. These interrelations are to be reflected in the agreements between each of the parties and the SPV.

Figure 12. Illustrative example of a project finance structure

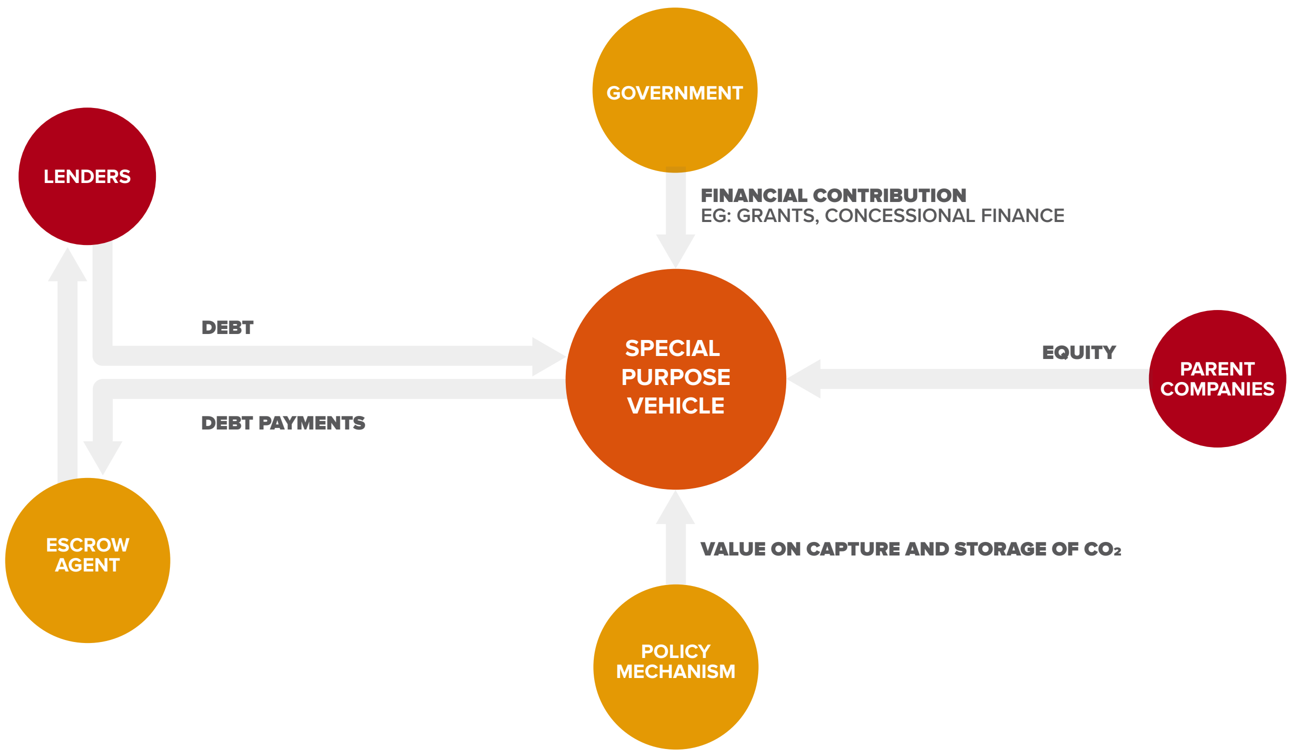
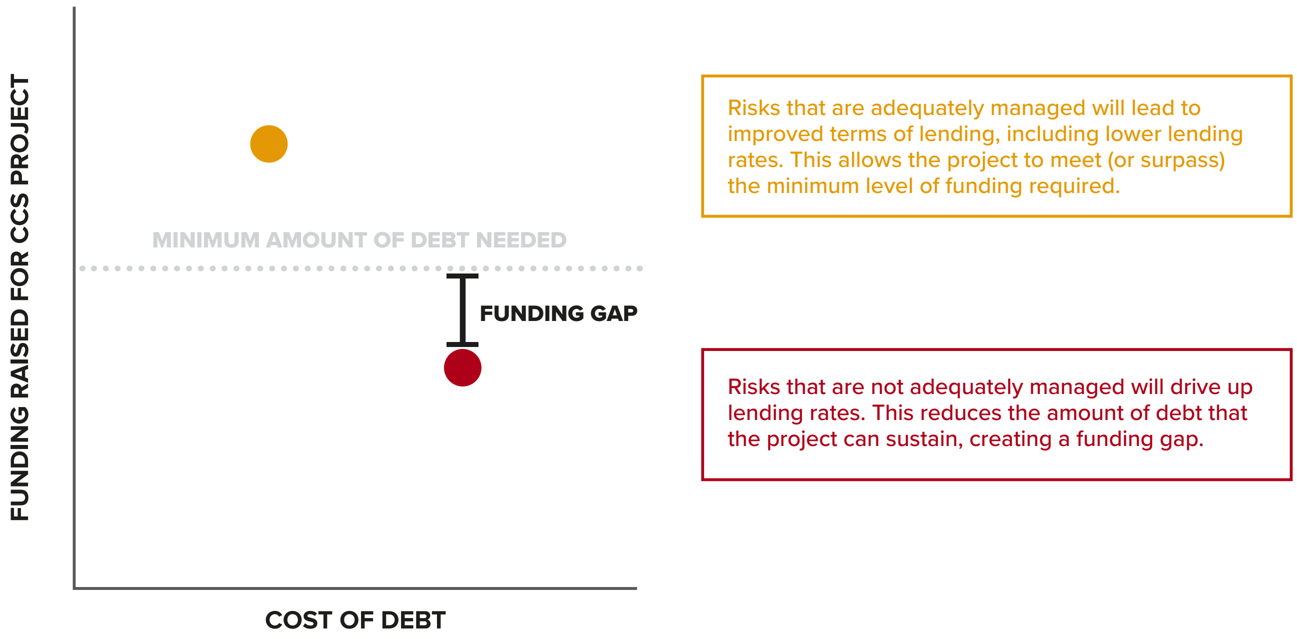


Figure 13. Illustrative example of how a funding gap emerges when the cost of debt increases because of unmanaged risks



The challenge for smaller emitters will be to assure financiers that their CCS projects, over the course of their debt's tenor, generate enough revenue to meet financing costs. Most CCS projects will have to rely solely on revenues generated through policy instruments to achieve this. Revenues may, however, be insufficient to meet some projects' costs. This will have the effect of reducing the amount of debt such projects can raise, creating a funding gap (Figure 13).

Such gaps could occur within specific sectors that will be particularly sensitive to the economics of CCS, so without additional capital support, these projects will not reach positive FID. To overcome this, governments can provide support through specialist financiers, that provide concessional lending or even grant funding to projects. Specialist financiers are mandated by governments to provide support to specific industries or to support investments in higher-risk environments and emerging markets.

Specialist financiers, which include Export Credit Agencies (ECAs) and Multilateral Agencies (MLAs), are prepared to accept a much lower risk-weighted return than commercial lenders. Table 3 provides a high-level summary of the different types of lenders, including specialist financiers, who can support CCS projects through project finance.

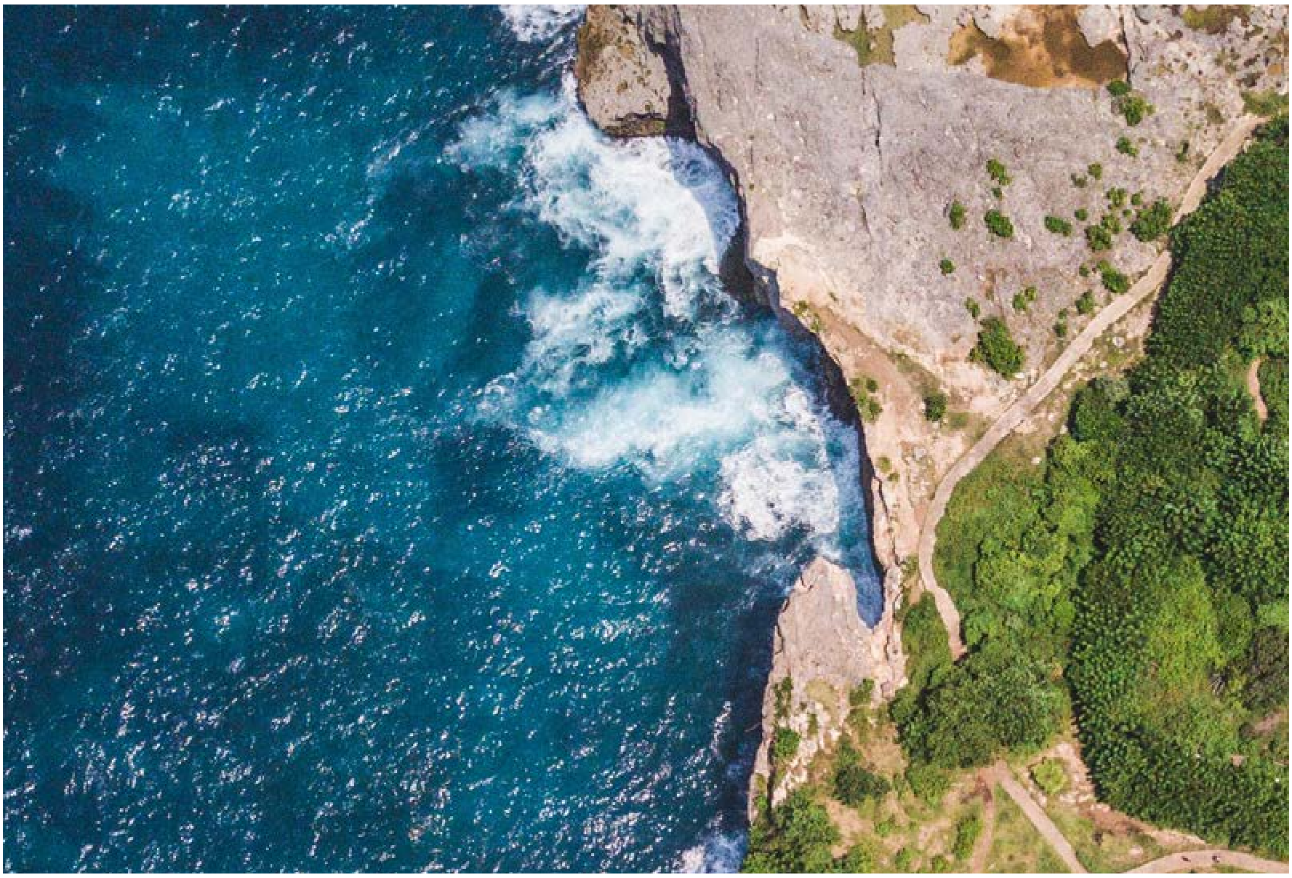
As the CCS sector evolves, costs as well as general project risks will come down. Lenders will become more comfortable with CCS investments, so the participation of financiers will diversify. Thus, commercial lenders will play a more prominent role than during the early stages of deployment when specialist financiers were needed. Over time, commercial banks will become more important contributors of non-recourse debt for project finance.

Table 3. Financiers and specialist areas of financing

FINANCING TYPE OR SOURCE	EXAMPLES OF FINANCIAL INSTITUTIONS	ROLE	EXAMPLES OF SPECIALIST AREAS OF FINANCING
Commercial Banks	HSBC, Wells Fargo. BNP Paribas	Experts at pricing term debt to projects. Commercial banks are sensitive to risks.	Long-term debt, Medium-term debt
Export Credit Agencies (ECAs)	NEXI, UK Export Finance,	ECAs provide risk guarantee to cover a significant proportion of a transaction. They also provide improved terms and conditions.	Medium-term debt, Political or commercial risk insurance, Guarantees, Concessional financing
Multilateral Agencies (MLAs) and Development Financial Institutions (DFIs)	World Bank Group, Asian Development Bank, Inter-American Development Bank, and the European Investment Bank.	Term debt providers that promote sustainable economic and social development in low-income member countries.	Equity, Long-term debt, Medium-term debt, Political or commercial risk insurance, Guarantees, Concessional financing
Developmental Financial Institutions (DFIs)	FMO (Netherlands), DEG (Germany), Proparco (France) and OPIC (USA).	DFIs are owned by singular governments and are tasked with promoting sustainable economic and social development	Equity, Long-term debt, Medium-term debt, Political or commercial risk insurance, Guarantees, Concessional financing

KEY

- EQUITY
- LONG-TERM DEBT
- MEDIUM-TERM DEBT
- POLITICAL OR COMMERCIAL RISK INSURANCE
- GUARANTEES
- CONCESSIONAL FINANCING



3.3 Drivers for private finance

Climate change engenders significant risks, called climate risks, to businesses and their sponsors. There are two types of climate risk:

- The first, physical risks, are physical manifestations of climate change – for example, wildfires, floods, and sea-level rise – that can damage assets, or directly affect their output.
- The second, called transition risks, are the result of government policies that aim to transition the economy towards a low-carbon or net-zero economy.

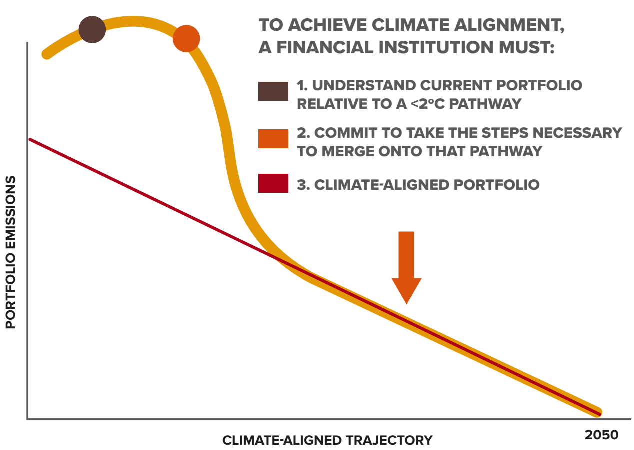
For hard to abate sectors, the materialisation of transition risks can mean increased costs and reduced profitability for companies. The incentive for companies and financial organisations to reduce their emissions is primarily in response to transitions risks. Since CCS is essential in substantially reducing emissions in the hard-to-abate sectors, investment in CCS is directly related to the expectation that transition risks will manifest in the near future.

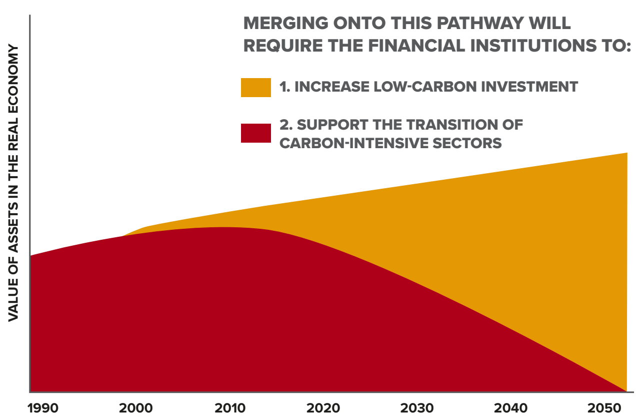
Private financial institutions are acutely aware of the material impact that transition risks can have on their portfolios. Since 2017, financial institutions representing at least US$17.2tn have pledged to become climate aligned[9] (Bloomberg 2019). Hard to abate sectors such as steel, petrochemicals, cement, oil and gas, and electricity are the backbone of the global economy. While these sectors underpin critical activities such as transport and construction, none are yet on a pathway to being aligned with the goals of the Paris Agreement. As the expectations of transition risks continue to rise, financial institutions will more rapidly align their portfolios with the objectives of the Paris Agreement. This, in turn, is expected to increase pressure on essential, but emissions intense industries, to invest in CCS and other measures to reduce their emissions.

Part of the challenge of climate alignment is assessing transition risks themselves. Financial institutions have often tended to assess their exposure by identifying emissions across their portfolio, which requires reporting by the emitters themselves, a voluntary process called carbon disclosure. In some parts of the world, the process of climate-related disclosure is becoming the norm and may soon be mandatory. For example, one of the key catalysts in advancing the understanding of climate risks has been the Task Force on Climate-related Financial Disclosures (ShareAction 2020).

The Task Force on Climate-related Financial Disclosures (TCFD) sets clear guidelines (Table 4) and recommendations to help businesses disclose climate-related financial information, which has led to an increased effort by companies to disclose their emissions.

Figure 14. Charts showing what is required to achieve climate-alignment and what the implications are for high-carbon assets (LaMonaca et al. 2020)





[9] For financial institutions, climate alignment means to reduce their operational and portfolio emissions in line with the temperature goals of the Paris Agreement.

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Table 4. High level summary of the TCFD's guidance on disclosure for various organisations (Task Force on Climate Related Financial Disclosure 2021)

ORGANISATION	TCFD GUIDANCE
Banks	• Banks should consider characterising their climate-related risks in the context of traditional banking industry risk categories such as credit risk, market risk, liquidity risk, and operational risk. • Banks should also consider describing any risk classification frameworks used (e.g., the Enhanced Disclosure Task Force's framework for defining "Top and Emerging Risks").

Insurance companies	• Insurance companies should describe the processes for identifying and assessing climate-related risks on re-/insurance portfolios by geography, business division, or product segments, including the following risks:
	  • physical risks from changing frequencies and intensities of weather-related perils,
	  • transition risks resulting from a reduction in insurable interest due to a decline in value, changing energy costs, or implementation of carbon regulation, and
	  • liability risks that could intensify due to a possible increase in litigation.

Asset owners	• Asset owners should describe, where appropriate, engagement activity with investee companies to encourage better disclosure and practices related to climate-related risks to improve data availability and asset owners' ability to assess climate-related risks. • Asset owners should describe how they consider the positioning of their total portfolio with respect to the transition to a lower-carbon energy supply, production, and use. This could include explaining how asset owners actively manage their portfolios' positioning in relation to this transition
Asset managers	• Asset managers should describe, where appropriate, engagement activity with investee companies to encourage better disclosure and practices related to climate-related risks in order to improve data availability and asset managers' ability to assess climate-related risks. • Asset managers should also describe how they identify and assess material climate-related risks for each product or investment strategy. This might include a description of the resources and tools used in the process • Asset managers should describe how they manage material climate-related risks for each product or investment strategy. • Asset managers should also describe how each product or investment strategy might be affected by the transition to a lower-carbon economy.

When companies disclose their emissions, this provides a clear indication to financial institutions of the extent to which their portfolios are exposed to transition risks, and in which sectors. In response, they can take action to reduce their exposure: they can choose to divest their interests in emissions intense assets or to engage with them.

The practice of divestment, however, simply transfers climate risks from one investor onto another. It does not bring the global portfolio towards climate alignment as demand for the products of these industries (steel, cement, fertiliser etc) will continue to drive production and the associated emissions. To achieve climate alignment, institutions must engage their customers to develop opportunities to invest in projects and activities that reduce emissions towards zero. This approach has been adopted by Norway's US$1tn Government Pension Fund and Japan's US$1.36tn Government Pension Investment Fund (GPIF). Both have decided against exiting fossil fuel investments and have instead favoured engaging with companies on climate change.

The COVID-19 crisis has triggered governments into developing a response to mitigate the pandemic's economic impacts. To meet the dual challenge of economic recovery and emissions reductions, several governments and industry groups have proposed economic recovery packages that include the development of new, climate friendly infrastructure. For example, the Canadian government is making it a requirement for large corporations that apply for government loans to publish annual climate disclosure reports as well as reports that link to wider environmental sustainability goals (Havercroft 2020).

Through this approach, key sectors that underpin the global economy – sectors such as steel, cement, oil and gas, and electricity can transition towards low-carbon emissions. CCS deployment in these sectors will be essential.

4.0 THE DEVELOPMENT OF CCS-SPECIFIC LEGAL AND REGULATORY FRAMEWORKS

4.1 The role of CCS-specific legislation

The development of law and regulation has been an important aspect of governments' policy response to CCS deployment. Early technical studies highlighted the absence, or perceived unsuitability, of existing law and regulation as significant barriers to investment. Several aspects were deemed particularly challenging, including, property and pore space access rights, operational requirements such as monitoring, reporting and verification and issues relating to the long-term liabilities.

Hastened by national policy commitments to rapid deployment of the technology, policymakers and regulators in several countries have developed a variety of CCS-specific regulatory models over the past decade, which are aimed at addressing these challenges. The period of concerted action has resulted in the removal of both national and international legal barriers to the technology, as well as the development of CCS-specific national regimes. Legal and regulatory developments have afforded early examples of incentive mechanisms and have proven critical in supporting early project deployment, with several major operational projects aided by these supportive models of regulation.

4.2 Removal of international barriers

Early legal and regulatory assessments that considered the legality of CCS operations, identified international and regional marine agreements as potential barriers to the technology's deployment. The focus of these discussions eventually focused upon the London Convention and its accompanying Protocol, as two agreements which posed unwitting barriers to offshore CCS activities.

These two international agreements are aimed at protecting the marine environment from the deliberate disposal of wastes at sea. Under the Protocol, Parties are required to prohibit the dumping of wastes, save for those listed within Annex 1 of the agreement. The exclusion of CO_2 from the original provisions of Protocol, therefore presented a clear obstacle to the development of offshore CCS projects.

Following an extensive review process, the Parties to the Protocol adopted a formal resolution to amend the new agreement, at the first meeting in November 2006. A new eighth category was inserted into the Protocol's Annex of wastes that may be considered for dumping. This category consists of "Carbon dioxide streams from carbon dioxide capture processes for sequestration".

Further clarification is provided and suggests that these CO_2 streams may be considered for dumping, where:

1. "Disposal is into sub-seabed geological formation; and
2. They consist overwhelmingly of carbon dioxide. They may contain incidental associated substances derived from the source material and the capture and sequestration processes used; and
3. No wastes or other matter are added for the purpose of disposing of those wastes or other matter."

Broad international support for CCS resulted in the substantive, timely amendment to the Protocol, which removed barriers to the technology's deployment and affords a formal basis for the regulation of sub-seabed geological storage of CO_2 under the Protocol's mechanisms. The swift ratification of the 2006 amendment, by the Protocol's Contracting Parties, also represents an important international commitment to the technology, one which recognises CCS as a vital element of future climate change mitigation activities.

4.3 The emergence of CCS-specific legislation

The past ten years have also witnessed the development of CCS-specific legislation, in jurisdictions across Europe, North America, Asia and Australia. In all but one instance, one of two approaches has been adopted, with policymakers and regulators deciding to either enhance existing regulatory frameworks with CCS-specific provisions or to enact stand-alone CCS-specific legal frameworks. A further option has been the development of 'project specific' legislation that regulates the operations of a single project; an example of which may be found in the Barrow Island Act that regulates Western Australia's Gorgon CO_2 injection project.

Clear from experience to date, however, is that the choice of approach in enacting CCS-specific legislation, has depended to a large extent upon the role and objectives underpinning legislation in each jurisdiction.

Removing barriers and incentivising technology deployment: the EU experience

The European Union's legal framework addresses the CCS project lifecycle, through the introduction of a Directive that is focused upon the storage aspect of the process and several wider amendments to a body of EU environmental, energy and planning legislation. The Storage Directive was enacted as part of the EU's wider climate and clean energy policy objectives; however, it also seeks to ensure and maintain the EU's environmental protection requirements. Ultimately, the Directive achieves this balance by removing several potential legal barriers to CCS activities and clarifying the status of the technology under a variety of EU Directives and Regulations, including those relating to waste and water. Consequential amendments to the EU ETS Directive and the Environmental Liability Directive, also address issues of operational liability and offer an incentive for project proponents.

In focusing the regulatory framework upon the storage aspect of the CCS process and utilising pre-existing legal instruments to manage some of the risks associated with the capture and transport aspects of the process, the Directive offers a comprehensive CCS-specific regime. The resulting legal framework includes requirements for the permitting of exploration and storage activities, monitoring and reporting obligations, liability and financial security provisions, as well as a process to enable the eventual closure and long-term stewardship of storage sites.

Supporting early project deployment: Alberta, Canada

The Canadian province of Alberta has also enacted legislation to support the deployment of early projects and its regulatory framework is one of the most comprehensive CCS-specific models developed to-date. The Shell Quest carbon capture and storage facility was an important stakeholder in the design and development of the province's CCS legislation and has been subsequently permitted and regulated under this new framework.

Predicated upon its existing oil and gas regime, the province introduced detailed CCS-specific amendments under the 2010 Statute Amendments Act and subsequent Tenure Regulation. The result was the removal of several discrete barriers to the commercial deployment of the technology and the establishment of a regulatory model for CCS activities.

Alberta's regulatory regime addresses many of the critical issues previously identified by project developers in the province as particularly challenging, or barriers to more widespread deployment of the technology. In addition to a process for obtaining the tenure rights, necessary for undertaking CO_2 geological storage in the province, Alberta's model also includes provisions to enable the potential transfer of liability for a storage site post-closure and the establishment of a stewardship fund to reduce the potential cost to government of the liabilities assumed during the post-closure period.

Responding to climate and environmental commitments: United States' federal and State regimes

In the United States, the Environmental Protection Agency's (EPA) Final Rule, developed under the auspices of the Underground Injection Control (UIC) Program of the Safe Drinking Water Act (SDWA), together with requirements around the reporting of CO_2 emissions under the Clean Air Act, remain the focus of the federal framework for CCS activities. Early studies had determined that the pre-existing federal UIC program, which seeks to protect underground sources of drinking water and already regulates the injection of fluids into the subsurface, would offer an optimal basis for the regulation of CO_2 storage activities. The Program had previously regulated the siting, design and construction, operation and abandonment of five classes of wells, injecting fluids into the subsurface; including for CO_2-EOR operations.

The introduction of a new well class, Class VI, under the Program was deemed necessary, to allow the EPA to fully regulate CO_2 injections into the subsurface for the purpose of long-term storage and to reduce emissions to the atmosphere. The new Class VI rules build upon many of the familiar aspects of the UIC program, however, they apply only to geological storage operations and further ensure a distinction between CCS activities and the existing Class II rules for CO_2-EOR operations. The resulting regulatory framework establishes the minimum technical criteria for geological storage operations and includes provisions relating to site characterisation, monitoring, post-injection site care and financial security.

In addition to the Class VI provisions, the EPA has also developed rules under the federal Clean Air Act, which seek to ensure the effective reporting of injected CO_2. Under Subpart RR of the Reporting Rule, which applies to any operator with a Class VI well permit (or a Class II operator that chooses to opt-in to the program), facilities are required to monitor and report to the EPA, all CO_2 injected for the purposes of long-term storage.

The activities at the federal level have also been complemented by the actions of several US States, which have also introduced legislation to regulate discrete aspects of CCUS activities. Provisions governing, amongst other items, pore-space ownership, the application of eminent domain rights to CCS operations, CO_2 pipeline infrastructure and liability have been enacted in approximately 20 states across the United States.

4.4 Core principles and essential elements

While the ambition and complexity of the CCS-specific models developed to-date varies greatly, several areas of commonality may be identified within the various legal and regulatory frameworks. Among policymakers and regulators, similar approaches to the core legal and regulatory elements of a CCS-specific framework have been adopted, when addressing the novel aspects of the CCS process or in seeking to support project deployment.

In many jurisdictions, an approach which reflects the project lifecycle and the allocation of responsibilities for the entire duration of a CCS operation, has proven essential and this element remains an important feature of many of the CCS-specific regimes. As a result, early frameworks have sought to clearly define processes and responsibilities from an initial planning and exploration stage, throughout the operational phase and beyond into a closure and post-closure period.

A permitting model which reflects the lifecycle approach, has been adopted in several jurisdictions, with regulators awarding various licences, permits and leases to undertake CCS-specific activities. Under this phased approach, an operator seeking to undertake storage activities will be required to obtain a series of authorisations, as they transition from the planning and exploration phase, through the operational stage of a project and ultimately into the eventual closure and post-closure phase.

The resolution and reconciliation of several core issues within domestic regimes, would appear to be fundamental to the development of a comprehensive regulatory model that provides certainty to investors and project operators. While it is not possible to provide an exhaustive review of all of the key elements here, the following have, to a greater or lesser extent, been addressed in many of the early regulatory frameworks:

- the ownership of and access to the subsurface;
- the staged permitting of operations;
- measures aimed at protecting public health, safety and the environment;
- monitoring and verification obligations;
- financial security requirements; various forms of liability and
- the requirements for closing a storage site.

Lifecycle permitting models

The Institute's analysis of the approach taken to CCS-specific law and regulation to-date, reveals that a largely similar approach to the permitting of CCS operations has been adopted. The regimes developed in Australia, Europe and North America, all rely upon the grant of a specific authority for an operator to undertake activities throughout the CCS project lifecycle.

While the development of these regimes has resulted in the creation of new authorities and processes, in many instances, regulators and policymakers have drawn upon concepts and models found in existing environmental and energy legislation. In some jurisdictions, this has resulted in the adaptation of mechanisms presently used in the regulation of the extractive and waste industries, to manage the risks associated with CCS operations. The Australian Commonwealth government's offshore regime offers a useful example of this approach, with CCS operations incorporated within the existing petroleum licensing regime. The resulting CCS-specific pathway, which draws upon familiar processes and concepts, enables the regulation of pipeline transportation, injection and storage activities within the Commonwealth's offshore area.

Notwithstanding the similarities in these lifecycle permitting models, however, it is also clear that the various authorities established under these regimes confer an array of different rights and obligations upon the holder. One example may be found in the UK, where the grant of two authorities will be necessary to undertake CCS activities, with a separate lease required to gain access to a CO_2 storage site, in addition to the license authorising injection and storage activities.

Monitoring, measurement and verification

Monitoring, measurement and verification (MMV) obligations, which are to remain throughout the project lifecycle, are an important aspect of many of jurisdictions' CCS-specific regulatory regimes. The submission of detailed plans that set-out an operator's proposed MMV activities throughout the operational phase of a project, and in some instances beyond, are required as part of the permitting process in some jurisdictions.

Operators will be required to provide the relevant authority with comprehensive MMV reports and up-dated project management plans, throughout a project's operational lifetime, to demonstrate the behaviour of the CO_2 plume is in-line with predicted models and there is permanent containment of the injected CO_2. Many of the regulatory frameworks contain detailed provisions as to the nature of the reporting requirements and the approach to monitoring. In some instances, for example the EU CCS Directive, secondary guidance has been developed to provide regulators and operators with further details of the type of information required and the types of practices necessary.

Several of the CCS-specific regimes developed to-date, have emphasised an iterative approach to regulation and include requirements for operators to review and update procedures and plans throughout the lifetime of a project. MMV requirements are one area where this approach is promoted, and operators' practices are to be based upon iterative and performance-based processes. In these instances, operators are obliged to ensure that monitoring techniques, throughout the lifetime of the project, reflect practical experience and continue to prove effective in meeting the regulatory objective.

Financial security

The need to ensure accountability and financial responsibility for CCS operations throughout the project life cycle, particularly in instances of operator default or serious incident, has resulted in the adoption of a range of financial security mechanisms. Several of the early CCS-specific regulatory frameworks require an operator to hold financial security and the ability of an operator to obtain and maintain the requisite form of security is a significant consideration for regulators when deciding to grant a permit or licence.

Several of the CCS-specific frameworks offer great flexibility in the form of financial security that may be acceptable to the regulator. Similarly, the opportunity for regular review and adjustment, as well for operators to manage their exposure through ongoing payments during the operational phase of the project, have also featured in some of the regulatory models.

In many instances, regulators have been strongly influenced by existing models of financial security in their jurisdiction. Models utilised in the regulation of landfill and oil and gas operations have provided useful analogues for regulators, with CCS-specific models adopting similar formats. While the nature and scope of these financial security provisions varies greatly, with some jurisdictions yet to provide full guidance as to the exact nature of the required security, the underlining policy goal of reducing the exposure of the taxpayer and general government funds would appear similar.

Liability

The management of liability throughout the project lifecycle, has proven a significant consideration for industry, governments and project proponents globally. Clarification and resolution of these issues continues to be highlighted as an important factor in addressing, the novel risks posed by the technology, public concerns as to the technology's safety and ultimately securing investor confidence.

Many early CCS-specific frameworks have introduced provisions aimed at addressing liability. In some instances, for example the EU Storage Directive, the regulatory models seek to clearly allocate the wide range of potential liabilities between the operator and regulator throughout the different stages of the project lifecycle. Ultimately this has been achieved through the design and implementation of new mechanisms, however in many instances far broader obligations are likely to be borne by operators through the implicit application of a wider body of legislation and domestic case law.

Liability has proven particularly contentious where injection activities eventually cease, and regulators and operators are confronted with the challenge of managing a storage site in perpetuity. Some, but not all, of the CCS-specific regimes developed to-date, have sought to address this through provisions which enable the closure of a storage site and for the eventual transfer of responsibility for the site from the operator to the State. The manner in which this transfer is to be effected and the nature of the liabilities which are to be eventually transferred, have proven critical issues for both operators and regulators alike. There remains variation between the transfer regimes in some jurisdictions, particularly with regard to the conditions to be fulfilled to enable a transfer and the nature of liabilities to be transferred to the State.

4.5 Wider legal and regulatory considerations

The development of the various CCS-specific regimes, as well as the project-level experience garnered by operators, policymakers and regulators to-date, also offer some further important lessons for those seeking to develop regulatory frameworks for the technology.

Beyond the structure and content of these early frameworks, however, there are further administrative and policy-focused considerations that policymakers and regulators may wish to consider and recognise when developing their own legislation.

Supporting all technologies and pathways

The combined urgency and challenge of reducing greenhouse gas emissions, will require policymakers to pursue all available technologies and pathways for achieving domestic net-zero targets, or those of the wider Paris Agreement. In this context, law and regulation will play a crucial enabling role, as those seeking to invest in and operate projects look for clarity and consistency in the application of legal and regulatory regimes.

Economy-wide emissions reductions will ultimately require policymakers and regulators to adopt a flexible approach to regulation. Legislation will be required to address many of the core legal and regulatory elements described previously, however, it may also need to be flexible enough to address further iterations of the technology, or even greenhouse gas removal from other sectors. To this end, all emissions reduction pathways and technologies must receive support and not be unfairly prejudiced by regulatory barriers.

The regulation of CCS activities to date, however, illustrates the challenges associated with adopting an inclusive approach when designing legislative frameworks, particularly in the context of a broad range of emissions reductions technologies. Various legislative frameworks, including those characterised as leading examples of CCS-specific regimes, have posed deliberate or unwitting barriers that have impeded the ability of investors and operators to proceed with certain types of CCS projects and technologies.

One example may be found where some legislative frameworks have excluded particular technologies from the scope of their regulatory framework. This was seen in the case of the EU CCS Directive, which presently focuses exclusively upon the regulation of projects aimed at dedicated geological storage of CO_2, thereby excluding wider potential applications and technologies such as CO_2 utilisation.

A further example was found within provisions of the London Protocol, which had the unintended consequence of effectively banning the transboundary transportation of CO_2 for geological storage purposes. Notwithstanding the earlier 2006 amendment and later amendments made to Article 6 of the Protocol, that were agreed by the Parties to address the transboundary issue in 2009, an insufficient number of ratifications meant that the issue remained a major barrier to deployment until October 2019. The issue was finally resolved, at the 2019 meeting of the Contracting Parties, when an agreement was reached between the Parties to allow the provisional application of the 2009 amendments to Article 6 of the Protocol. The agreement, which concluded over 10 years of uncertainty, finally allowed countries who wished to engage in cross-border transport and export of CO_2 for geological storage in sub-seabed geological formations to do so, subject to certain conditions.

These examples demonstrate how a failure to regulate the entirety or even discrete aspects of a process, either deliberately or unintentionally, presents a substantial barrier to investment and the deployment of projects. Eliminating regulatory barriers and adopting an inclusive and holistic approach to the design of legal and regulatory frameworks is critical, especially within a context of the urgent need to deploy a wide range of emissions reduction technologies to achieve climate targets within proposed timeframes.

Impact of legislation upon the development of policy support mechanisms

Legislation that implements climate change objectives may also lead to the development of supportive policies for various mitigation technologies. To this extent, legislation may therefore play an important role in creating a level playing field for the deployment of all technologies.

Several countries have gone beyond policy-based approaches, with some ultimately mandating the achievement of net-zero emissions by 2050 within their legislation. France, the United Kingdom, Sweden, Denmark, Netherlands and New Zealand have all now adopted legislation committing them to formal emissions reductions. Despite the absence of national legislative targets, several states within countries with significant GHG emissions such as California and New York in the United States and Victoria in Australia, have also enacted legislative commitments to achieving net-zero emissions. Statutory net-zero commitments vary in their application across different countries. In the UK, France, Sweden and New Zealand, legislative targets apply across all sectors, while in other countries, they apply to targeted sectors, such as the electricity sector in the Netherlands and in the US state of California.

Legislated targets are frequently accompanied by policy packages, which include support for the deployment of CCS as a mitigation strategy. In the Netherlands, for example, CCS has been highlighted as a crucial technology for achieving its statutory commitment to net-zero emissions in the electricity sector and accompanying policy packages have allocated subsidies to assist with deployment of the technology, along with other technologies as long-term energy transition solutions.

In California, a bill committing to a zero-carbon electricity sector by 2045 has led to policies – subsequently enacted in law - that recognise CCS as critical to achieving targets. As a direct result, California's Air Resources Board (CARB), a body with major responsibility for developing the state's climate policy, has determined that CCS projects which reduce lifecycle emissions from transportation fuels are eligible to receive credits under the state's Low Carbon Fuel Standard (LCFS).

Timeframe for the development and implementation of legislation

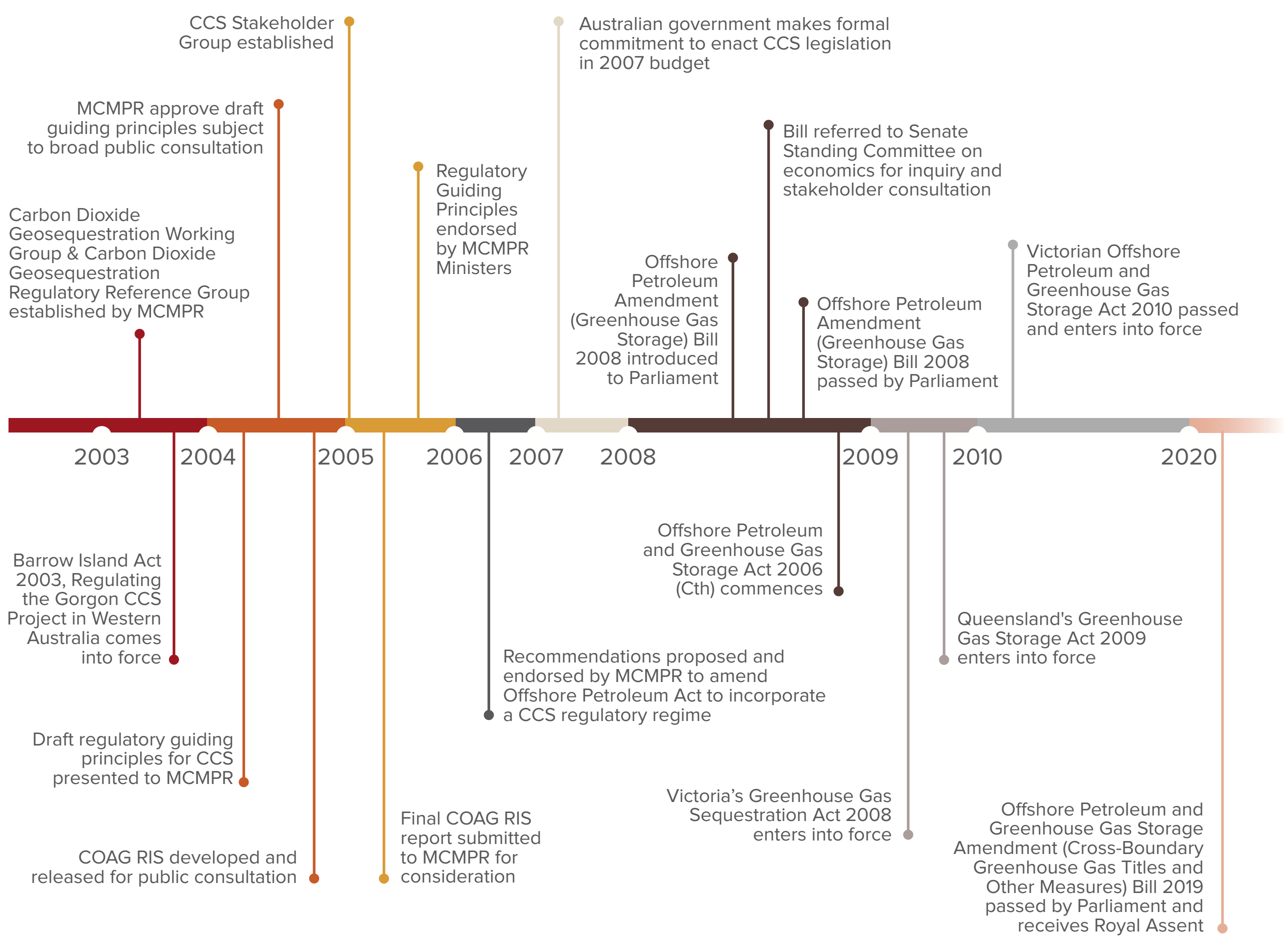
The realisation of national policy ambitions for emissions reduction and technology deployment, within the timeframes specified within domestic policy commitments, will require concerted and timely action. Where jurisdictions shift their focus towards CCS, as part of wider strategies or commitments towards achieving net-zero, the development of enabling policy and legislation will become an important factor. In this context, the failure to develop a comprehensive and supportive legal and regulatory framework, may ultimately lead to the frustration of national policy commitments and unnecessary project delays.

The experience of several jurisdictions to-date, indicates that developing and implementing comprehensive legislation to facilitate the deployment of CCS projects, incurs a significant time commitment. Legislation has taken several years to develop, even in those jurisdictions where CCS is supported by strong policy commitments. The need for urgency in beginning the legislative process, as well as developing the administrative framework for the regulation of CCS activities, will be essential for those nations with policy ambitions for the technology, but have yet to consider their legal regimes for the technology.

Australian policymakers and regulators have developed some of the world's most advanced and comprehensive CCS-specific regulatory frameworks. The Australian experience, however, also reveals the substantial challenges and time commitments, faced by those seeking to develop CCS-specific legislation.

The following diagram offers an illustration of the timeline of events leading up to the enactment of the Commonwealth's Offshore Petroleum and Greenhouse Gas Storage Act in 2008, as well as the subsequent amendment in 2020. Not included in the diagram are the subsequent iterations of this legislation or the development of the secondary regulations which support its implementation. As may be seen from the illustration, the legislative process in Australia has proven complex and time consuming, notwithstanding the supportive policy environment for the technology.

Figure 15. Timeline of events leading to the development of Commonwealth CCS legal regime in Australia



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5.0 CONCLUSIONS & RECOMMENDATIONS

The fundamental virtue of the Circular Carbon Economy is that its adoption will drive the most efficient, lowest cost and lowest risk strategy for reducing greenhouse gas emissions. That strategy will utilise the optimum mix of technologies, behaviours and approaches, which will differ between locations depending upon many factors such as the availability of resources and the nature of the existing economy. This report has briefly described the most important policy, finance and legal factors that can impact the success or failure of establishing a Circular Carbon Economy with respect to one class of technologies; carbon capture and storage.

In many respects, CCS today is where intermittent renewable electricity generation was in the early 2000s – technologically mature (but still improving), and with very few exceptions, commercially unattractive without policy to underpin the business case for investment. Fortunately, policy makers understood the importance of renewable energy, promulgating policies that drove investment. To stabilise the global climate, policy must now evolve at an increasing rate, moving beyond the old thinking that renewable electricity and efficiency alone can deliver deep emission reductions to a more progressive approach that facilitates a comprehensive strategy to achieve a higher ambition; net-zero emissions. CCS is part of that strategy.

Rising expectations of civil society, of shareholders, stakeholders and voters, of governments and the private sector to align with a net-zero emissions future has driven unprecedented growth in the CCS project pipeline. However, barriers to investment are preventing the allocation of sufficient private capital to build a global net-zero emissions economy. Those barriers are very well understood and have been defeated countless times in other industries over the past century where the public interest was otherwise not being well served by private investment incentives. Examples include action by governments to establish road and rail, electricity generation and distribution, sanitation, telecommunications and internet, and renewable energy industries. The same general set of policy tools and approaches that have been successful across these and other industries can be applied to CCS. Without them, achieving net zero emissions will be more difficult, more expensive, more risky and more delayed.

This report makes a series of high level recommendations addressing policy, finance and regulatory matters that are intended to contribute to policy development, rather than be prescriptive. The precise formulation of policy and legislation in every jurisdiction must always be cognizant of local circumstances to be effective.

Recommendations

1. **Based on rigorous analysis define the role of CCS in meeting national emission reduction targets and communicate this to industry and the public.**

   A thorough analysis of the role of CCS is necessary as part of a broader assessment of the lowest cost and risk pathway to net-zero emissions. Communicating the outcomes of such an assessment, including the social and economic benefits that will accrue from the protection of existing industries and the creation of new industries will assist in building the public support and political capital required by governments to take strong action on climate change. It will also provide the private sector with a clear statement of the government's intent and accelerate analysis as to how to align business strategy with that intent.

2. **Create a certain, long term, high value on the storage of CO_2.**

   Businesses must make an appropriate risk-weighted return on material investments, including CCS. The act of capturing and storing CO_2 rather than simply emitting must create value for the business. This value may be in the form of a financial reward for CO_2 stored (eg, the tax credit in place in the USA), or a financial penalty which is avoided by storing CO_2 (eg, the carbon tax that applies to Norwegian petroleum production). In any case, the value must be sufficiently high, and the market must have confidence that it will remain so for a period that is sufficiently long to make an appropriate return on the CCS investment.

3. **Support the identification and appraisal of geological storage resources – leverage any existing data collected for hydrocarbon exploration.**

   Expenditure on identifying and appraising geological storage resources, which will cost from ten million to over $100 million per resource, is at-risk as there is no guarantee that a suitable storage resource will be discovered in every case. The business case for storage resource exploration is currently weak causing underinvestment in the development of these resources which are critical to achieving net-zero emissions. Government can redress this by investing in the collection and analysis of geological data and by ensuring that existing data collected for hydrocarbon production is available, as appropriate.

4. **Develop and promulgate specific CCS laws and regulations that include transfer of long-term liability to the Government subject to acceptable performance and behaviour of the stored CO_2.**

   Uncertainty around operational compliance requirements, rights to access pore space for CO_2 storage, and the management of long-term liability for stored CO_2 will in most cases be an insurmountable barrier to investment. Governments should promulgate clear and predictable legislation that allows project developers to understand and manage their compliance and liability risks.

5. **Ensure policies and legislation developed to drive emissions abatement are inclusive of all options, including CCS, to enable the optimum mix of technologies to be deployed in order to maximise abatement and minimise cost and risk.**

   The unintentional or deliberate exclusion of any applicable emissions abatement technology by policy or regulation will prevent their selection even where they are the best option, increasing the cost of abatement. Consistent with the fundamental tenet of the Circular Carbon Economy, every technology is essential and therefore none should be disadvantaged through exclusion or prohibition.

6. **Identify opportunities for CCS hubs and facilitate their establishment. Consider being the first investor in CO_2 transport and storage infrastructure to service the first hubs.**

   CCS hubs significantly reduce the unit cost of CO_2 storage through economies of scale and offer commercial synergies that reduce the risk of investment. Creation of CCS hubs in existing emissions-intense industrial precincts protects existing jobs, creates new jobs, and builds support for strong climate action in communities that would otherwise perceive it as a threat to their economic security, enabling governments to take strong action on climate change. CCS hubs reduce counterparty or cross chain risks as they provide capture and storage operators with multiple customers/suppliers. Availability of CO_2 transport and storage infrastructure is essential to enable investment in CCS necessary to create net-zero emissions economies.

7. **Provide capital grants, low-cost finance and/or guarantees or take equity to reduce the cost of capital for CCS investments.**

   Project finance enables far more CCS investments because smaller companies are not able to fund CCS projects on their balance sheets. Since project finance is non-recourse debt, it increases the cost of capital for investors as well as the length of time it takes to structure projects. Governments can play an important role in enabling project finance since they can support investments, either directly or through specialist financiers such as Export Credit Agencies and Multilateral Agencies, reducing the cost of capital. Governments can also provide capital grants or low-cost debt to fund areas of projects that banks are unwilling to apply debt to. Such support can form part of funding programmes that are linked to policies that enable investments in CCS.

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