



Evolving the Carbon Capture and Storage Value Chain

A Decarb Connect report in association with Gaffney Cline

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Introduction

In 2021 an estimated 37 MT/annum of CO₂ was captured globally, the majority from the processing of Natural Gas, just 11 MT/annum of the CO₂ was permanently stored, the remainder was injected into hydrocarbon reservoirs to Enhance Oil Recovery (EOR).

The global pipeline of Carbon Capture and Storage (CCS) projects currently under development and construction promises to increase the amount of CO₂ captured by almost fivefold to 170 MT/annum, with the majority due to be permanently stored in either saline aquifers or depleted hydrocarbon reservoirs. This marks a rapid growth in the development of CO₂ capture capacity along with a fundamental shift in the application of CCS towards the permanent sequestration and storage of CO₂. Yet even this current pipeline appears modest when considering the potential of CCS to support the decarbonisation of hard to abate industries. The IEA in its Net Zero scenario forecast that CCS could remove around 8000 MT/annum of CO₂ by 2050, completely dwarfing the current capture capacity.

The growth of CCS has been anticipated for well over a decade and the technology is well proven, Equinor's Sleipner project, one of Europe's largest and oldest operating CCS projects, has been capturing and storing CO₂ at a rate of around 1 MT/annum since 1996. However from the responses received to this market survey it seems that this time the global growth of CCS is underpinned and being driven by an increasing commitment to invest capital in CCS, largely by the end of the current decade.

Florent Rousset, President of GaffneyCline highlights that "CCS has become a major focus area for our Carbon Management projects globally. Over the last four years we have been increasingly engaged by a wide range of clients including E&P operators, industrial emitters, governments, project developers, the private equity and the lending communities to assess and mature an exciting array of CCS investment opportunities. We are delighted to have had the opportunity to partner with Decarb Connect on this market survey, that aims to bring current insights and first-hand experience from all stakeholders to accelerate the deployment of CCS at scale".

Report Methodology and Contributors

This Decarb Connect Report on the CCS supply chain combines both qualitative and quantitative techniques to give a thorough insight into the current state of play for carbon capture, transport and storage across hard to abate sectors.

The report statistics and figures have been compiled from an anonymised survey of almost 100 senior executives representing a range of experience and perspectives from across the CCS space. A third of respondents represent the hard-to-abate asset owners, and the remainder a mix of policymakers, financial executives, academics and industry.

In addition, we are honoured to have worked with a panel of senior experts on the qualitative stage of report research, who provided their insight and context to the data gathered through a series of in-depth interviews.

Many thanks to the Decarb Connect Report contributing panel:



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All views are my own and need not reflect
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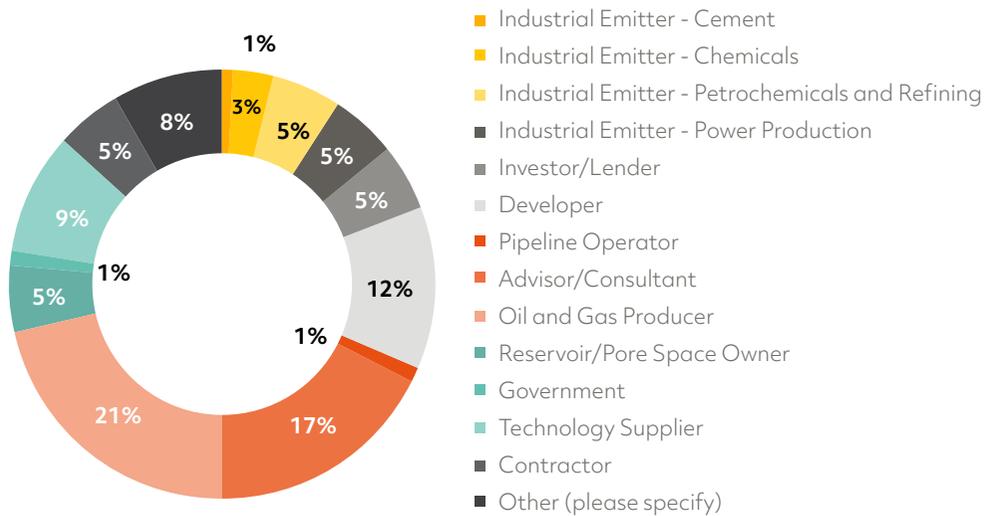
Alan James
Founder
Storegga

About the Respondents

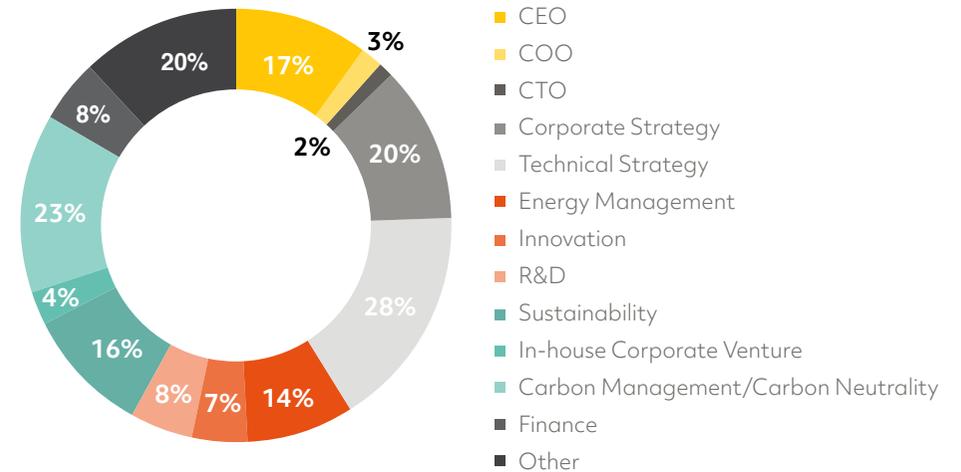
What is the geographic presence of your organisation?



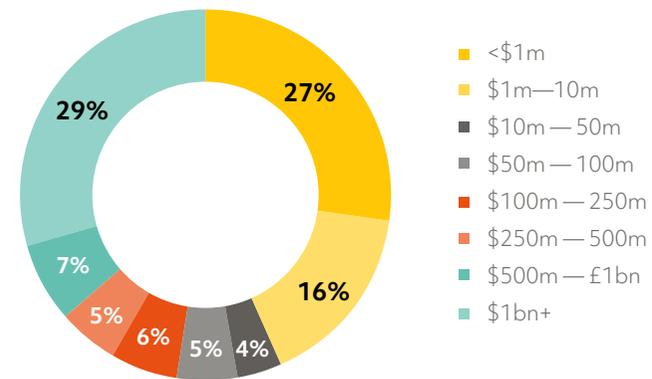
What is your company type?



What functions does your role include?

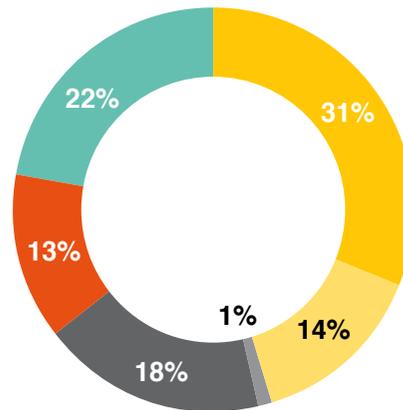


What is the size of your company by turnover?



Section One: The Outlook for CCS

Are you planning to invest capital or are you supporting the financing of CCS project(s), if so, when will the project(s) be likely to start operation?



- By 2025
- By 2030
- By 2040
- Yes, but the project is in early planning stages
- As yet undecided
- Not currently envisaged

CCS rollout accelerating

Over two thirds of respondents are planning or supporting the investment in CCS projects that will be operational by 2040, with almost a third (31%) involved in the financing of CCS projects due to start operation by 2025. Less than a quarter of respondents (22%) were not envisaging any investment in CCS at this stage. Whilst the split between early adopters and followers is typical of most technology adoption curves, many experts anticipate rollout accelerating very quickly due to increasing carbon prices.

Wim Van der Stricht, Technology Strategy – CO2 and circular economy at ArcelorMittal explains that the cost of energy has had an impact too, “the price of natural gas and events in Ukraine could push up the cost of hydrogen and delay the transition to hydrogen, meaning CCS could be a better win in the short term as the technology is already proven. If you took this survey again next year, you’d see an even bigger shift.”

Experts anticipate the rollout of CCS will rapidly accelerate

More than two thirds of respondents are involved in the financing of CCS that will be operational by 2040

Almost half of respondents are planning investment in CCS that will start capturing emissions by 2030



Factors Determining CO₂ Storage Opportunities

Several factors influence the opportunity to store and permanently sequester CO₂ and although incentives are important, regulation was flagged as the perhaps the most influential factor by Decarb Connect's panel of contributors.

Responses indicated that the USA lends itself to onshore sequestration whilst Europe leads the development of depleted offshore reservoirs for CO₂ storage and sequestration. Alan James, a Founder of Storegga sees the sequestration situation in **Europe as a catalyst for world-leading change.**

"Storage will be mainly, if not entirely, offshore" he says, leading to a situation where **"Europe will be the birthplace of a maritime transport industry which will support other regions of the world."**

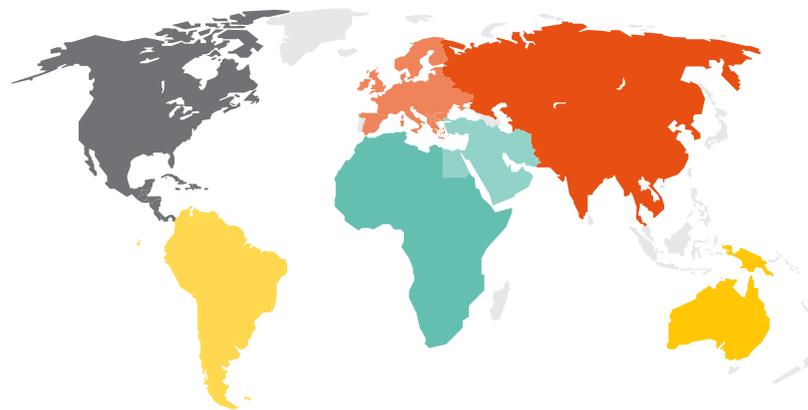
In terms of utilisation of captured CO₂, the European market seems to be further ahead, with a push from governments to support development of CO₂ as a co-product to be utilised rather than a waste product to be stored. In the USA, 45Q includes an incentive mechanism specifically targeting utilisation. "The U.S. Inflation Reduction Act (IRA) offers \$60/metric tonne for CO₂ captured and utilized. Such incentives are expected to boost

circular carbon economy where CO₂ captured from industrials is recycled as feedstock for biofuels and other products and excess CO₂ permanently sequestered" explains Joshi of Talos Energy. "You could be seen as a bad actor or you can invest a similar amount and say you're doing something for the environment. Utilisation for petrochemicals can develop in Europe and deploy worldwide."

Europe a catalyst for world-leading change

“ Europe will be the birthplace for maritime transport of CO₂

Where do you foresee the greatest opportunities for the deployment of CCS to reduce CO₂ emissions?



% of respondents ranking region as high potential for CCS

■ North America	88%
■ Europe	69%
■ Australasia	60%
■ Middle East	56%
■ Asia	50%
■ South America	26%
■ Africa	22%

CCS Value Chain

"I think the geographies which will create CCS opportunities need to bring three key elements together" says James of Storegga, who agrees with our community that North America and Europe are best positioned for growth.

“The three elements are emitters with the motivation to drive down emissions, proximal storage resource of a high enough quality and the business models to enable the system to kick off.

"The areas which tick all of these boxes are the USA, Europe and the UK." He believes that while regions such as Australasia or South East Asia have massive potential, they lag in terms of business models and policy development, which is holding back commercial motivation. As business models in Europe and the USA gain momentum and net zero declarations in markets such as Japan or South Korea are made, there will be a rich portfolio of case studies to allow nations to pick and choose the models most suitable for their own economies.

Richard Gwilliam, Head of Cluster Development at Drax Group is largely in agreement with James, identifying **innovative industry, political will and viable geology as the factors needed to make CCS work.** "Look for existing clusters and hubs where concentrations of high emitting industries

can take advantage of economies of scale." Irrespective of government incentives and policy, **the emergence of hubs or clusters which will drive technology acceleration and create economies of scale, is a clear factor influencing the development of CO₂ transportation and storage.**

Cross-border Shipment

"2030 isn't a crazy target for the international shipping of CO₂" says Winde of Porthos, "it's a matter of cost...high CO₂ producers will work in hubs or connect to the main system to combine with other industries and ship from there. From a regulatory standpoint it will be fairly straightforward as standards are already in place for existing pipelines."

Unsurprisingly, Decarb Connect's survey found that European respondents felt that cross-border shipping of CO₂ would happen sooner than those in North America. With 39% of those with European operations anticipating that this will be happening by 2030 compared to 31% of North American respondents.

Given the potential distances between viable CO₂ sequestration sites in Europe and sources of emissions that can be viably captured, trans-border shipment of CO₂ will be necessary to scale CCS in Europe.

"Legislation for transporting CO₂ over borders in Europe is getting closer and closer to resolution" says Van der Stricht of ArcelorMittal. "If you put a pipeline between two EU member states you need a permit to cross the border, and more and more countries are signing up to the (IMO) London

Protocol, which will make it possible to put a network across Europe."

Although there are still commercial and regulatory obstacles to overcome Joshi of Talos Energy believes that CO₂ transportation will not be limited intra-region cross border shipment but "CO₂ could be shipped globally".

What % of respondents in each region expect to see cross-border shipping taking place by 2030 within their region? (Respondents could choose more than one answer)

1. Middle East 50%
2. Australasia 47%
3. South America 44%
4. Europe 39%
5. Africa 38%

European respondents felt that cross-border shipping of CO₂ would happen sooner than those in North America.

Section Two: Challenges and Risks

Identifying the Risks

What do you see as the top five risk that could permanently derail the development of your CCS project(s)?

Most commonly occurring answers when respondents were asked to list their top risks for CCS

1. Cost/funding
2. Policy/regulation
3. Liabilities/responsibility
4. Carbon market uncertainty
5. Lack of commitment from emitters

Issues around cost and funding were the stand-out risks identified in the broader survey, followed by the worry of policy and regulation. Liability and responsibility followed in third place, with a few people raising issues around the lack of certainty of long term contract commitments from emitters, carbon market

uncertainty and local community buy-in as risks which might still derail the rollout of CCS.

Nath of Munich Re Energy Transition Finance says that **regulation and funding often go hand-in-hand, and financing (of CCS) will not be resolved without supporting policy** "As a capital provider you want to be sure there is a demand for any product or service you invest in, and right now the demand for the capture and storage of carbon is still developing. Essentially for CCS there needs to be certainty on the future value and the ability to monetise that value of CO₂ in order to invest in CCS. Although it is possible to register CCS projects for Carbon Credits through international registries, the value and stability of the price of Credits is too volatile to finance a project.

The 45Q tax credit in the US addresses this by providing certainty on the future value of capturing and storing CO₂

which is helping to support the development of CCS. However in the US there remains uncertainty on the permitting for the permanent sequestration of CO₂ through the Class VI permit process. The Class VI permitting process remains cumbersome, with only two Class VI permits being issued in the last eleven years. If you don't have an efficient permitting regime this won't stack up as it creates further uncertainty."

Van der Stricht, of ArcelorMittal flags more issues which he fears many have overlooked. "One of **the biggest challenges I see is getting the right infrastructure in place**. You can't expect private enterprise solely to invest in shared (CO₂ transportation) infrastructure but it will be critical to success (of CSS)" he explains. "Social acceptance (of CO₂ storage) is also a key issue, that's the main reason why stores are located in the North Sea."

“ Financing of CCS won't be resolved without supporting policy

“ The biggest challenge is getting the right infrastructure in place

“ Social acceptance is also a key issue

Partnerships for Success

Who are the top five partners, that you consider critical to the successful development and delivery of your CCS project(s)?

Most commonly occurring answers when respondents were asked to list their top partners for CCS:

1. Government/regulators
2. Emitters
3. Funders
4. Service/solution providers
5. Oil & gas players

“We couldn’t have gone ahead with the Porthos project without the government” states Winde of Porthos, “you need a party who can provide (financial) guarantees so commercial partners join up and commit to a project like this. In the Netherlands we have a €2bn subsidy scheme which will be counterbalanced by the rising price of emissions through the emission trading system.”

Indeed, governments were by far the most frequently mentioned as a partner that is critical to the development and delivery of CCS. More than twice as many respondents flagged governments as important partners than Funders who were considered the next most important by respondents. However, while governments are critical for getting CCS off the ground, there is no one partner that will guarantee success.

James of Storegga commented that “Governments in both Europe and the USA are driving CCS forward but that’s looking very different in each

of the regions. The tax credit system in the USA is creating one of the largest development pipelines of CCS projects globally but with only a few projects in execution. Whereas a number of European countries are supporting the development of CCS through capital subsidy of the core infrastructure to establish CO₂ collection hubs. **Once a binding net zero declaration and timeline are in place you’re on a one way street and the question is only how fast you move along it.** The UK government has made phenomenal progress in CCS through the development of innovative business models such as **Contract for Difference. This provides assurance for investors in sequestration projects.** Whilst commercial investors have been happy to support the effort needed to build conceptual plans for CCS on a speculative basis, the **much more significant financing is needed for project deployment requires stable business model maturity** in order for them to progress.”

Comparisons were made between the role of regulators in driving decarbonisation and the way the regulators responded to COVID-19 and the rollout of vaccinations. “Undoubtedly the way you get these markets moving is by creating the right economic circumstances” highlights Gwilliam of Drax Group. “The birth of CCS in the USA is being driven by the 45Q tax credit for carbon sequestration and in the UK the government is looking to replicate the model they used for offshore wind, where they underpinned the investment risk for development. Another reason why the UK is leading on CCS is because the government took **the decision to split the supply chain up, creating specialisms across capture, transport and storage which are more investible propositions.**”

“ In the UK Contract for Difference provides the assurance required by investors for CCS power projects

“ The decision (in the UK) to split the supply chain creates specialisms across capture, transport and storage which are more investible propositions

High Risk Points in the Supply Chain

Across the complete CO₂ value chain, what are the main risks to the viability of a CCS project?

Percentage of respondents who regarded each factor as 'very high' or 'high risk'

1. Availability or viability of CO₂ pipeline from source to sink 49%
2. Availability of secure CO₂ storage reservoir 43% (ranked ahead due to more 'very high risk' votes)
3. Viability of capture technology 43%
4. Requirement for transboundary shipping 42%
5. Suitability and volume of CO₂ emission source(s) for capture 41%

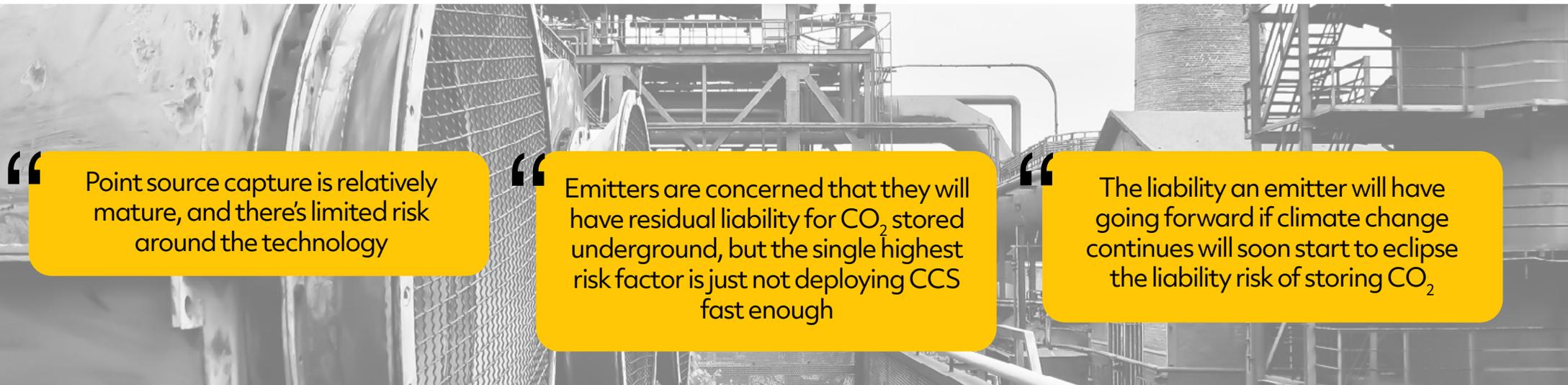
The identification of risk points which threaten the viability of CCS were pretty evenly split across the survey results, with the availability or viability of CO₂ pipelines from source to sink just ahead of

other concerns, closely followed by the availability of a secure CO₂ storage reservoir the shipping and capture technologies.

One thing highlighted by Nath of Munich Re Energy Transition Finance is that the capture technology is not the issue, but rather the inexperience of emitters in adopting and financing the technology. **"Technologically, point source capture is relatively mature, and there's limited risk around the technology per se, but if you're a refinery or a power plant then capturing CO₂ is not your core competency.** There's a lot of value in outsourcing to someone who makes carbon capture or storage their core business. As such, outsourcing this work to carbon capture-focused companies will be more efficient and should unlock both expertise and financing."

Others take a different view and believe that hard-to-abate sectors are overlooking the biggest risk of all. **"Emitters are concerned that they will have residual liability for CO₂ stored underground, but the single highest risk factor is just not deploying CCS fast enough,"** says James of Storegga. **"The**

liability an emitter will have going forward if climate change continues will soon start to eclipse the liability risk of storing CO₂. Part of the challenge is that too many people are chasing a silver bullet, whereas they need to focus on rapid deployment (of the available abatement technologies) as quickly as possible."



“ Point source capture is relatively mature, and there's limited risk around the technology

“ Emitters are concerned that they will have residual liability for CO₂ stored underground, but the single highest risk factor is just not deploying CCS fast enough

“ The liability an emitter will have going forward if climate change continues will soon start to eclipse the liability risk of storing CO₂

Section Three: Investment Appetite and Commercial Agreements

What sources of funding will be critical to the financing of your CCS project(s)?

In order of ranking:

1. Tax credits or other fiscal incentives
2. Government grants and subsidies
3. (100% equity) capital investment
4. Limited recourse project financing
5. Balance sheet financing
6. Voluntary market carbon credits

Getting Critical Funding in Place

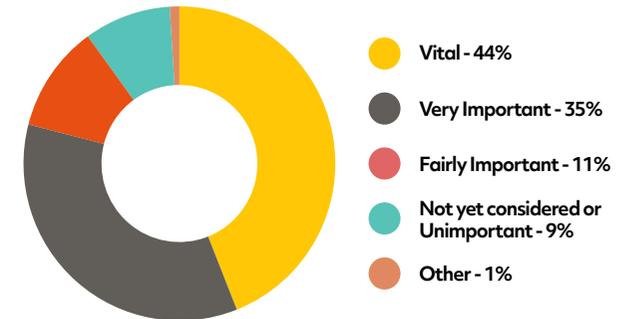
Given the importance attributed to governments by the Decarb Connect community in this survey, it should come as no surprise that **almost half of respondents consider government funding to be critical to the success of CCS. This funding may take the form of tax credits, other fiscal incentives, grants or subsidies.** Our contributors acknowledge that in the longer term CCS will need to be self-financing. However in the short-term support from government will be required due to the capital investment required in CO₂ infrastructure and the volatility of carbon prices.

Gwilliam of Drax Group explains that **“the future of CCS will be determined by the price of CO₂”** as we’re still getting the necessary mechanisms in place to account for that, so there are very few projects which are commercially viable at present without governmental support mechanisms. We can see there’s the making of a market that will drive the future CCS industry, but we don’t yet know when it will take off.”

Joshi of Talos Energy agrees that government stimuli are needed as a seed to the CCS market. “In the US, capital is available for CCS projects ...

but with its nascency, robust return on capital is expected.”

How critical is the accounting and verification of carbon removal and permanent storage to the viability or bankability of your CCS project?



“Government support mechanisms are critical in the short term

“The future of CCS will be determined by the price of CO₂”

The Role of Carbon Accounting

44% of survey respondents consider the accounting and verification of carbon removal 'vital' for the viability of their CCS project, with just 10% saying that they haven't considered it or think it is unimportant.

James of Storegga explains that **"carbon accounting and verification is a fundamental requirement.** We have many sectors with effective accounting and verification systems, such as gas, water, electricity and even landfill which is more akin to CO₂. Permanency will become very important, I'd encourage anyone interested to take a look at the Oxford Offsetting Principles from Smith School for more insights."

Although verification will be important, Gwilliam of Drax Group points out that international alignment is needed to really help it take off. "We need international consensus on the framework for carbon accounting and consensus on where the benefits of storage are accrued. What's taking off is the voluntary carbon market, where we've seen major tech giants such as Microsoft committing to remove historic CO₂ from the atmosphere. These **businesses are potential buyers of carbon credits via CCS and want a recognised form of verification** that carbon has been removed and stored on a permanent basis."

What would an optimal CO₂ value chain look like?

"It's hard to find an emitter which has the capability to see the whole thing through to permanent storage" says James of Storegga. "In fact the UK government's model specifically

precludes that. Transport and storage has to operate at arm's length to ensure that all emitters get open access to key shared Transport & Storage (T&S) infrastructure. Who will the operators of T&S be? Well the oil and gas companies certainly have all the technical capability to do this, but I often remind people that shareholders don't invest in oil and gas because of their excellence in CO₂ waste is a different sector with different economics and risk/ reward profile. Ultimately this will see the rise of independent carbon storage operators fully focused on CO₂ reduction and removal who have no interests in fossil fuel extraction – very much like Storegga."

"Ultimately, we can expect to see the model go through more iterations before it settles down, and there will still be variance caused by different factors. Emitters don't want the long-term liability for (storing) their captured carbon, they just want it taken away." - says Joshi of Talos Energy.

Which commercial model did respondents consider vital to the success of their CCS project? (Respondents could choose more than one answer)

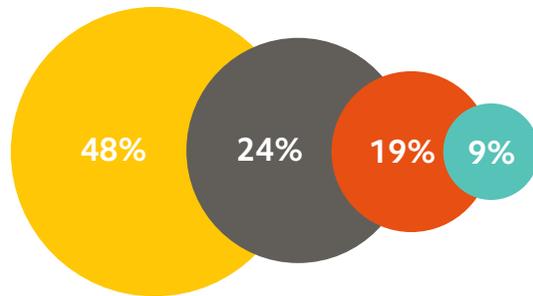
In order of ranking:

1. Capture, transport and storage 44%
2. CO₂ disposal agreement with committed volumes 40%
3. Direct ownership 27%
4. Transport and storage 'pay for use' agreement 19%

"Emitters don't want the long-term liability for (storing) their captured carbon"



Which party should take financial liability for the long-term storage of CO₂?



- CO₂ T&S company (solely or with emitter)
- Government/emissions authority
- CO₂ emitter
- Other - 9%

Other Liability and Timelines

When asked about long-term liability for storage, almost half of respondents felt the responsibility should sit with transport and storage companies, either exclusively or in conjunction with the CO₂ emitters. We saw some differences in the way North American and European respondents viewed the role of government, with a third of Europeans believing governments and emissions authorities should take on long term liability, compared to only a fifth of those with operations in North America.

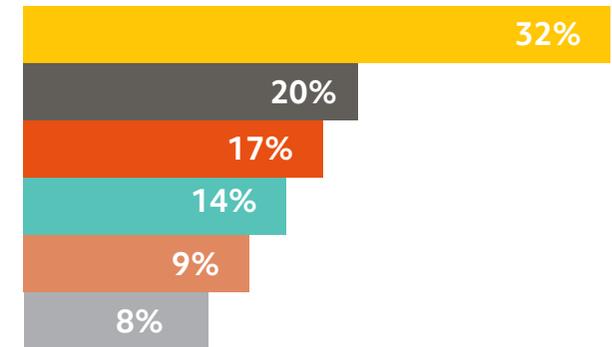
The key challenge is the guaranteed permanence of stored CO₂ required and the associated liability for this guarantee. The length of liability storage would likely exceed the life of most commercial businesses and a corporate guarantee could only be accepted from companies with a sufficient balance sheet to cover those potential liabilities.

“At the end of the day whoever puts it in the ground has to take responsibility, but the question is for how long?” says Joshi of Talos Energy. “The operator sequestering must be responsible for doing everything correctly, but it’s hard for any entity to hold liability indefinitely. Evolving insurance market could provide coverage for multiple years and governments are essential step in after that”.

Nath of Munich Re Energy Transition Finance sees commercial insurance companies as a long-term solution...but not yet. “Working in insurance of course I think insurance companies would be best positioned to take that risk...but at the moment there’s no insurance product to take that risk off an individual company. If you’re a supermajor (O&G producer) you’ll be fine but for smaller players who don’t know they’ll be there in 20-30 years down the line, having an insurance company rubberstamp the quality of your service will be very useful.”

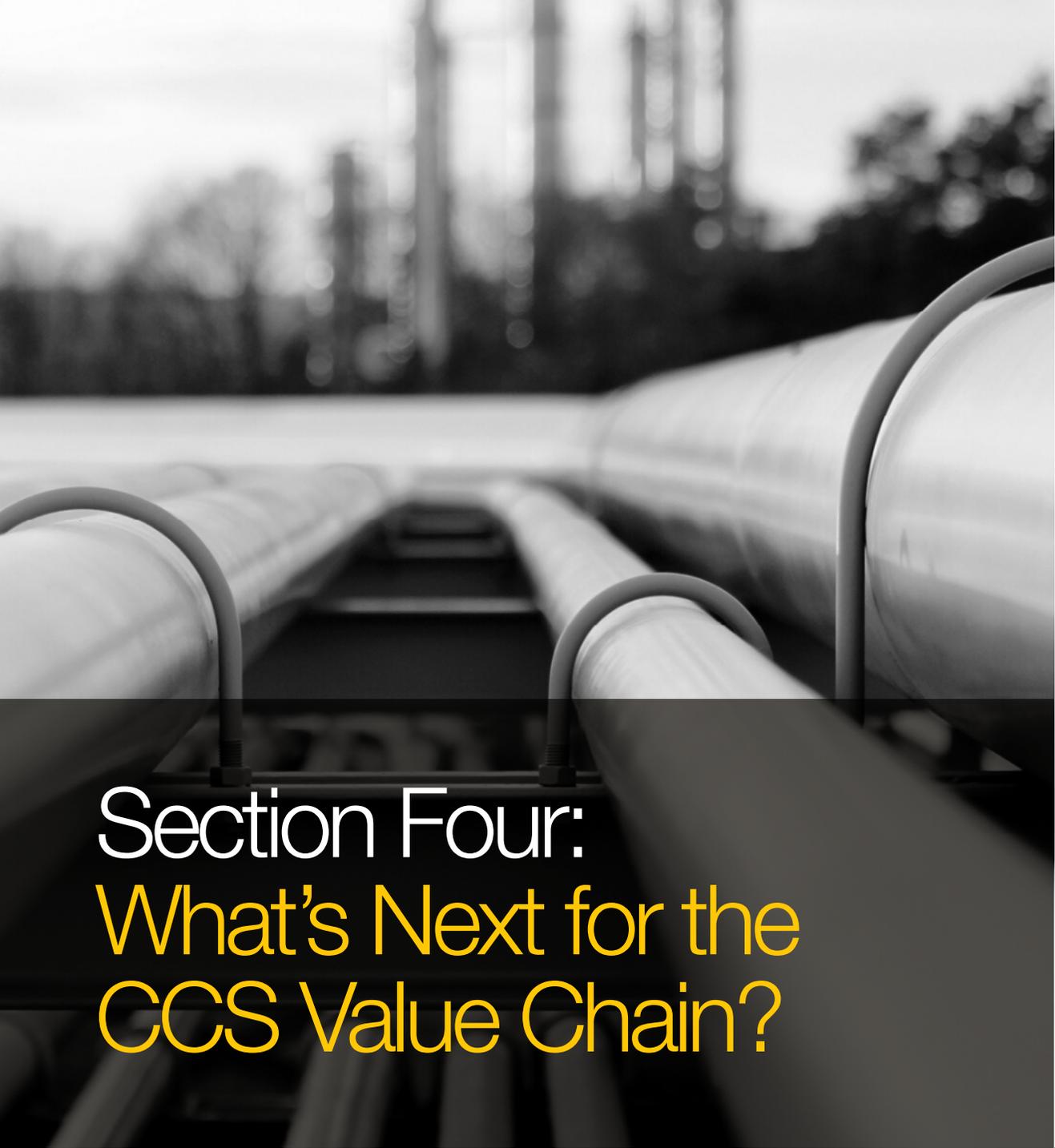
Half of respondents felt the responsibility for storage and CO₂ should sit with transport and storage companies

How do you anticipate your CCS project will cover the financial risks associated with the potential long-term liability of the permanent storage and containment of CO₂ and any potential remedial work due to leakages?



- Commercial insurance
- Other
- National Leakage Fund
- Sovereign guarantee
- Project escrow
- Bonds

Almost a third of respondents felt commercial insurance markets could adequately cover financial risks associated with CO₂ storage



Section Four: What's Next for the CCS Value Chain?

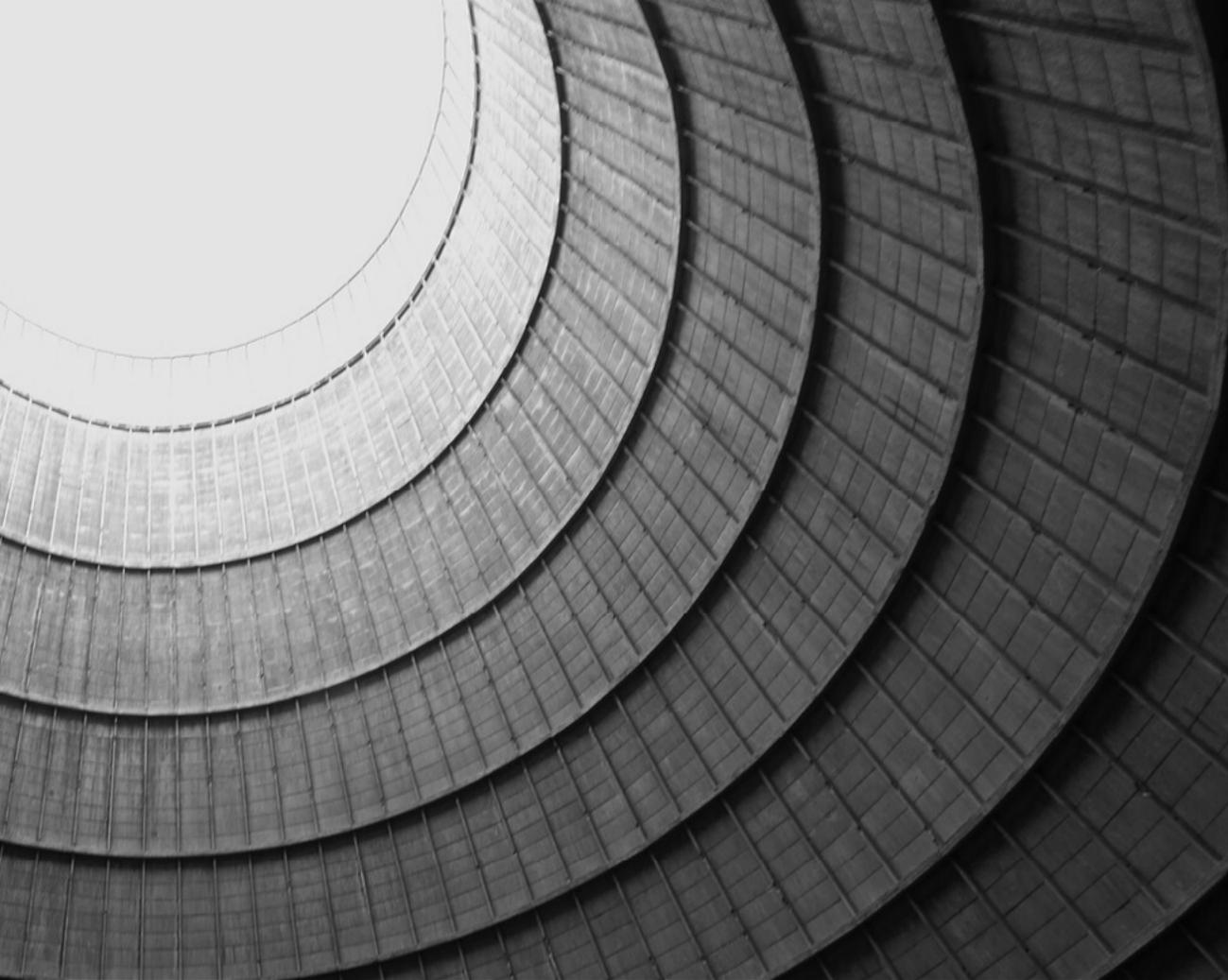
One of the underlying themes of the feedback received is that, people do not appreciate the importance of carbon capture as a climate change mitigation technology. “Everyone should start taking notice of this industry and have confidence that it’s for real and not another greenwashing platform” asserts Nath of Munich Re Energy Transition Finance.

Even in the 18 months since Decarb Connect published its first report on carbon capture technology, there has been a rapid ramp up in the speed of development of carbon capture and storage projects. Governments continue to stimulate the market (whether through direct funding, tax breaks or carbon tax) and the focus of public opinion falls more acutely on emitters of CO₂. There is a sense that CCS is a solution that can be developed right now as a key solution for hard-to-abate industries.

Despite the immediate challenges of funding, establishing viable commercial models and allocation of liability, there’s a definite sense that with support from governments, emitters, technology providers and other stakeholders from across the value chain are getting organised. This is leading to the creation of clusters that will launch and scale CCS for adoption around the world. We can expect to see the growth in the adoption of CCS accelerate as the models being trialled in more developed markets such as Europe and North America are replicated around the rest of the world.

Follow Decarb Connect on **LinkedIn** to stay updated on how the CCS value chain is progressing in the coming months or years.

To discuss the report or to find out more about your options in CCS, contact Gaffney Cline.



Find out more

Gaffney Cline

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Decarb Connect focus on supporting the hard-to-abate sectors including cement, steel, O&G, power & utilities, ceramics and more, on their decarbonisation journey.

Through the Decarbonisation Leaders Network, events, reports, webinars and podcast, Decarb Connect support those in heads of corporate strategy, innovation/R&D, carbon management, C-Suite and finance leadership positions. Whether this is selecting technologies, establishing high performing collaborations, initiating pilots or working out how to scale innovative projects – each element of the Decarb Connect offering helps to solve the systemic and technical barriers to decarbonisation.

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