REPORT

Making Carbon Capture & Storage Work

A strategic guide to economic viability and enabling conditions

Roland Berger

Management summary

Carbon capture and storage (CCS) is a vital technology for decarbonizing energy-intensive industries and mitigating climate change. After decades of evolution, over 200 million tons of CO_2 safely stored globally, and costs declining toward breakeven, the challenge is no longer technical – it's aligning the institutional, regulatory, and social conditions that allow economically viable CCS projects to get built.

Interviews with leaders from across the CCS value chain revealed three unanimous concerns: financial viability challenges, unclear liability frameworks, and low social acceptance. The economics are context-dependent. Capture costs vary dramatically by sector: In chemicals, ammonia production enjoys natural advantages due to high CO_2 concentrations, while cement and steel face higher costs. Energy sourcing also proves decisive – heat pumps enable viability in 35 of 42 countries by 2040 versus just six using electric heaters. Customer willingness to pay is also emerging as a key factor, creating a strategic window before markets commoditize.

Beyond economics, social acceptance of CCS lags behind that of other climate technologies and varies by geography. Regulatory stability matters at least as much as subsidy generosity and liability clarity is urgent, as current frameworks remain immature across five risk categories.

A decisive window exists from 2025 to 2035 where early movers will capture advantages through green premiums and infrastructure access. To succeed, industry players should establish competitive positioning, manage uncertainty proactively, and secure customer-backed offtake. Conversely, regulators can support by prioritizing stable frameworks over generous but unpredictable subsidies, clarifying liability allocation, and enabling cross-border abatement.

Success requires multidimensional excellence. The countries and companies excelling at orchestration – building trust, creating alignment, maintaining commitment – will lead the CCS era.

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Fast facts

70 %

of CCS operating costs come from energy consumption

35

countries (of 42 analyzed) achieve CCS viability by 2040 using heat pump technology

85 %

reduction in pipeline transportation costs from scale economies (transporting 10 m vs. 5 m tons annually)

1

Understanding the economics of CCS viability

For industrial leaders weighing investments in carbon capture and storage (CCS), the question is not whether the technology works, but rather when it becomes economically compelling for their specific circumstances. The answer depends on a complex interplay of factors that vary dramatically by sector, geography, and timeline.

This chapter examines the full economic picture of CCS viability, moving beyond simple cost estimates to explore how capture technology, transportation logistics, storage options, energy sourcing, market dynamics, and regulatory incentives combine to determine commercial feasibility. Our analysis reveals that CCS is already viable for certain applications in advanced economies, while other sectors and regions face timelines extending to 2030 or beyond.

1.1/ The three-part value chain

Understanding CCS costs requires examining three distinct activities: capturing CO_2 from industrial processes, transporting it to storage sites, and injecting it underground for permanent sequestration. Today, transportation and storage can account for up to 50% of the total costs due to limited scale. However, as technology evolves and projects scale, we expect capture costs to dominate, accounting for around 60 to 75% of total expenses. The percentage of costs associated with transportation and storage would likely decline relative to capture, depending on scale, distance, and geology, as these vary considerably across projects. ▶ A

A Capture will account for the largest share of total costs in CCS in the future

Expected CCS cost drivers along the value chain by 2040

1 CO_2 capture	2 CO_2 transportation	3 CO_2 storage
Costs associated with capturing, purifying, and compressing CO_2 from industrial processes or power plants	Costs associated with transporting captured CO_2 to storage sites	Costs associated with injecting CO_2 into geological storage sites

Source: Roland Berger

Current carbon capture costs, including all steps before transportation, e.g., capture, purification, and compression, range from 60 to 80 USD per ton of CO_2 across most sectors, but these figures mask important variations depending on CO_2 concentration, partial pressure, and impurity. Chemicals and refining industries enjoy substantially lower baseline costs – often starting at 40 to 50 USD/t because their processes naturally generate higher concentrations of CO_2. In the ethanol fermentation process, for instance, CO_2 concentration can reach 99 %, compared to just 3 to 5 % in natural gas-based power generation. This difference translates directly into energy requirements: Concentrating and separating CO_2 from dilute gas streams requires significantly more energy than capturing it from concentrated sources. ▶ B

B Higher pressure levels make the CO_2 capture process more cost-effective and technically feasible

CO_2 concentration [%] and partial pressure by sector [kPa]

Industry	CO_2 concentration [%]	CO_2 partial pressure [kPa]	Scale maximum [kPa]
Power generation (gas)	3-5 %	3 – 5	10
Power generation (biomass)	10-15 %	10 – 15	100
Iron & steel	15-30 %	20 – 50	100
Cement	15-30 %	10 – 35	100
Refining	10-30 %	5 – 500	1,000
Chemicals (ammonia)	15-20 %	500 – 1,000	
Chemicals (ethanol)	99 %+	85 – 1,000	
Ease of capturing/purification	Low → High	Low → High	
Carbon capture cost	High → Low	High → Low	

Source: IPCC, GCA, IEA WEO 2021, World Steel, Biofuels Digest, US DOE, Cell Press, IAI, Global CSS Institute, Roland Berger

The relationship between CO_2 concentration, partial pressure, and capture costs creates a natural hierarchy of sectoral readiness. Industries producing concentrated and pure CO_2 streams can potentially implement CCS more cost-effectively, giving them earlier access to viable decarbonization pathways. This technical reality shapes competitive dynamics and explains why chemicals and refining sectors show stronger near-term economics than power generation or steel.

TECHNOLOGY EVOLUTION RESHAPES THE COST CURVE

Today's carbon capture market relies heavily on first-generation amine technology, which accounts for the vast majority of current installations across most sectors. While proven and reliable, amine systems face competition from emerging alternatives, including solid sorbents, cryogenic separation, physical absorption, and advanced combustion cycles that promise improved efficiency or lower costs for specific applications.

These secondary technologies currently cost between 30 and 150 USD/t depending on the approach, compared to amine's 30 to 50 USD/t range. By 2040, our analysis projects that amine technology will retain the leading position, but that, secondary technologies will capture 10 to 40% market share depending on the sector, driven by their advantages in specific contexts. The oxy-cycle, for instance, has the potential to generate high thermal efficiency (approximately 60%) in power generation, while solid sorbents excel in applications with low CO_2 pressure with more than 85% adsorption efficiency. ▶ C

> **"CCS is technically mature and commercially proven. The challenge now is extending viability to base commodities like steel, cement, ammonia. Product carbon standards as qualifying criteria for market participation will be key to scaling this industry."**
>
> **Niall Mac Dowell, Professor of Future Energy Systems, Imperial College London**

C Amine is the dominant carbon capture technology today, with secondary technologies showing potential to penetrate by 2030

CC technology share assumptions by industry

Industry	Primary technology	Other competing technologies[1]	2022 Primary	2022 Other	2030 Primary	2030 Other	2040 Primary	2040 Other
Power generation - **Gas**	Amine	**Secondary technologies** (e.g., oxy-cycle)	95%	5%	90%	10%	60%	40%
Power generation - **Biomass**	Amine	**Secondary technologies** (e.g., solid sorbent)	95%	5%	90%	10%	60%	40%
Iron & steel	Amine	**Secondary technologies** (e.g., physical absorption)[2]	100%	0%	90%	10%	90%	10%
Cement	Amine	**Secondary technologies** (e.g., cryogenic)	95%	5%	80%	20%	60%	40%
O&G refining	Amine	**Secondary technologies** (e.g., oxy-fuel combustion)	95%	5%	80%	20%	60%	40%
Chemicals	Amine	**Secondary technologies** (e.g., oxy-fuel combustion)	95%	5%	80%	20%	60%	40%

1 Competing technologies excludes renewables; 2 DRI as a mature, low-carbon alternative process (but not considered here as it's not a carbon capture technology)

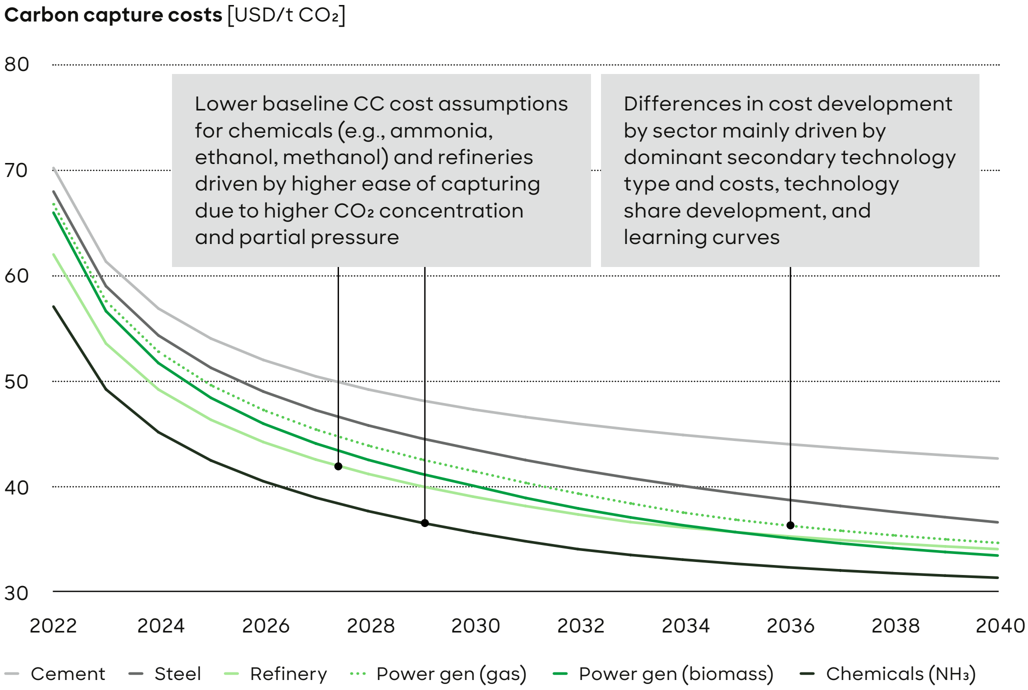
Source: IEA, Global CCS Institute, Hong, W.Y. (2022), Palma, C.F. (2021), Svante, NET Power, Chart, Roland Berger

Cost reductions over the next two decades will come from two sources: learning-by-doing as deployment scales, and technology improvement. These dynamics should drive carbon capture costs down to 30 to 40 USD/t across most sectors by 2040, though a cost floor around 30 USD/t reflects irreducible operational requirements. ▶ D

This cost evolution timeline has profound implications for financial viability. Projects that

D Carbon capture costs are expected to decline to 30-40 USD/t CO_2 by 2040

Carbon capture costs estimated by sector, 2022-2040 [USD/t CO_2]



Calculations and forecasts for each sector consider primary technology and the secondary technology expected to be most prominent; weighted average of reported technology costs in 2022; ease of capture by sector; technology learning curve assumptions (learning rate of 0.85 for primary amine and 0.9 for secondary technologies); lower cost boundaries driven by cost structure (lower cost boundaries reflect a minimum 30 USD/t CO_2 cost); and regional nuances

Source: Roland Berger

appear economically marginal today may become compelling within five to seven years purely through technology cost reductions, even without changes in carbon pricing or policy support.

TRANSPORTATION: THE SCALE AND DISTANCE EQUATION

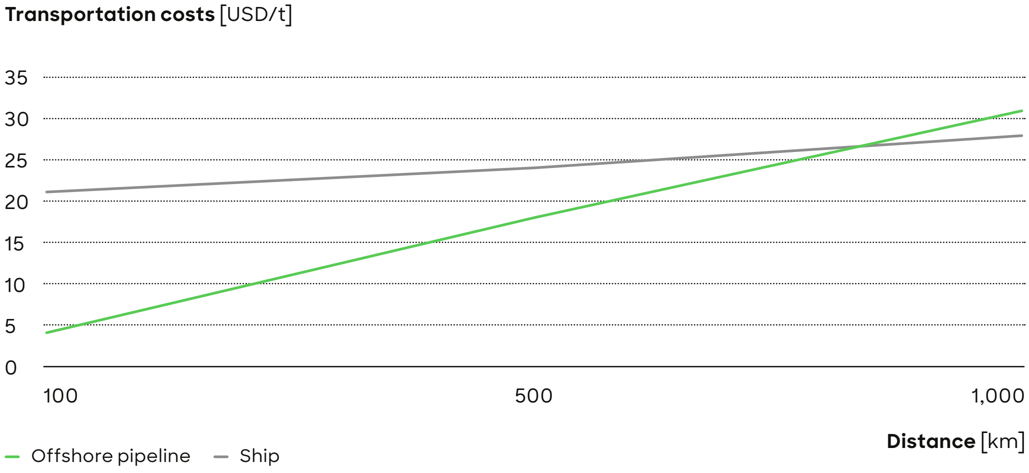
After capture, CO_2 must travel – sometimes hundreds of kilometers – to reach suitable storage sites. This transportation requirement introduces a second major cost component with its own distinctive economics.

Pipelines dominate CO_2 transportation today, especially in the US, and are projected to carry 81 to 90% of volumes through 2040. Their economics depend critically on terrain, scale, and distance. In general, offshore pipeline is 50 to 120% more expensive than onshore network. With capital expenditures of one to four million euros per kilometer, pipeline costs drop precipitously as volume increases: from 75 USD/t at 0.5 million tons annually to 11 USD/t at 10 million tons annually for offshore networks, assuming a distance of 1,000 km. ▶ E

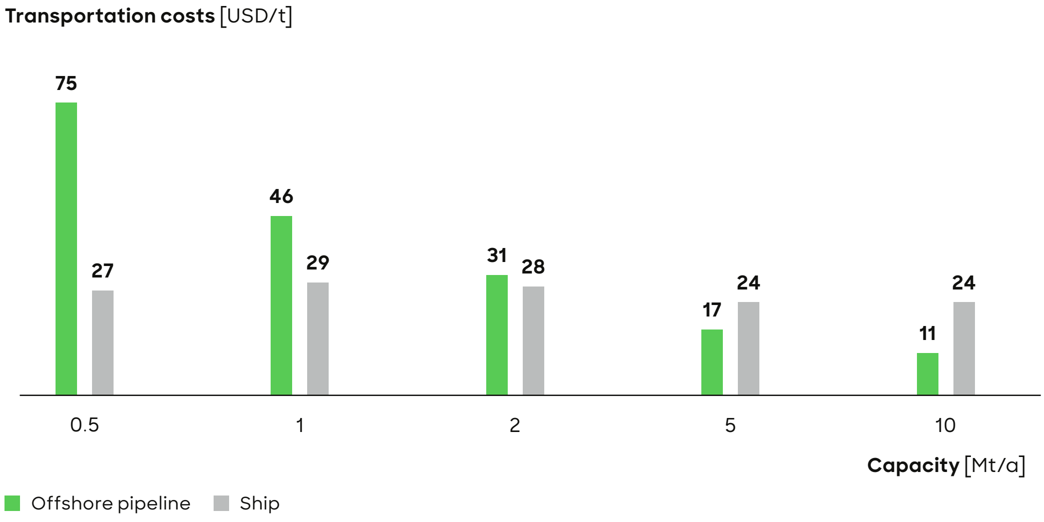
E Shipping CO_2 can be an alternative to offshore pipeline transportation, but only for long-distance transportation of small volumes

Shipping and offshore pipeline transportation costs [USD/t CO_2]

Assuming a capacity of 2 Mt/a



Assuming a distance of 1,000 km



Source: IEA

This scale dependency creates a fundamental challenge for smaller emitters. A facility producing 100,000 tons of CO_2 annually cannot economically justify dedicated pipeline infrastructure, as the per-ton costs would be prohibitive. This reality drives the industrial logic behind CCS hubs, where multiple emitters share transportation infrastructure to achieve the volumes necessary for viable pipeline economics.

For some applications, particularly long-distance transportation of smaller volumes to offshore storage, shipping offers a competitive alternative. Ship transportation costs remain relatively flat at 24 to 28 USD/t (assuming a distance of 1,000 km considering different transportation pressures, ship sizes, and volumes), making it attractive for distances exceeding 1,000 kilometers at capacities below two million tons annually. The flexibility to route CO_2 to different storage facilities as opportunities arise provides additional value, particularly in regions developing multiple offshore storage sites.

The most economically attractive scenario, however, involves repurposing existing oil and gas pipelines for CO_2 transportation. Where feasible, this approach can reduce costs by more than 90% compared to new pipeline construction, providing a significant advantage to emitters located near legacy fossil fuel infrastructure.

STORAGE: BALANCING CAPACITY, COST, AND ACCEPTABILITY

The final link in the core CCS value chain – permanent underground storage – presents abundant global capacity but significant variation in costs, technical requirements, and public acceptability.

Depleted oil and gas fields currently dominate operational storage projects. These sites offer several advantages: Existing geological data reduces exploration costs, wells and facilities can potentially be repurposed, and the presence of a caprock that successfully trapped hydrocarbons for millions of years provides confidence in long-term containment. Levelized costs vary between 5 USD/t and 20 USD/t depending on onshore or offshore location, though concerns about well integrity and potential leakage from aging infrastructure require careful management.

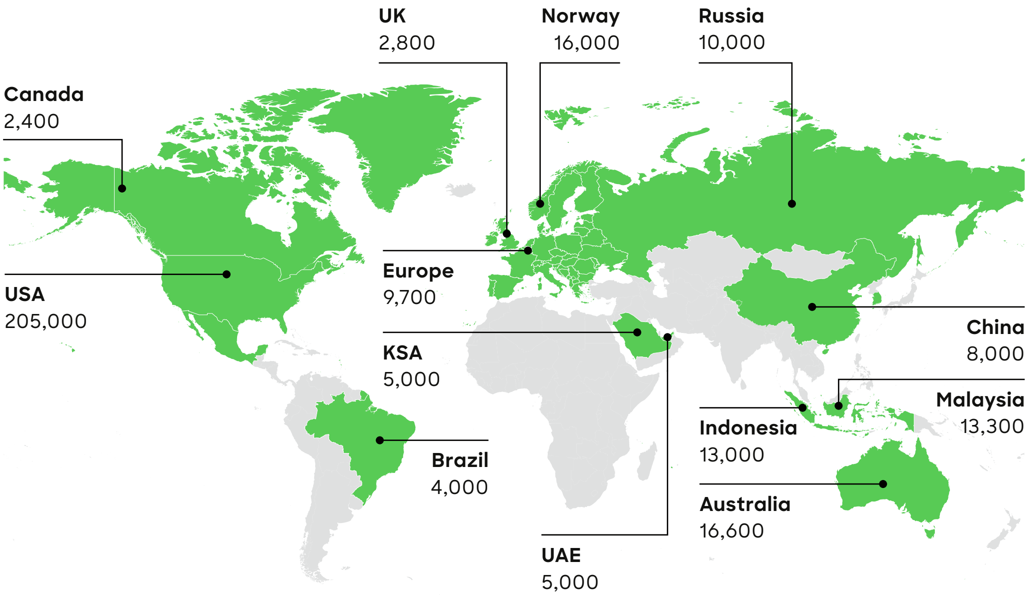
Saline aquifers – deep underground formations containing brackish water – offer the largest theoretical storage capacity globally, with costs ranging from 20 to 50 USD/t, depending on the region and the geological conditions. However, developing new aquifer sites requires complete reservoir characterization in the absence of prior production data. The need for ongoing monitoring to detect potential groundwater contamination adds to long-term costs.

Basalt formations represent an intriguing alternative with unique long-term advantages, despite lower efficiency and higher water consumption. When CO_2 comes into contact with basalt rock in the presence of water, it mineralizes over time into solid carbonate minerals, effectively converting the gas into stone. This eliminates long-term leakage concerns and reduces monitoring requirements. However, basalt storage is a relatively new storage solution, with higher upfront capital investment required.

Global storage capacity is not a limiting factor for CCS deployment in the medium term, with 2,000 Gt of storage available. Depleted oil and gas fields alone offer approximately 300 billion tons of capacity, with the United States accounting for 205 billion tons. Saline aquifers provide several times this amount. Major offshore storage developments in the North Sea – including Northern Lights (up to six million tons per annum), Smeaheia (around 20 million tons per annum), and a potential Dutch Sea project exceeding 100 million tons per annum – demonstrate the availability and accessibility of large-scale storage infrastructure. ▶F

F Storage resources for CCS are available at high capacities in all geographies

Global CO_2 storage resource estimates – Example: Depleted oil or gas fields[1] [millions of tons]



The focus is on the **storage of CO_2** in depleted **oil and gas fields at ~300 billion tons.**
In addition, there are **other storage options** with high future capacities, e.g. **salt caverns.**

1 Geological storage resources for CO_2 in saline formations not considered in this figure but estimated to be several times as much as in oil or gas fields

Source: Global CCS Institute

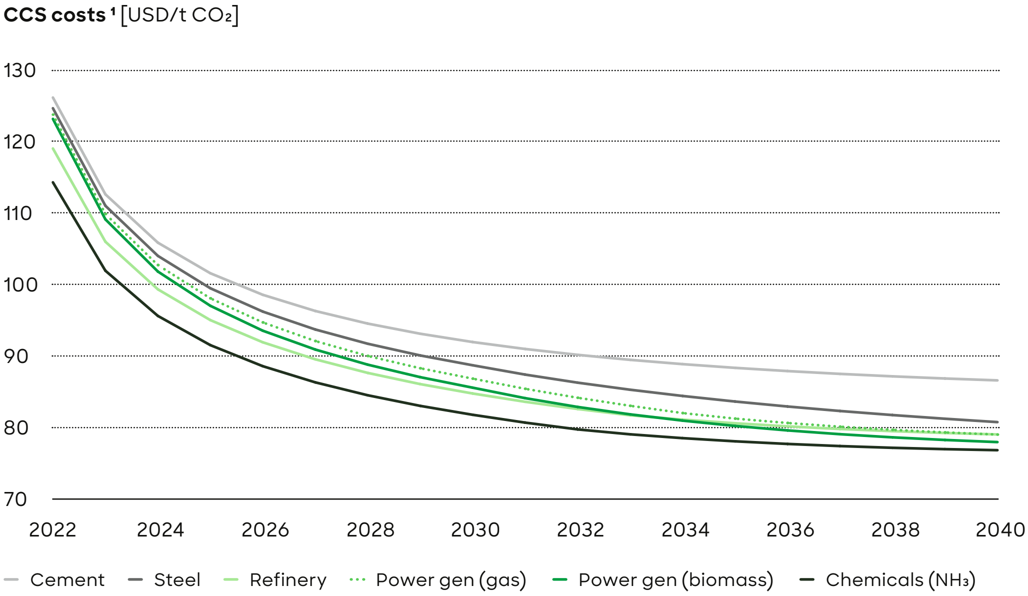
The constraint is not geological but social and regulatory. European publics show greater acceptance of offshore storage compared to onshore options, while the United States and Canada have successfully operated onshore storage for decades, even including enhanced oil recovery. These divergent attitudes shape regional CCS strategies and influence project economics through permitting timelines and regulatory requirements.

Aggregating costs across the full value chain reveals significant sectoral variation. Using mid-range 2024 cost assumptions, total CCS expenses range from 96 EUR/t for chemicals (ammonia) to 106 EUR/t for cement. Steel, power generation via gas and biomass, and refining cluster in the 99 to 104 EUR/t range. In comparison to mid-cost ranges, min-cost ranges can vary by up to 36 USD/t and max-cost ranges by up to 50 USD/t.

By 2040, costs converge substantially as learning effects compound and infrastructure matures. The range falls between 77 and 87 EUR/t. This convergence suggests that sectors enjoying early cost advantages may see these diminish over time, while currently expensive applications become more accessible. ▶ G & H

G CCS costs vary between different industry sectors, but all of them show declining trends, which become flatter after 2035

CCS costs estimated by sector – Mid-cost range

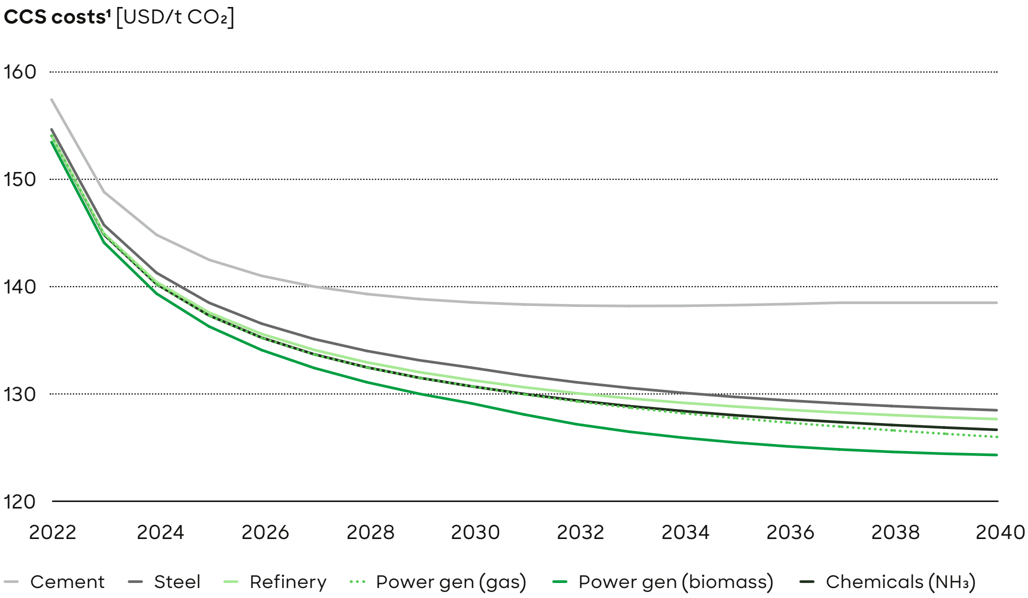


1 Estimated CCS costs include cost ranges for carbon capture, transportation, and storage

Source: Roland Berger

H High-cost ranges are approximately 40-50 USD/t higher than the mid-ranges but more aligned with bottom-up estimations

CCS top-down cost estimation by sector – High-cost range



1 Estimated CCS costs include cost ranges for carbon capture, transportation, and storage

Source: Roland Berger

1.2/ Energy: The hidden cost multiplier

While capital expenditure for capture equipment and infrastructure receives considerable attention, operational energy consumption often determines whether CCS projects succeed or fail economically. Energy typically represents approximately 70 % of total levelized costs, with the amine reboiler, which regenerates the chemical solvent that absorbs CO_2, consuming roughly two-thirds of energy-related operating expenses. This energy intensity creates sharp cost differentials across countries and fundamentally shapes the geography of CCS competitiveness. A project that achieves financial viability in Saudi Arabia or Norway may struggle in Germany or Poland, not due to differences in capture technology or CO_2 characteristics, but because of energy prices and grid carbon intensity.

To understand these dynamics, we analyzed three energy sourcing scenarios for power generation via natural gas with carbon capture across 42 countries, examining how energy sourcing technology choices affect viability timelines. In our analysis, realistic but conservative assumptions are applied.

SCENARIO 1: WASTE HEAT – BEST USE OF WASTE ENERGY, BUT LIMITED APPLICABILITY

The most economic approach uses waste heat from the power generation process itself to drive amine regeneration. This largely eliminates incremental energy costs for the reboiler, keeping total CCS costs at their lowest possible levels.

Under this scenario, three countries – Kazakhstan, Saudi Arabia, and Norway – achieve financial viability by 2030, when their CCS costs fall below projected carbon prices. By 2040, thirteen countries reach viability, adding the United States, Ukraine, Thailand, Malaysia, Azerbaijan, Canada, Brazil, Türkiye, Japan, and China. ▶ I

However, waste heat integration requires careful system design and may not be feasible for all installations, particularly retrofit applications at existing facilities. Its applicability is therefore limited, even though it offers the most attractive economics, where achievable.

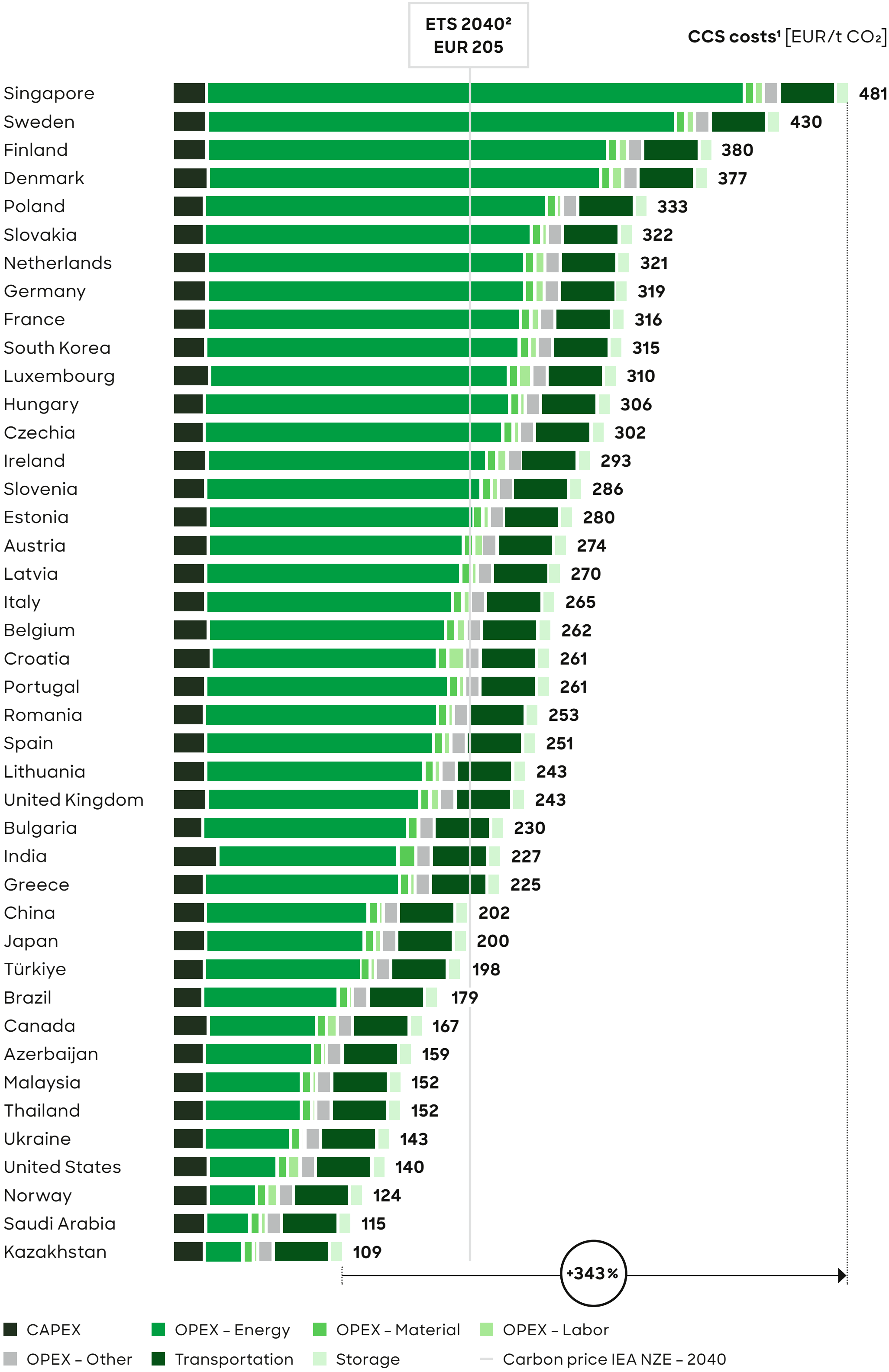
SCENARIO 2: ELECTRIC HEATER – SIMPLIFIED, BUT CONSTRAINED

Electric resistance heaters simplify system design and eliminate the need for system integration, reducing capital expenditure. However, their lower energy efficiency compared to heat pumps creates higher operating costs that prove economically challenging in most markets.

Under this scenario, no countries achieve CCS viability by 2030. Even by 2040, only six countries – Norway, Saudi Arabia, Canada, Finland, Sweden, and Ukraine – reach breakeven, all characterized by low electricity prices and relatively clean grid mixes that minimize the cost of grid decarbonization. ▶ J

Cost curve for global abatement – Gas power generation

Amine reboiler energy source: Waste heat, 2040

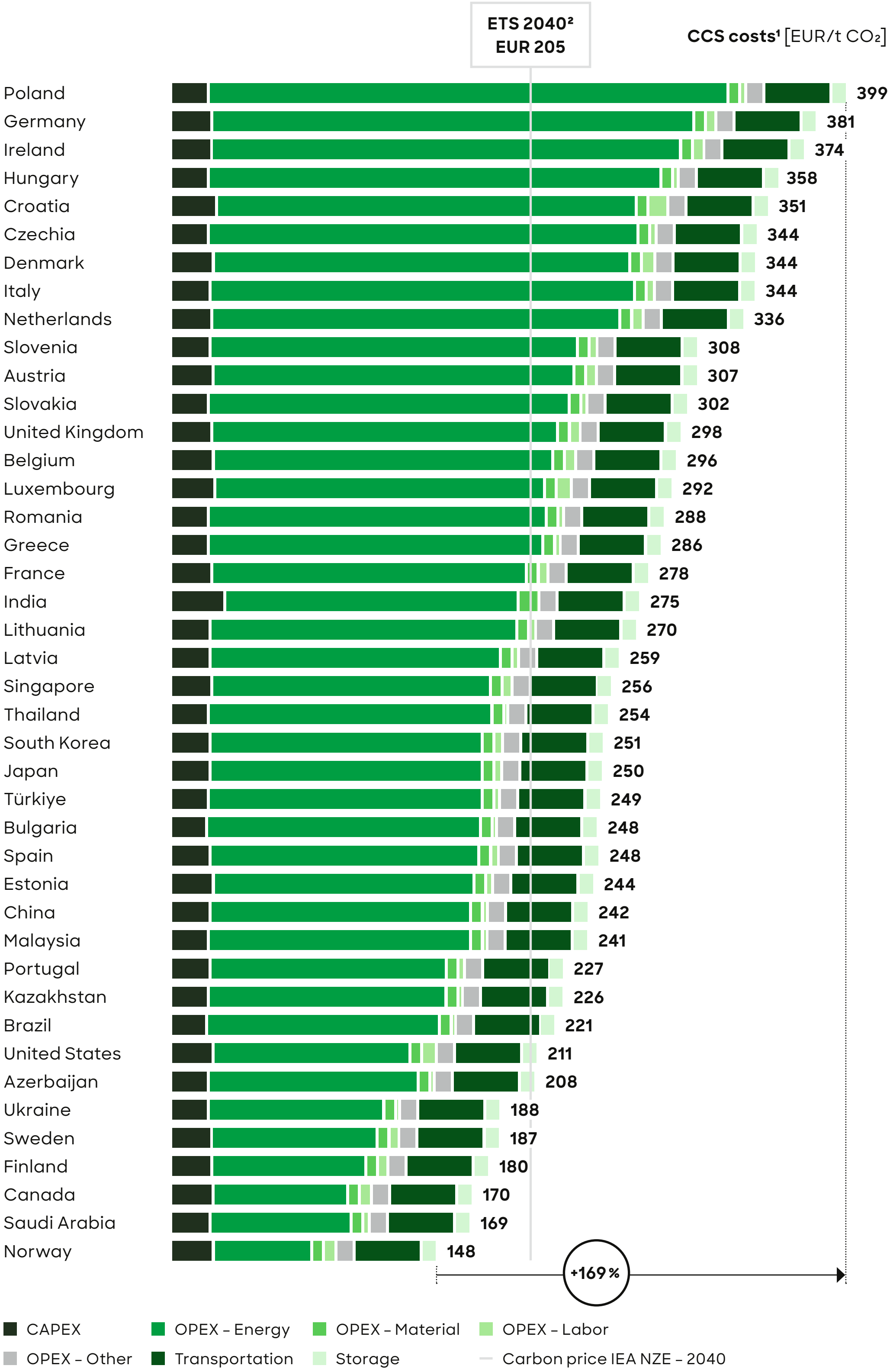


1 Assumptions: Electricity is decarbonized, grid mix and carbon intensity are stable since 2024, and decarbonization costs is break even at ETS price; 2 ETS price considered based on IEA NZE scenario – EUR 205

Source: Oxford Economics, Bloomberg, Global CCS Institute, Roland Berger

J Cost curve for global abatement – Gas power generation

Amine reboiler energy source: Electric heater, 2040



1 Assumptions: Electricity is decarbonized, grid mix and carbon intensity are stable since 2024, and decarbonization costs is break even at ETS price; 2 ETS price considered based on IEA NZE scenario – EUR 205

Source: Oxford Economics, Bloomberg, Global CCS Institute, Roland Berger

The lesson is clear: While electric heating simplifies system design, its inefficiency creates a fundamental economic barrier in most markets, particularly those with expensive electricity or high grid carbon intensity.

SCENARIO 3: HEAT PUMP – MOST PROMISING PATH FOR HIGH GAS PRICE COUNTRIES

Heat pumps offer a middle path: higher capital costs than electric heaters but dramatically better energy efficiency through a coefficient of performance around three. This means they deliver three units of thermal energy for each unit of electrical energy consumed, compared to a 1:1 ratio for resistance heating.

This efficiency advantage proves decisive. While no countries achieve viability today, Saudi Arabia crosses the threshold by 2030. By 2040, thirty-five of forty-two countries analyzed become viable, with only seven European nations with high electricity prices or grid decarbonization costs, including the Netherlands, Hungary, Denmark, Ireland, Croatia, Germany, and Poland, remaining above breakeven costs. ▶ K

The heat pump pathway creates the most universal viability of any energy approach, with costs mostly ranging between 140 and 200 USD/t. Costs from lowest- to highest-cost countries span approximately 62%. This compares favorably to the 340%+ difference observed in the waste heat scenario and 170% in the electric heater scenario, suggesting that heat pumps may offer the most scalable route to global CCS deployment, especially in countries with higher gas prices.

ENERGY'S STRATEGIC IMPLICATIONS

These scenarios reveal several critical insights for CCS strategy.

First, energy sourcing decisions have first-order importance. The choice between waste heat, electric heating, or heat pumps can determine whether a project achieves viability in the 2020s, 2030s, or not at all within our analysis period.

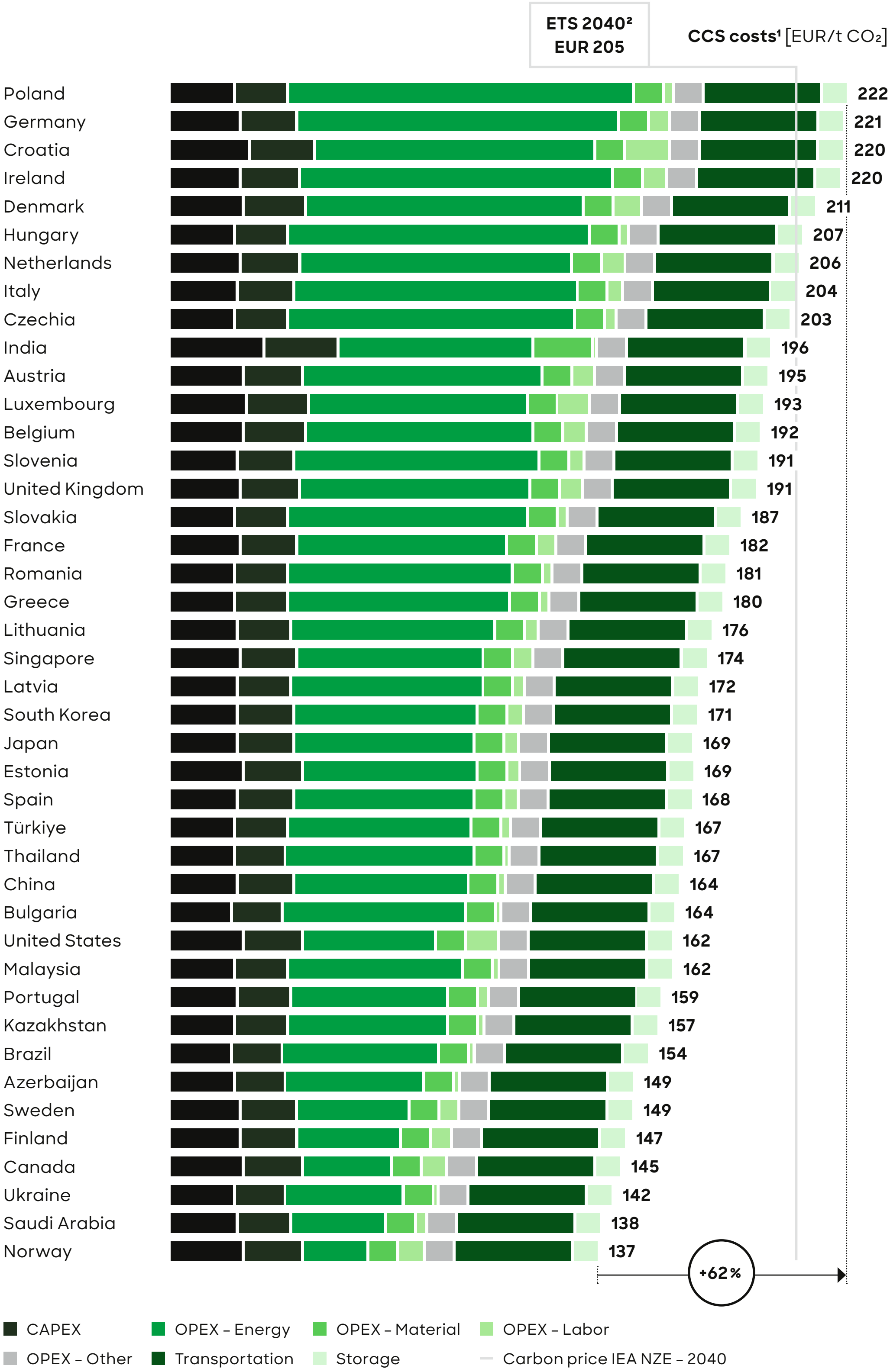
Second, countries with low energy costs gain structural competitive advantages in CCS. This creates opportunities for international carbon abatement mechanisms where emissions are captured in lower-cost jurisdictions on behalf of emitters in higher-cost regions.

Third, grid decarbonization becomes essential. Using electricity generated from fossil fuels for CCS simply shifts the emissions problem, requiring capture of additional CO_2 and increasing overall costs. Countries that decarbonize their electricity grids create more favorable conditions for electrically powered CCS systems.

Fourth, the analysis suggests that by 2040, combinations of declining capture costs, falling equipment costs, and improved energy efficiency through heat pump deployment could make CCS viable in most developed and middle-income countries. The technology is not perpetually uneconomic – the question is whether carbon prices and policy support provide sufficient incentive to bridge the gap until cost reductions materialize.

K Cost curve for global abatement – Gas power generation

Amine reboiler energy source: Heat pump, 2040



1 Assumptions: Electricity is decarbonized, grid mix and carbon intensity are stable since 2024, and decarbonization costs is break even at ETS price; 2 ETS price considered based on IEA NZE scenario – EUR 205

Source: Oxford Economics, Bloomberg, Global CCS Institute, Roland Berger

1.3/ Customer willingness to pay: The revenue side of the equation

While the previous sections examined the cost of producing decarbonized products through CCS, commercial viability also hinges on whether customers will pay enough to cover these costs. In some markets, green premiums already exist; in others, price parity with conventional products remains years away.

THE GREEN PREMIUM REALITY

Consumer and business willingness to pay for decarbonized products varies dramatically across end markets, driven by factors including regulatory pressure, proximity to end consumers, brand positioning, and competitive dynamics.

Consider green steel, where automotive original equipment manufacturers (OEMs) – particularly premium brands with strong Scope 3 emission reduction commitments – demonstrate willingness to pay up to 20% premiums by 2030. These companies face direct pressure from regulators and sustainability-conscious consumers, and they possess pricing power to absorb or pass through green premiums. Mercedes-Benz, BMW, and Volvo have announced commitments to green steel that signal market acceptance of higher costs.

In contrast, in construction and shipbuilding, which are more removed from end consumers, there is a more modest premium willingness. Construction firms face tighter margins and less direct consumer pressure, while shipbuilding operates in highly competitive international markets with limited ability to pass costs downstream. Consumer goods applications show the least willingness to pay, with most companies still in the early stages of considering steel decarbonization.

Cement markets demonstrate similar dynamics. An initial green premium of approximately 5 to 10% has been observed for low-carbon cement, with 20 to 30% for net-zero cement.

"CCS is essential for avoiding and removing CO_2 but needs regulatory and policy certainty. It doesn't require endless subsidies – just recognition that mitigation costs less than adaptation. Product carbon standards can guarantee market access without continuous government spending."

Niall Mac Dowell, Professor of Future Energy Systems, Imperial College London

Several factors make green premium strategies more successful, including government support. For example, Heidelberg Materials, which pre-sold all of the 2025 production of its evoZero (net-zero) cement, captures 400,000 tons of CO_2 annually from its facility in Brevik, Norway as part of the Longship project. Two-thirds of the project costs were covered by Norwegian government subsidies. Other strategies, such as targeting customers with strong sustainability commitments, early-mover positioning before markets commoditize, and marketing that emphasizes regulatory compliance and environmental responsibility rather than simply price can further strengthen the offer.

TEMPORAL DYNAMICS: THE PREMIUM WINDOW

Crucially, green premiums are not permanent. They follow a predictable lifecycle as markets mature: ▶L

- **Initiation phase (now-2030):** Supply constraints exist as only pioneering companies invest in decarbonization. Early adopters pay premiums to secure supply, differentiate their products, and meet emerging regulatory requirements. Premium percentages are highest, but the volume of customers willing to pay remains relatively small.

- **Growth phase (2030-2040):** More companies deploy low-carbon technologies as costs fall and regulations tighten. Competition increases, putting downward pressure on premiums even as the share of customers requiring decarbonized products grows. Volume scales but margins compress.

- **Plateau phase (2040-2050):** Most companies in advanced economies achieve decarbonization targets. Decarbonized products begin commoditizing as they become the norm rather than the exception. Premium percentages decline substantially.

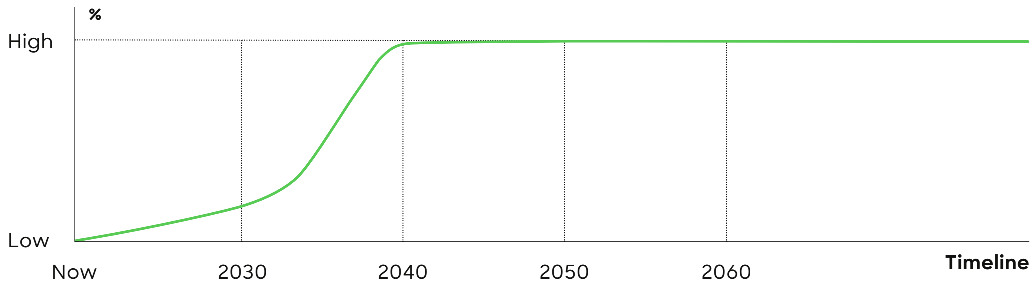
- **Maturity phase (2050+):** Decarbonized products become standard. The remaining premium, if any, reflects only residual technical costs rather than market differentiation value.

This timeline creates a strategic window for CCS investors. Projects completed in the 2025 to 2035 period may capture significant green premiums, providing additional revenue to offset higher early-stage costs, although the number of customers who pay more will be limited. Projects delayed until after 2040 will likely face commoditized markets where premiums have largely evaporated, meaning they must achieve viability through cost reductions and carbon pricing alone. An industry-specific optimum penetration timeline and speed should be assessed on a case-by-case basis.

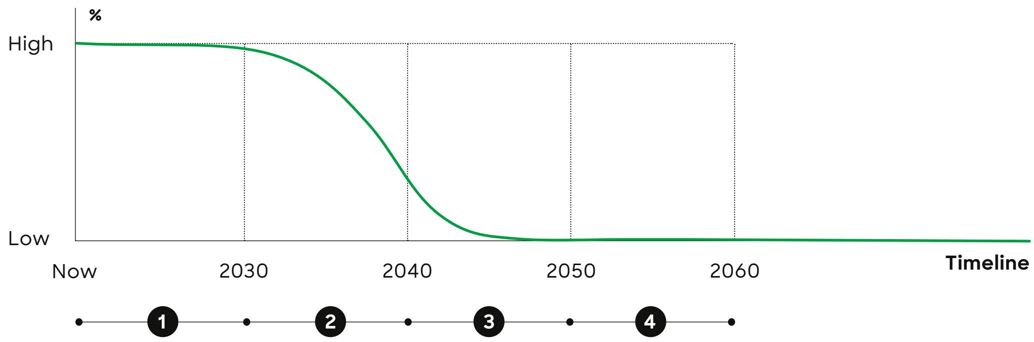
L Added value from customers' willingness to pay a green premium depends on two factors

Customer willingness to pay development over time

Share of customers who will pay higher premium



Customers willingness to pay more as % higher premium



Source: Roland Berger

1.4/ Financial viability: When does it all come together?

Having examined costs, energy economics, and revenue potential separately, we now integrate these factors to answer the central question: When does CCS become commercially viable across different sectors and regions?

THE CARBON PRICE BREAKEVEN FRAMEWORK

The most straightforward path to CCS viability comes through carbon pricing that makes capture economically rational even without green premiums. When the price of emitting CO_2 exceeds the cost of capturing it, companies face clear incentives to invest in CCS regardless of whether customers value decarbonized products.

Using the International Energy Agency's Net Zero by 2050 scenario for carbon price projections, we applied a top-down approach and analyzed breakeven timing across sectors and regions, considering different cost ranges (minimum, mid-range, and maximum) that reflect variation in plant-specific circumstances.

ADVANCED ECONOMIES: NEAR-TERM VIABILITY FOR MANY APPLICATIONS

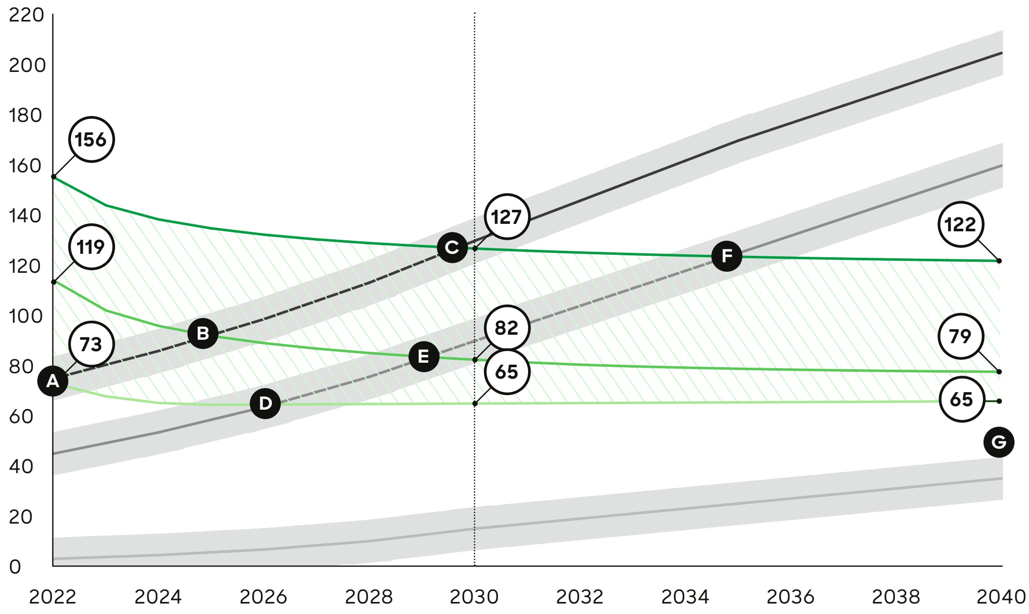
In advanced economies including the European Union and United States, multiple sectors have already reached or will soon reach carbon price breakeven for lower-cost projects.

Chemicals (ammonia, for example) and refining led the way, with minimum-cost-range projects achieving viability in 2022-2024. The combination of naturally higher CO_2 concentrations, existing technical expertise with gas processing, and favorable site characteristics creates conditions where CCS economics already work at current carbon prices of 80 to 90 USD/t CO_2. ▶ M

Steel and power generation follow closely, with low-cost projects viable now and mid-range projects reaching breakeven in 2026. By 2030, even higher-cost projects in these sectors should achieve viability as carbon prices rise toward 200 USD/t under net-zero scenarios. ▶ N

M **CCS for chemicals is already financially viable at the lower-cost range and can soon be viable at the mid-cost range**

CCS financial viability by sector – Chemicals (ammonia as an example)



— CCS cost (maximum range)
— CCS cost (mid-range)
— CCS cost (minimum range)
● Breakeven point
— CO_2 price (advanced economies with NZE pledges)
— CO_2 price (emerging market and developing economies with NZE pledges)
— CO_2 price (other emerging market and developing economies)

1 Estimated CCS costs include cost ranges for carbon capture, transportation, and storage;
2 Carbon price forecast based on IEA NZE scenarios

Source: IEA, interviews with market participants, Roland Berger

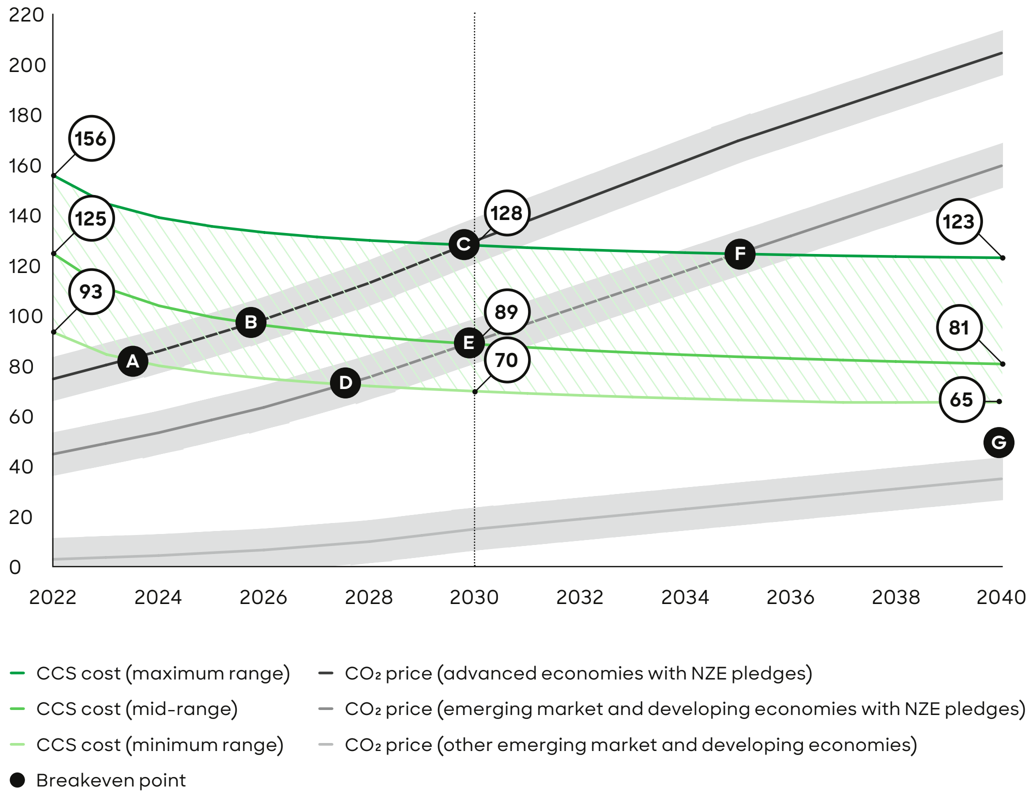
Cement presents a more challenging timeline, with mid-range projects viable around 2026 but maximum-cost projects not reaching breakeven until 2031. This reflects cement's lower CO_2 concentration (15 to 20 %) compared to chemicals or refining, requiring more energy-intensive capture. ▶ O

Across all sectors, the pattern is clear: Minimum-cost projects are viable now, mid-range projects achieve viability by 2026 to 2028, and maximum-cost projects reach breakeven by 2030 to 2031. This three-to-seven-year timeline from early-mover viability to broad market viability characterizes the advanced economy opportunity.

Based on our assessment, the actual cost corridor for natural gas-based power generation, for example, lands in the high-cost range, which could delay the business case breakeven by four to five years across different sectors.

N CCS for steel is already financially viable at the lower-cost range and viable within one year for the mid-cost range in advanced economies

CCS financial viability by sector – Steel



1 Estimated CCS costs include cost ranges for carbon capture, transportation, and storage;
2 Carbon price forecast based on IEA NZE scenarios

Source: IEA, interviews with market participants, Roland Berger

EMERGING AND DEVELOPING ECONOMIES: A THREE-TO-FIVE YEAR LAG

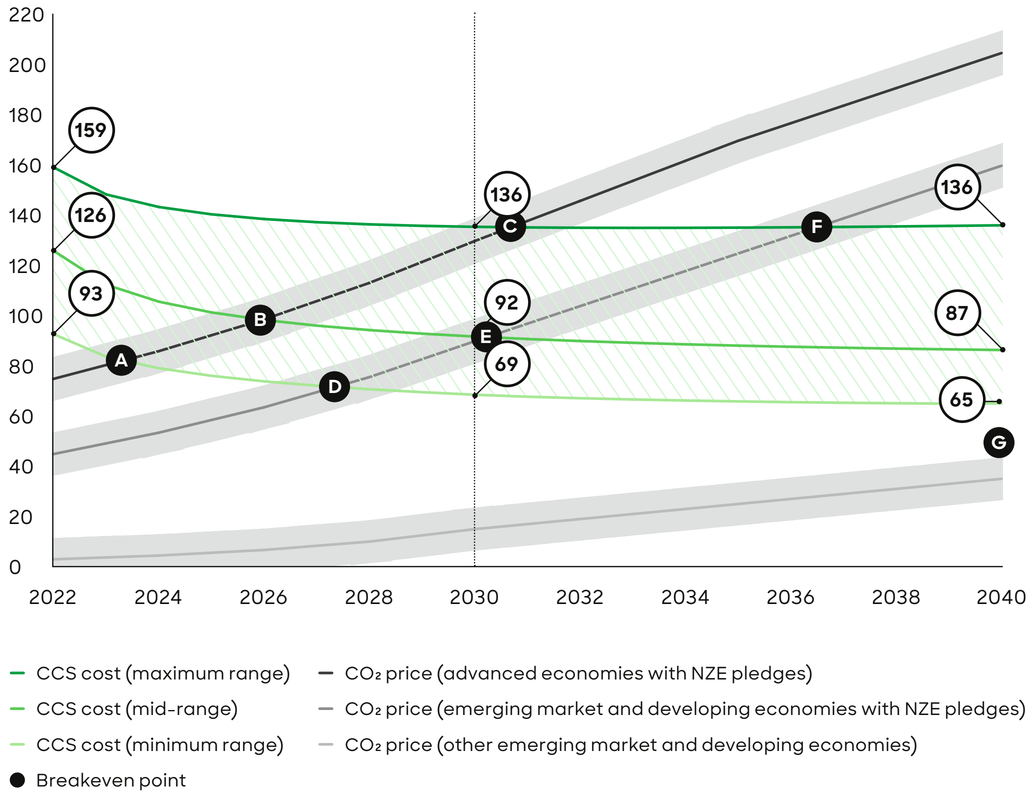
Major emerging economies including China, India, Brazil, and South Africa follow similar trajectories with a three-to-five-year delay. Minimum-cost projects reach viability in 2026 to 2028, mid-range projects in 2029 to 2031, and maximum-cost projects in 2035 to 2037.

This lag reflects lower projected carbon prices in these regions under IEA scenarios, driven by different economic development priorities, energy mixes, and climate policy frameworks. It suggests that while CCS will eventually become viable in major emerging economies, the initial deployment will concentrate in advanced economies with higher carbon prices.

For other emerging economies with less developed climate policies and lower projected carbon prices, viability timelines extend beyond 2040 for most applications, suggesting very limited near-term CCS deployment potential. ▶ P

O CCS for cement can be viable at the mid-cost range in the near future

CCS financial viability by sector – Cement



1 Estimated CCS costs include cost ranges for carbon capture, transportation, and storage;
2 Carbon price forecast based on IEA NZE scenarios

Source: IEA, interviews with market participants, Roland Berger

P In advanced economies and at lower-cost ranges, CCS is financially viable in all sectors – Feasibility is projected in the near future, between min- and max-cost ranges

Summary of sectoral financial viability[1]

Expected year of reaching financial viability based on IEA NZE scenario

	CCS cost vs. IEA NZE carbon prices in **advanced economies**[2]			CCS cost vs. IEA NZE carbon prices in **emerging & developing economies**[3]			CCS cost vs. IEA NZE carbon prices in **other emerging economies**		
	Min-cost range	**Mid-cost range**	**Max-cost range**	**Min-cost range**	**Mid-cost range**	**Max-cost range**	**Min-cost range**	**Mid-cost range**	**Max-cost range**
Power generation - **Gas**	2024	2026	2030	2027	2030	2035	2040+	2040+	2040+
Power generation - **Biomass**	2023	2026	2030	2027	2030	2035	2040+	2040+	2040+
Iron & steel	2024	2026	2030	2028	2030	2036	2040+	2040+	2040+
Cement	2024	2026	2031	2028	2031	2037	2040+	2040+	2040+
O&G refining	2023	2026	2030	2027	2030	2035	2040+	2040+	2040+
Chemicals	2022	2025	2030	2026	2030	2035	2040+	2040+	2040+

1 Considering costs and prices from 2024 onwards to eliminate effects from carbon prices peak from EU ETS in 2023; 2 E.g., EU and USA; 3 E.g., China, India, Brazil, and South Africa

Source: IEA, Roland Berger

THE TOP-LINE PERSPECTIVE: POLICY INCENTIVES AND GREEN PREMIUMS

Carbon price breakeven analysis provides one lens on viability, but it overlooks the impact of sector-specific policy incentives and customer willingness to pay green premiums. A more complete picture emerges by converting CCS costs to per-unit-output basis and examining what would be the required decarbonization premium to make a business and/or investment case breakeven.

For the United States, the 45Q federal tax credit has provided between 60 and 85 USD/t CO_2 for qualified projects. Taking an average of this price range into consideration, refining becomes clearly viable, with a mere 1% required price increase to reach breakeven. In iron & steel and chemicals (ammonia example), a 9% decarbonization premium is required. In gas power generation, biomass power generation, and the cement industry, however, a 24 to 26% premium is required. Interestingly, current observations show net-zero cement is able to command a 20+% higher price.

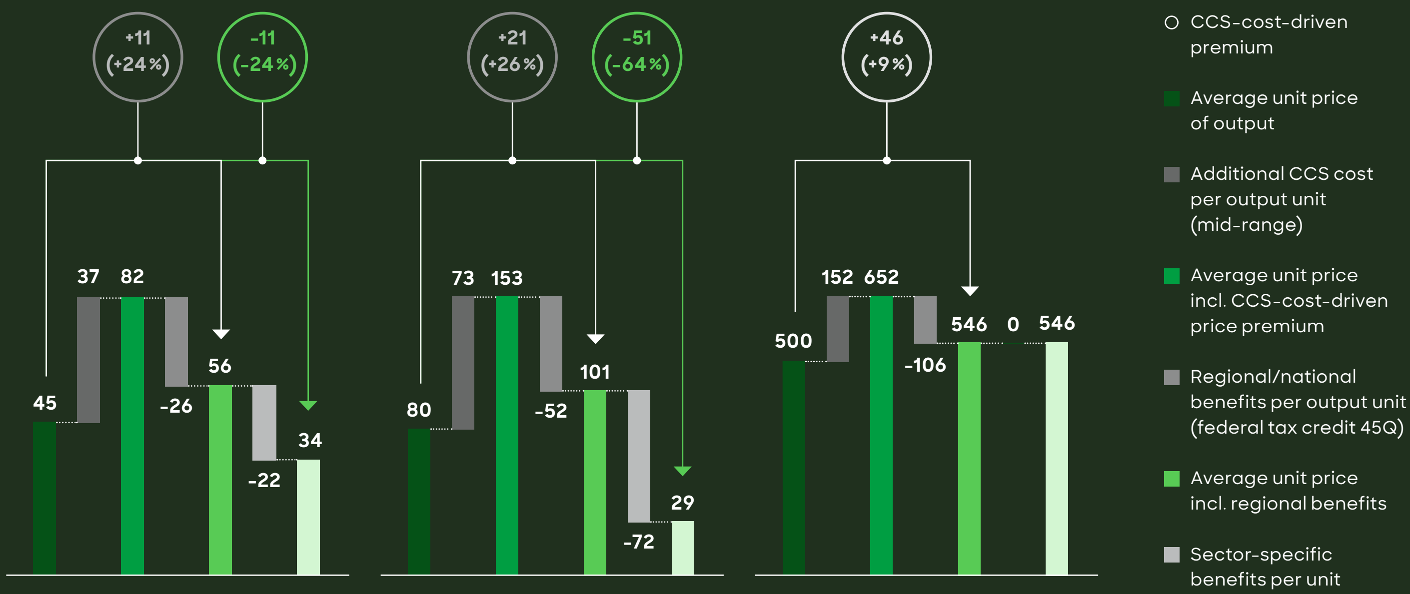
In gas and biomass-based power generation, where customer willingness to pay is lower, sector-specific incentives are providing essential support, such as California's Low Carbon Fuel Standard (LCFS) for power generation, or BECCS certificates for biomass. Without those incentives, gas and biomass power generation would not be viable before 2040. Combining 45Q and sector-specific benefits, gas and biomass power generation are viable with 11 USD/MWh and 51 USD/MWh gross margin, respectively. With current incentives sitting at 85 USD/t (at the time of publication), however, the business case is stronger. ▶ Q & R

The picture in the European Union looks similar but relies on avoided compliance costs under the Emissions Trading System (ETS) rather than direct tax credits. With ETS prices averaging 76 USD/t CO_2 in 2024-2025, refining achieves clear viability with a 1% premium requirement. Biomass with BECCS certificates is viable with a 54 USD/MWh gross margin. Chemicals (ammonia) and steel require modest 8% premiums, achievable in premium applications. Gas power needs a larger 21% premium, pushing viability into the 2030s. Cement requires the highest premium at 23%, but with positive trends on significantly increasing customer willingness to pay. ▶ S & T

Q In the US, 45Q provides attractive incentives – With additional sector-specific benefits, financial viability will increase significantly

Financial viability of CCS in relation to output prices, US, 2024 (1/2)

Power generation – Gas USD/MWh | **Power generation – Biomass** USD/MWh | **Iron & steel** USD/t



Power generation – Gas

- Considering 45Q[1] and LCFS[2], CCS of gas base power generation at mid-range is financially viable[4] now in California with 11 USD/MWh lower price
- In other states with 45Q[1] solely, around 24 % premium is required to cover additional CCS costs. Financial viability is expected by 2040/2041[5]

Power generation – Biomass

- Considering 45Q[1] and BECCS[3] certificates, CCS of biomass base power generation at mid-range is financially viable[4] now in California with 51 USD/MWh lower price
- In other states with 45Q[1] solely, around 26 % premium is required to cover additional CCS costs. Financial viability is expected by 2040/2041[5]

Iron & steel

- Considering 45Q[1] solely, around 9 % (46 USD/t) green premium is required in iron & steel industry to cover additional CCS costs
- With anticipated decline in CCS costs, financial viability is expected by 2030[5]

1 Assumed 72.5 USD/t CO_2 (average of 60-85 USD/t CO_2; 2 Assumed 60 USD/t CO_2 (average of 35-85 USD/t CO_2); 3 Assumed 100 USD/t CO_2; 4 Assumed financial viability if average unit price including benefits is not more than 5 % greater than average unit price; 5 Assumed declining CCS cost while maintaining current financial benefit levels

Source: IEA, Bloomberg, S&P Global, Roland Berger

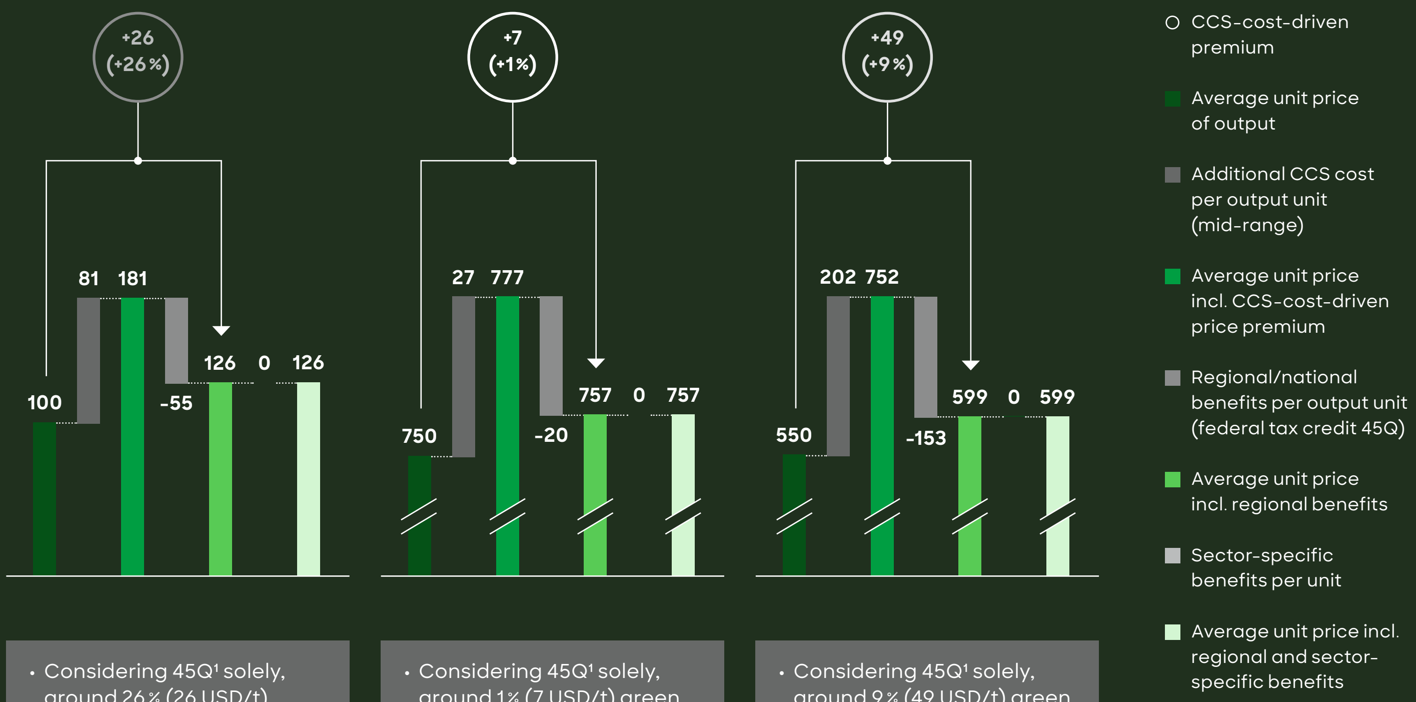
R In the US, 45Q provides attractive incentives – With additional sector-specific benefits, financial viability will increase significantly

Financial viability of CCS in relation to output prices, US, 2024 (2/2)

Cement — USD/t

O&G refining — USD/t

Chemicals – Ammonia — USD/t



Cement

- Considering 45Q[1] solely, around 26% (26 USD/t) green premium is required in cement industry to cover additional CCS costs
- Without higher customer willingness to pay, financial viability cannot be reached before 2040[5] through declining CCS costs alone

O&G refining

- Considering 45Q[1] solely, around 1% (7 USD/t) green premium is required in refining industry to cover additional CCS costs
- We assume, therefore, existing financial viability[4] for CCS at mid-cost range in refining industry now

Chemicals – Ammonia

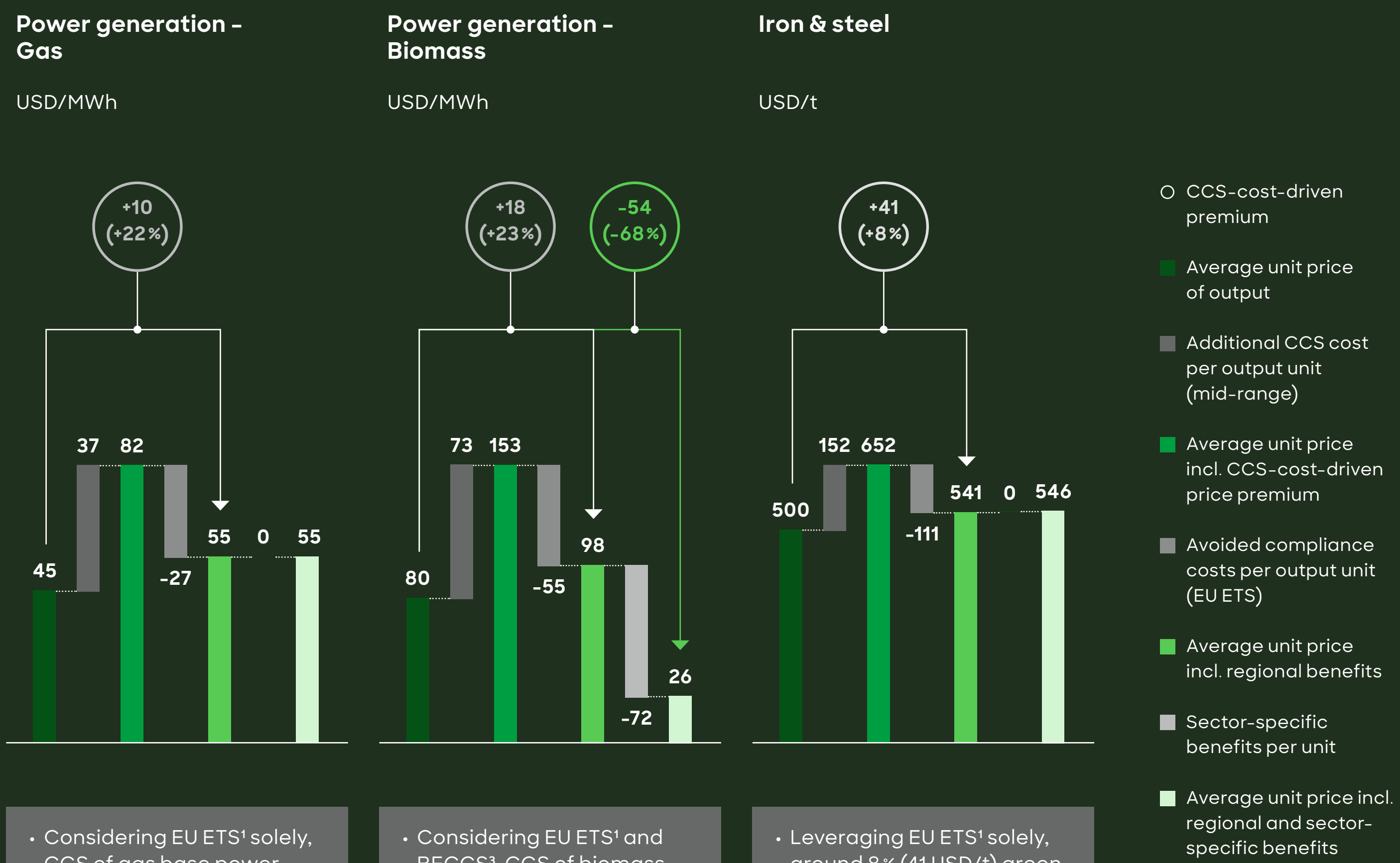
- Considering 45Q[1] solely, around 9% (49 USD/t) green premium is required in ammonia production to cover additional CCS costs
- With anticipated decline in CCS costs, financial viability will likely be achieved by 2028[5]

1 Assumed 72.5 USD/t CO_2 (average of 60-85 USD/t CO_2; 2 Assumed 60 USD/t CO_2 (average of 35-85 USD/t CO_2); 3 Assumed 100 USD/t CO_2; 4 Assumed financial viability if average unit price including benefits is not more than 5% greater than average unit price; 5 Assumed declining CCS cost while maintaining current financial benefit levels

Source: IEA, Bloomberg, S&P Global, Roland Berger

S Under EU ETS, refining industry shows emerging financial viability – Additional BECCS certificates push biomass-based power generation to higher feasibility

Financial viability of CCS in relation to output prices, EU, 2024 (1/2)



- Considering EU ETS[1] solely, CCS of gas base power generation at mid-range requires 21% (10 USD/MWh) premium to cover additional CCS costs
- Financial viability is expected by 2034[5]

- Considering EU ETS[1] and BECCS[3], CCS of biomass base power generation at mid-range is financially viable[4] now in EU with 54 USD/MWh lower price
- With EU ETS[1] solely, around 23% (18 USD/MWh) premium is required to cover additional CCS costs. Financial viability is expected by 2034[5]

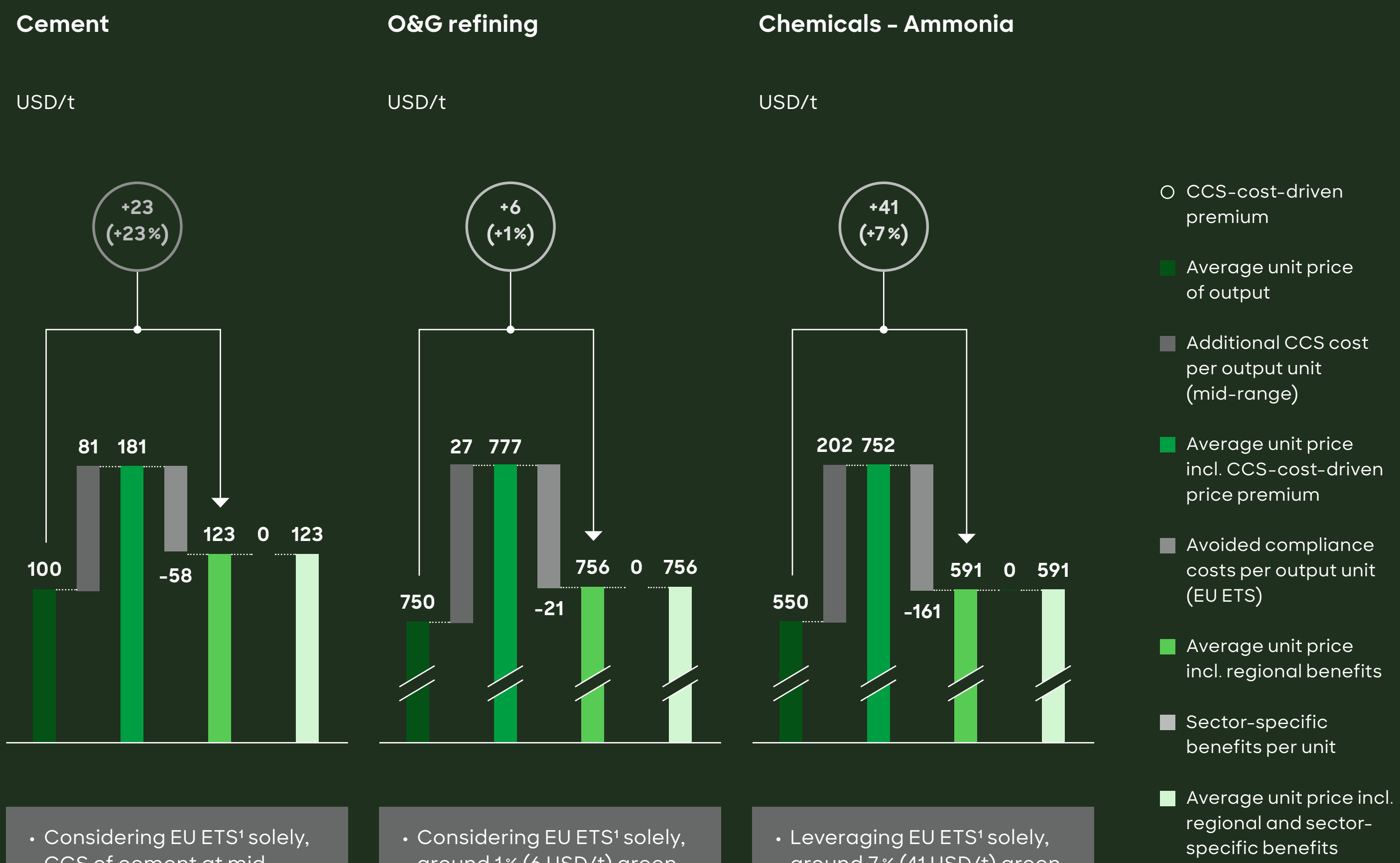
- Leveraging EU ETS[1] solely, around 8% (41 USD/t) green premium is required in iron & steel industry to cover additional CCS costs
- With anticipated decline in CCS costs, financial viability is expected by 2028[5]

1 Assumed 72.5 USD/t CO_2 (average of 60-85 USD/t CO_2; 2 Assumed 60 USD/t CO_2 (average of 35-85 USD/t CO_2); 3 Assumed 100 USD/t CO_2; 4 Assumed financial viability if average unit price including benefits is not more than 5% greater than average unit price; 5 Assumed declining CCS cost while maintaining current financial benefit levels

Source: IEA, Bloomberg, S&P Global, Roland Berger

Under EU ETS, refining industry shows emerging financial viability – Additional BECCS certificates push biomass-based power generation to higher feasibility

Financial viability of CCS in relation to output prices, EU, 2024 (2/2)



Cement

- Considering EU ETS[1] solely, CCS of cement at mid-range requires 23% (23 USD/t) premium to cover additional CCS costs
- Without higher customer willingness to pay, financial viability is projected beyond 2040[5]

O&G refining

- Considering EU ETS[1] solely, around 1% (6 USD/t) green premium is required in refining industry to cover additional CCS costs
- We assume, therefore, existing financial viability[4] for CCS at mid-cost range in the refining industry now

Chemicals – Ammonia

- Leveraging EU ETS[1] solely, around 7% (41 USD/t) green premium is required in ammonia production to cover additional CCS costs
- With anticipated decline in CCS costs, financial viability is expected by 2026[5]

1 Assumed 72.5 USD/t CO_2 (average of 60-85 USD/t CO_2; 2 Assumed 60 USD/t CO_2 (average of 35-85 USD/t CO_2); 3 Assumed 100 USD/t CO_2; 4 Assumed financial viability if average unit price including benefits is not more than 5% greater than average unit price; 5 Assumed declining CCS cost while maintaining current financial benefit levels

Source: IEA, Bloomberg, S&P Global, Roland Berger

2

Beyond economics: Regulatory, social, and risk factors

Exploring the economics of CCS viability demonstrates that lower-cost projects in chemicals, refining, and power generation can achieve breakeven today, with mid-range projects across most sectors reaching viability by 2026-2028. However, commercial reality depends on factors that exist outside traditional financial analysis. A project that achieves carbon price breakeven and attracts green premiums can still fail if regulators reverse course, communities mobilize in opposition, or liability frameworks make financing impossible.

This chapter examines three critical "extra-economic" factors that determine whether CCS moves from financial viability to actual deployment: regulatory uncertainty that can paralyze investment decisions, social acceptance that varies dramatically by geography, and risk allocation across complex value chains that can render otherwise sound projects unbankable.

2.1/ Regulatory uncertainty: The investment killer

Interviews with industry executives from across the CCS value chain reveal uncertainty around policies and regulations is one of the most frequently mentioned barriers to CCS investment. This is not coincidental; CCS projects require investment horizons of 15 to 20 years from initial planning through operational maturity. Policy changes within this window can transform viable projects into stranded assets. ▶U

Within the context of CCS, regulatory uncertainty typically manifests itself in three interconnected questions:

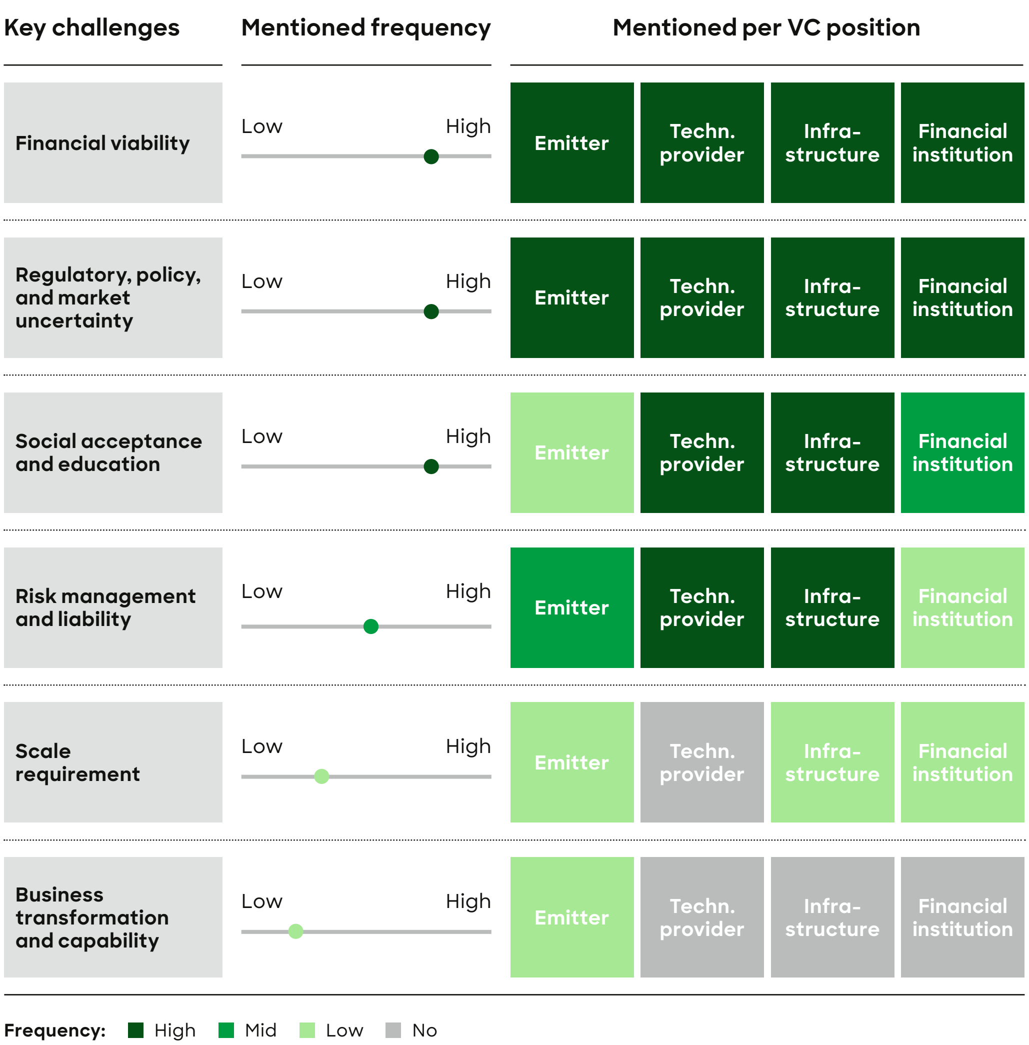
1. Will subsidies and incentives continue?
2. Which sectors will be included in emissions trading systems and decarbonization mandates?
3. What are the actual decarbonization targets?

For instance, the United States' 45Q tax credit and the European Union's ETS provide substantial support for CCS economics. But both have faced political challenges, periodic restructuring, and uncertain long-term trajectories. Further, a company may invest in CCS only to find their sector excluded from compliance obligations, eliminating the regulatory driver for adoption of decarbonized products. And while many jurisdictions have announced net-zero commitments, many lack specified interim targets, sectoral allocations or clarity on the role of CCS compared to alternatives, creating added ambiguity. Companies evaluating 20-year investments must wager on the scope, depth, and political durability of current policy frameworks.

Regulatory approaches can either mitigate or amplify uncertainty, with profound implications for investment. In 2024, Denmark introduced a green tax reform featuring a ceiling and floor mechanism for carbon pricing. Rather than allowing prices to fluctuate based on market dynamics and regulatory changes, the system establishes a bounded range within which prices can move. Emitters and investors know that carbon prices will

U Uncertainty, financial viability and social acceptance are key challenges and hurdles for CCS project decision-making

Summary of key challenges of CCS project decision-making



Source: Interviews with market participants

remain within a predictable range, allowing them to model upside and downside scenarios with confidence. While the mechanism is not particularly generous compared to other European carbon pricing schemes, it transforms uncertainty – a barrier to investment – into manageable risk that can be priced, hedged, and incorporated into standard investment analysis.

The US offers a contrasting example. Despite the 45Q tax credit providing among the world's most generous CCS incentives (60 to 85 USD/t for qualified projects), regulatory instability has repeatedly disrupted deployment. In May 2025, the Department of Energy (DOE) canceled funding for over 20 previously granted projects, many related to CCS. These were not denials of new applications but reversals of existing commitments; projects that had received awards, made investment decisions based on those awards, secured private co-financing, and begun development activities.

The immediate impact was predictable: project delays, financing withdrawals, and partner defections as the commercial foundations shifted. Some projects will ultimately proceed without DOE funding if alternative financing can be secured; others will be abandoned entirely as economics deteriorate without promised support. The broader impact, however, may prove more damaging. Every CCS project developer in the US must now incorporate elevated policy risk into their investment analysis. If funding commitments can be reversed after announcement, no amount of regulatory analysis provides certainty.

The example illustrates why a stable but modest support mechanism often enables more investment than a generous but unpredictable one. This has practical implications for both policymakers and companies:

- **For policymakers:** The most impactful intervention may not be increasing subsidy levels but establishing credible long-term frameworks with clear triggers for any adjustments. Carbon price floors with legislated escalation paths, multi-year funding commitments with contractual protections, and automatic sunset provisions that require explicit legislative action to terminate (rather than automatic termination unless renewed) all contribute to investable certainty.

- **For companies:** Regulatory risk assessment should receive equal weight with technical and financial analysis in project evaluation. Projects in jurisdictions with unpredictable policy environments require higher return hurdles to compensate for elevated risk. Conversely, projects in stable regulatory environments may justify investment even at more modest expected returns because downside scenarios are bounded.

The regulatory environment shapes not just whether individual projects proceed but the pace and scale of entire industry development. Markets with regulatory certainty will see faster deployment, more aggressive cost reduction through learning effects, and earlier development of supporting ecosystems including transportation infrastructure, storage capacity, and insurance products. Markets with regulatory instability will lag behind regardless of their underlying economic advantages.

2.2/ Social acceptance: The hidden veto

Public perception presents a paradox for CCS deployment. The technology attracts less public attention than renewable energy, energy efficiency, or electric vehicles, with lower awareness in surveys across all regions studied. And among those who are aware, CCS receives notably lower support compared to these alternatives.

Solar and wind projects may face local opposition, but they benefit from broad public understanding of what they are and general agreement that they contribute positively to climate goals. Debates focusing on siting, visual impact, and local environmental concerns are important but can be addressed through project design and community engagement. ▶V

V Public awareness and support of CCS is low compared to other sustainability and decarbonization-associated technologies

Public perception on different decarbonization technologies

Source: Tardin-Coelho et al. (2025), Wuppertal Institute, Fraunhofer Institute, Roland Berger

CCS faces different challenges. Public opposition often comes from communities with limited understanding of what carbon capture involves, how CO_2 is transported and stored, how risks are managed, and why CCS is necessary as part of decarbonization strategies. This is not to suggest that all public concerns are the result of misunderstanding or lack of knowledge, but that low baseline awareness means projects have a dual challenge of educating and addressing concerns – a more complex task than wind or solar developers face.

GEOGRAPHIC PATTERNS IN ACCEPTANCE OF CCS

Social acceptance of CCS varies across countries and regions based on cultural factors, historical experiences with similar industries, trust in institutions, and economic contexts.

Countries with established offshore oil and gas industries, strong government backing with visible investment, and clear economic benefits show systematically higher CCS acceptance. This is reflected in countries such as Norway, where the technology is viewed as integral to national climate identity rather than a controversial last resort. Major projects including Longship (integrating Norway's industrial emissions with carbon capture) and Northern Lights (an open-access CO_2 transportation and storage infrastructure project in the North Sea) enjoy strong government backing, signaling long-term commitment and reducing perceived risk. Additionally, decades of offshore oil and gas experience have created familiarity and built trust in Norway's technical capability to manage complex energy infrastructure safely, and offshore storage location eliminates "not in my backyard" concerns.

Conversely, countries where CCS is perceived as technology to prolong fossil fuels rather than to decarbonize genuinely hard-to-abate industrial processes face substantially greater skepticism. For example, Germany faces deep environmental skepticism rooted in memories of canceled CCS projects and persistent fears of groundwater contamination. The association of CCS with prolonging fossil fuel use resonates particularly strongly in a country with powerful renewable energy advocacy. Support exists but is heavily conditional: Offshore storage is preferred over onshore, and pairing with demonstrated emissions reductions (not merely offsetting continued fossil fuel use) is expected.

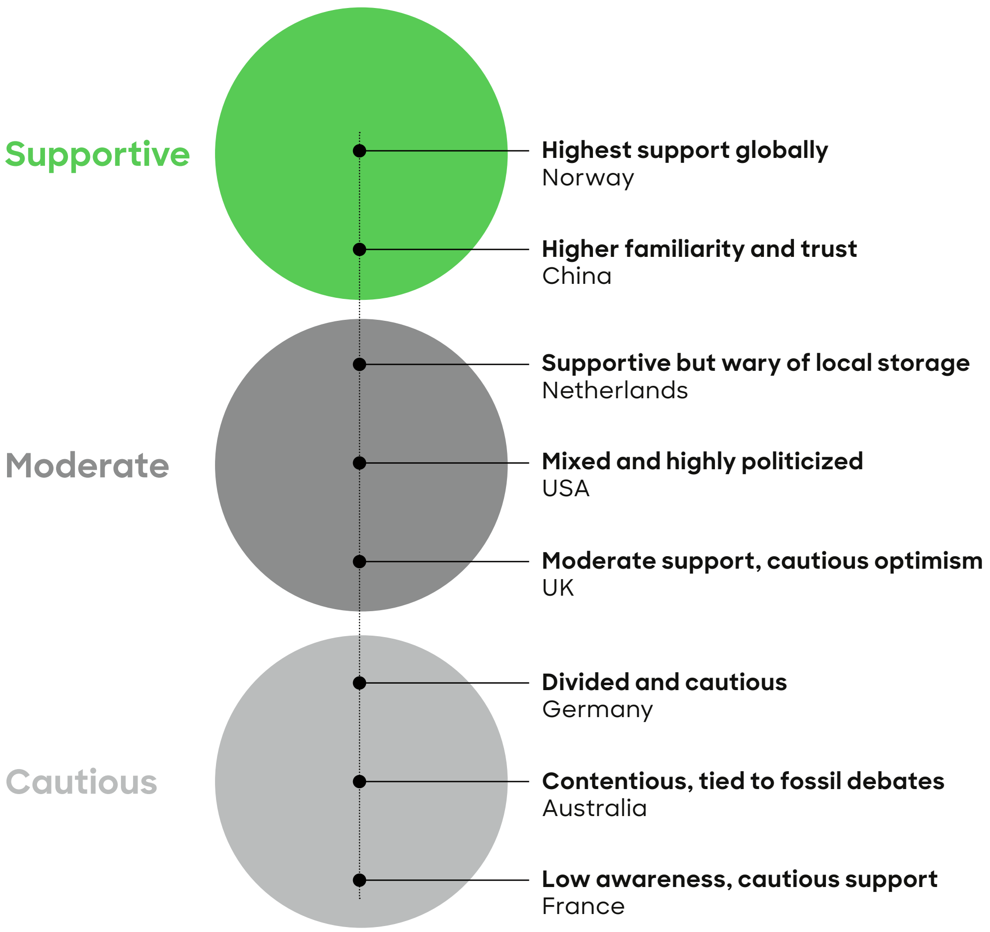
Similarly, Australia's mining regions view CCS as a strategy for preserving jobs as global energy transitions accelerate. However, environmental groups criticize CCS as a "fossil fuel lifeline" that delays necessary transitions to renewable energy, creating contentious public debates tied to broader disagreements about Australia's energy and economic future. ▶ W

"Regardless of country, public perception of CCS lags behind other climate technologies. Acceptance isn't automatic – it requires policy support, economic benefits, institutional trust, technology knowledge, and transparent decision-making. Companies cannot afford to treat social license as an afterthought."

Ruirui Zong-Ruehe, Partner, Roland Berger

W **CCS acceptance differs among countries and toward different storage locations driven by various positive and negative drivers**
Reasons and drivers for public perception around CCS in selected countries

Social acceptance level differs among countries



Source: Kiel Institute for the World Economy

This pattern suggests strategic implications: CCS deployment will advance fastest in regions where it addresses industrial emissions that lack alternative solutions, where offshore storage avoids local siting opposition, and where government commitment is visible and sustained. However, perfect acceptance is unrealistic anywhere. Even Norway, which demonstrates higher support for CCS, still experiences significant public worries about costs, safety, and fossil fuel implications. CCS deployment requires managing concerns, rather than eliminating them. The goal is sufficient acceptance for permitting and operation, with continued engagement to maintain social license, rather than waiting for opposition to disappear.

2.3/ Risks and liabilities: The bankability challenge

While regulatory uncertainty and social acceptance can slow or halt CCS projects, unclear liability allocation can prevent them from ever reaching investment decision. Banks and investors require clarity about who bears consequences if something goes wrong – such as a leak, an underperformance, or a long-term storage issue. When liability chains are ambiguous, projects become unbankable regardless of their economic merits or social acceptance.

There are a variety of different risk categories across the CCS value chain, from capture to transportation to trade:

- **Capture** facilities encounter typical industrial challenges including CO_2 leaks, cost overruns, technology underperformance, and operational downtime – risks that are significant but manageable through conventional project management.

- **Transportation** poses potential dangers, although they are not necessarily limited to the transportation of CO_2 specifically. Transporting any gases in a supercritical state can be harmful in the event of a rupture or leak.

- **Storage** introduces the most complex long-term risks, as CO_2 must remain underground for centuries. Issues include potential leaks and migration (as seen in Algeria's In Salah project), induced seismicity from injection pressure, and uncertain long-term liability – particularly regarding who bears monitoring responsibilities after 100+ years.

- **Certificate trading** adds market risks including production shortfalls, fraud (highlighted by the CFTC's October 2024 charges against carbon credit developers for falsifying data), price volatility, and limited market demand.

While mitigation strategies exist for each risk category – from robust monitoring systems to government-backed price guarantees – many hazards cannot be entirely eliminated. Public acceptance remains challenging throughout the value chain, as communities rationally resist bearing catastrophic risks for broader climate goals, creating permitting delays and local opposition that can halt projects entirely. ▶X

THE LIABILITY DILEMMA

The fundamental question of who bears liability when CCS incidents occur has no universally accepted answer. Two main approaches exist: emitter-responsible models where the original CO_2 source bears complete liability from capture through permanent storage, and shared liability models that distribute responsibility based on control and expertise.

The emitter-responsible approach offers simplicity and clear accountability but concentrates unbankable risk on emitters for technical domains outside their competence; asking a cement manufacturer to guarantee geological storage for decades makes little sense. Shared liability allocates risks more sensibly (pipeline operators manage transportation risks, storage operators manage geological risks), enabling the hub models essential for economies of scale, but it introduces complexity around liability interfaces and makes regulatory oversight more challenging.

X Carbon capture generates liabilities that need to be managed across the value chain – While mitigation is possible, allocating liabilities can be challenging

Liabilities across value chain steps

Value chain	CO_2 capture	CO_2 transportation	CO_2 storage	Certificate trading
	Low … High	Low … High	Low … High	Low … High
Risk	**Leak:** Venting or leak of CO_2 after capturing **Cost overruns:** Due to delayed construction or inability to secure incentives **Under performance:** Due to novel technology or process changes, captured CO_2 less than design **Downtime:** Less than contracted CO_2 generated due to capture or process downtime	**Leak:** Due to pipeline ruptures or corrosion – Higher risk given higher pressure and volume **Environmental/ societal damage:** Large releases of asphyxiating gas can harm human life and fauna **Blockages or downtime:** Due to excursions or pump downtime – Can impact CO_2 capture operation **Public acceptance:** Population around CO_2 infrastructure may raise concerns	**Leak:** Migration above caprock or wellbore leak **Induced seismicity:** Damage to ground structures and houses in the community **Long-term control requirement:** Need to monitor and control reservoir long after cease of injection **Public acceptance:** Storage facilities may bring long-term risk to local communities	**Production shortfall:** Certificates may not be available due to downtime at plant (e.g., lower power plant demand due to high availability of wind/solar) **Market integrity:** While harder in CCS than in other methods, it is still possible given reliance on flowmeters **Price volatility:** Price fluctuations create uncertainty **Limited demand:** Insufficient demand for CCS carbon credits

1 Carbon Contracts for Difference – government-backed mechanisms designed to support CCS by guaranteeing a fixed carbon price over time

Source: Desk research, interviews with market participants

Real-world projects are gravitating toward shared liability frameworks, exemplified by Norway's Northern Lights project, where the operator bears transportation and storage responsibility while emitters retain capture performance obligations. However, several critical dilemmas remain unresolved across most jurisdictions: long-term stewardship questions about when and how liability transfers from private operators to governments after potentially 100+ years; credit integrity issues regarding who bears responsibility if CO_2 leaks decades after carbon credits were issued and retired; and innovation barriers where novel technologies face higher uncertainty that liability frameworks may punish through uninsurable risks. ▶ Y

Y As the CCS value chain develops, ownership of liabilities is expected to be a concern

While having the emitter responsible simplifies the process, it creates inefficiencies

Liability management and sharing

	Description	Pros	Cons
At emission source	• Emitter is responsible for providing compensation for leaks that happen downstream of capture point to honor carbon certificates • Emitter is responsible for delivering agreed volumes to storage, per carbon certificates • Risks unrelated to carbon capture (e.g., environmental) are managed by custodians of equipment or reservoir	• **Simplicity** – One party is fully accountable • **Fewer handoffs** – Easier to track carbon flow and storage • **Aligns incentives** – Emitter is motivated to ensure reliability of partners by choosing reputable providers	• **Risk concentration** – Emitter bears technical, legal, and financial risks, even beyond their control • **Higher financing burden** – Can deter financing partners • **Misaligned expertise** – Emitters may not be suitable to manage storage and transportation risks
Shared across chain	• Custodians of equipment or reservoir are responsible for providing compensation for leaks • Shared responsibility for contract delivery across value chain – Flexibility built into system to account for volume fluctuations	• **Risk sharing** – Each party takes on the risks they can control • **Encourages ecosystem development and shared infrastructure** – Pipelines and storage can be shared across emitters • **Allow specialization** – Each actor can focus on their area of expertise	• **Increased costs and liabilities** – Players not involved in emitting activity share risk of emissions • **More complex contracts** – Requires detailed interface agreements and legal clarity • **Difficult regulatory oversight** – Fragmentation can complicate enforcement

Source: Roland Berger

LEARNING FROM THE NATURAL GAS INDUSTRY

The carbon capture and storage sector can draw valuable lessons from the natural gas industry, which has successfully addressed similar challenges over decades. For instance, natural gas contracts use take-or-pay clauses to balance volume fluctuations, ensuring revenue stability for infrastructure operators while offering buyers flexibility. CCS can adopt similar long-term contracts with minimum volume commitments, though it requires additional flexibility due to the volatility of carbon credit markets and variable CO_2 flows, influenced by factors like renewable energy availability and carbon pricing.

Quality control and custody transfer protocols in natural gas also provide a blueprint for CCS. Natural gas systems enforce strict quality standards at transfer points, rejecting off-spec gas to protect infrastructure. Similarly, CCS must monitor CO_2 purity, moisture, and contaminants, with stricter requirements due to the corrosive nature of wet CO_2. Additionally, CCS introduces the complexity of dual tracking – monitoring both physical CO_2 flows for operational needs and credit chains for carbon accounting. This dual responsibility necessitates sophisticated systems, especially when multiple emitters share infrastructure.

Risk transfer and insurance frameworks from the natural gas industry are also applicable to CCS, with modifications for CO_2-specific risks. Established insurance structures, such as environmental liability and business interruption coverage, are being adapted to accelerate CCS market development. Furthermore, clear ownership and custody transfer rules, as seen in natural gas, can help delineate liability in CCS operations, ensuring accountability at each stage of the value chain. While some mechanisms, like volume flexibility, are already adopted in CCS projects, others, such as standardized quality control and insurance frameworks, are still evolving.

3 Improving CCS decision-making and outcomes

This report has demonstrated that while CCS economics are improving rapidly, financial feasibility alone cannot guarantee successful deployment. Projects that make compelling sense on paper still require clear regulatory frameworks, social acceptance, well-defined liability allocation, and effective risk management.

Imperial College London and Roland Berger have developed a practical framework for navigating this complexity. It guides industry decision-makers through the critical questions they must answer before committing capital, helps them understand and mitigate the risks that make projects unbankable, and offers concrete recommendations for building competitive positioning in the emerging CCS landscape.

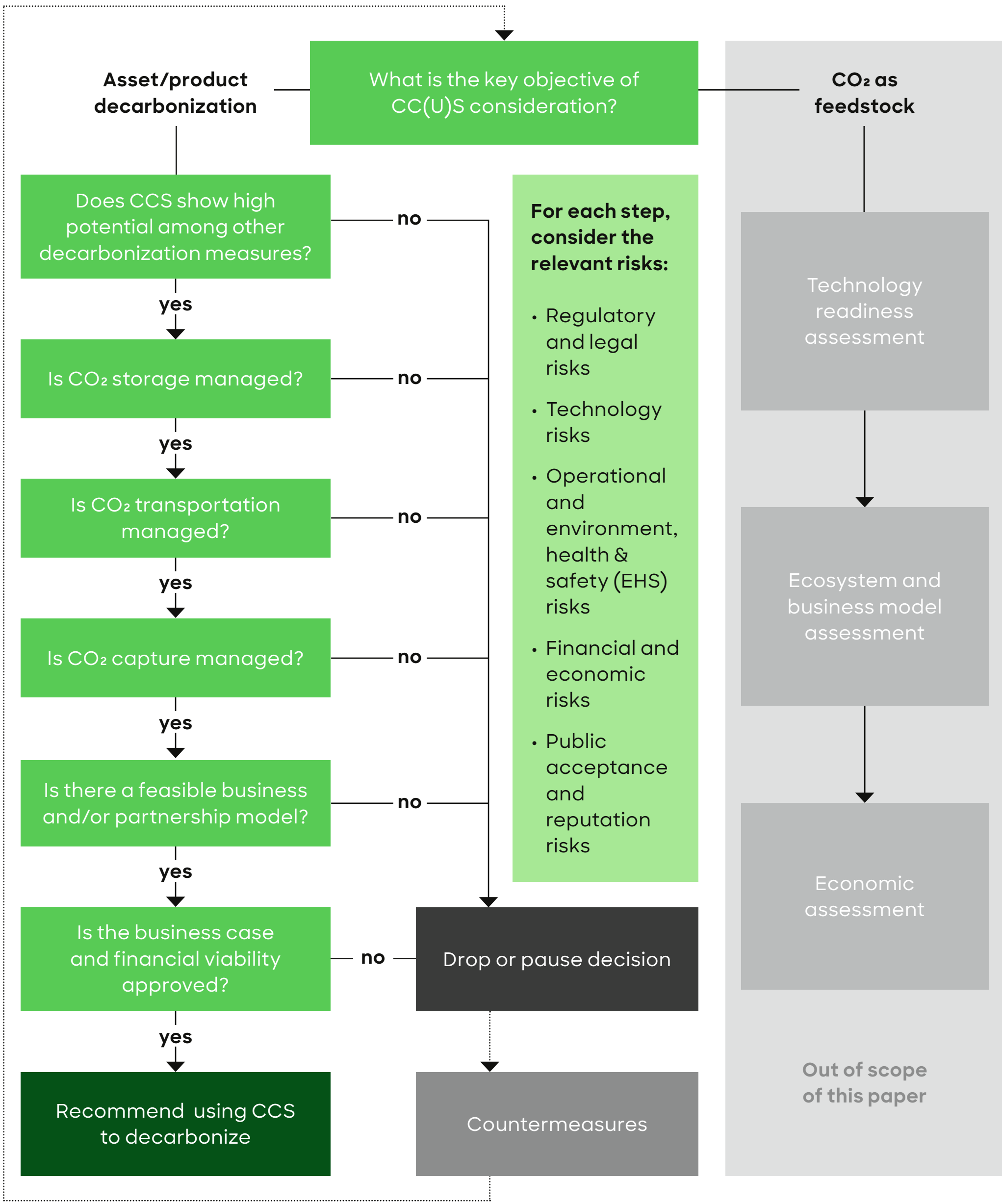
The framework draws on our interviews with industry leaders across the CCS value chain – emitters, technology providers, infrastructure operators, and financial institutions – combined with analysis of successful and failed projects globally. It reflects the reality that CCS decision-making is not a linear process but rather an iterative evaluation across multiple dimensions that must align simultaneously for projects to proceed.

3.1/ The CCS decision framework

The starting point is clarity about objectives. Companies consider CCS for fundamentally different reasons: Some seek to decarbonize existing assets and products to meet regulatory requirements or customer demands, while others view CO_2 as a potential feedstock for carbon utilization pathways. These objectives lead to different analytical frameworks and decision criteria. This report focuses on the former: using CCS to decarbonize industrial processes that lack viable alternatives.

The framework envisions decision-making as a series of gates, each of which must be satisfied before proceeding to the next level of analysis and investment. ▶ Z

Z CCS decision tree with key risks



Source: Imperial College London, Roland Berger

DECARBONIZATION OPTIONS

For asset and product decarbonization, the first question is whether CCS shows high potential among different avaialble decarbonization measures. This requires understanding the regulatory landscape: What is the regulatory certainty around emissions requirements? What are the key greenhouse gas emission reduction steps expected in the coming decade? What are the explicit decarbonization targets for the sector? Most importantly, what alternative decarbonization measures exist, and how do their costs, technical maturity, and implementation timelines compare?

The high-level industry abatement cost curve provides crucial context. In some sectors, such as cement and steel, CCS represents one of very few technically viable pathways to deep decarbonization given process emissions that cannot be eliminated through energy efficiency or fuel switching alone. In other sectors, alternatives such as electrification, green hydrogen, or biomass substitution may offer more attractive economics or technical maturity.

Customer acceptance toward CCS-decarbonized materials matters decisively. If customers in your end markets show willingness to pay green premiums for decarbonized products, CCS becomes more financially attractive. Conversely, in commodity markets where customers show no premium willingness and competitors lack decarbonization pressure, investing in CCS may simply increase costs without creating competitive advantage. The timeline matters too: Moving during the 2025-2035 window when green premiums are highest and before markets commoditize creates first-mover advantages that later entrants cannot capture.

Key questions – Decarbonization options

- What is the regulatory certainty?
- What are key GHG emission steps?
- What are the decarbonization targets?
- What are alternative decarbonization measures?
- What is the timeline?
- What is the customers' affinity toward CCS-decarbonized materials?
- What is the high-level industry abatement cost curve across different decarbonization measures?

STORAGE MANAGEMENT

The permitting and regulatory status of storage sites deserves particular attention. Sites that appear available in theory may face years of additional permitting delays, particularly for new formations without prior production history.

The liability question becomes unavoidable at this gate. Who is responsible for long-term liability, monitoring, and potential remediation 50 to 100 years after injection ends? What is the mechanism for liability transfer from private operators to government entities, and under what conditions does that transfer occur? If storage operators cannot provide satisfactory answers, either because regulatory frameworks remain unclear or because they lack the financial strength to credibly bear long-term liability, the project may be technically sound but financially unbankable.

Key questions – Storage management

- Where is the storage location?
- What are the permitting and regulatory requirements and the status?
- Is the storage site proven?
- Who owns the storage site?
- Who will operate the site?
- Who will provide whole-life MRV for the site?
- What is the accessibility of the site?
- Is the site part of a hub?

TRANSPORTATION MANAGEMENT

Another decision factor is whether your facility can access transportation infrastructure economically. For large emitters producing several million tons annually located near suitable storage formations, dedicated pipelines may be viable. For everyone else, hub participation or ship transportation becomes necessary.

If shared infrastructure is required, the gate involves confirming that hub development is sufficiently advanced, that governance and cost-sharing arrangements are acceptable, and that timing aligns with your needs. Many projects have stalled at this gate when anticipated hubs faced delays, when cost allocations proved unacceptable, or when anchor tenants withdrew and altered hub economics for remaining participants. The question is not just whether infrastructure might exist eventually, but whether it will exist on your timeline with terms you can accept.

Key questions – Transportation management

- Who provides the CO_2 transportation service?
- What are the permitting and regulatory requirements to deliver the transportation service?
- What are the CO_2 purity requirements of the T&S operators?
- How will the risk and liability of CO_2 losses be handled?

CAPTURE MANAGEMENT

The questions outlined earlier about CO_2 volume, concentration, purity, and variability determine which capture technologies are feasible. Technology selection must balance proven reliability against potential cost advantages from newer approaches. How much does each option cost, and how have individual choices impacted cost? How can costs be minimized without increasing technology or engineering risk?

For many companies, the capture gate also involves fundamental questions about capability and control. Do we have or can we develop the in-house expertise to design, build, and operate capture systems? If not, can we access reliable technology providers who will assume performance risk through guaranteed delivery? The limited availability of full-service providers willing to take on performance risk means many companies face a choice between developing capabilities they may lack or accepting underperformance risk themselves.

Key questions – Capture management

- How much CO_2 is produced?
- Is flue gas produced in a steady flow, dynamically, or in batches?
- How does the flue gas volume vary with time?
- What is the purity and composition of the flue gas, incl. solids and trace elements?
- Is CO_2 concentration static or dynamic?
- What are the options for CO_2 capture technology?
- How much does this cost? How have individual choices impacted cost?
- How can cost be minimized without increasing technology or engineering risk?

BUSINESS MODEL VALIDATION

This gate integrates capture, transportation, and storage into coherent operational arrangements. Do all partners involved properly participate in risk- and value-sharing mechanisms? The choice between fully integrated models where one entity controls the entire chain versus disaggregated models with specialized providers at each stage carries implications for control, risk allocation, and economics. Integrated models offer simplicity and clear accountability but require capabilities across domains that few companies possess. Disaggregated models leverage specialized expertise but create complex interfaces and liability questions at each handoff point.

This gate also involves confirming that all prerequisites can be fulfilled on time by all partners. Does the technology provider have the engineering capacity to deliver on schedule? Can transportation infrastructure be built or accessed when needed? Will storage permitting be complete before CO_2 flow begins? Misalignment in timing across the value chain has caused numerous project delays, as each partner's investment depends on others proceeding in coordination.

Key questions – Business model validation

- What is the business model and operating model?
- Who is the technology provider & CCS operator?
- Is a proper and reliable reporting system available?
- Do all ecosystem partners have clear responsibilities and accountability?
- Are all partners involved properly in risk- and value-sharing mechanisms?
- Can the ecosystem and infrastructure prerequisites of all partners be fulfilled on time?

FINANCIAL APPROVAL

By this stage, technical feasibility has been established, partnerships are in place, and risk allocation is defined. The question becomes whether the comprehensive business case – incorporating all costs, revenues, risks, and uncertainties – justifies the investment given alternative uses of capital and the company's risk appetite.

The financial approval gate requires stress testing the business case against scenarios for carbon price trajectories, green premium evolution, cost overruns, operational underperformance, regulatory changes, and market demand. Companies must also confirm financing arrangements. What is the debt-to-equity structure, and what covenants do lenders require? Are specialized project finance structures necessary, or can the investment be funded from the corporate balance sheet? What role will government grants or concessional finance play, and are those commitments binding? The expectations of financial partners regarding returns, security, and governance rights must align with the company's plans before proceeding.

Key questions – Financial approval

- What is the business case?
- What is my value proposition?
- What are potential revenue streams? How can I grow and protect my revenue stream?
- What is the customers' willingness to pay? How will it change with time?
- What are costs incl. CAPEX and OPEX? What are key influencing factors? How will cost change with time?
- What is the project return expectation?
- Can it be benchmarked against competitors?
- What is the impact on other products and/or assets?
- How will the project be financed?
- What is the expectation of the financial partner(s)?
- What are potential incentives and grants?

"CCS decision-making faces all the challenges of large capital projects plus additional hurdles: regulatory uncertainty, immature ecosystems, and high policy dependency. Without a systematic framework considering the full value chain, companies risk optimizing individual components while missing critical interdependencies."

Ruirui Zong-Ruehe, Partner,
Roland Berger

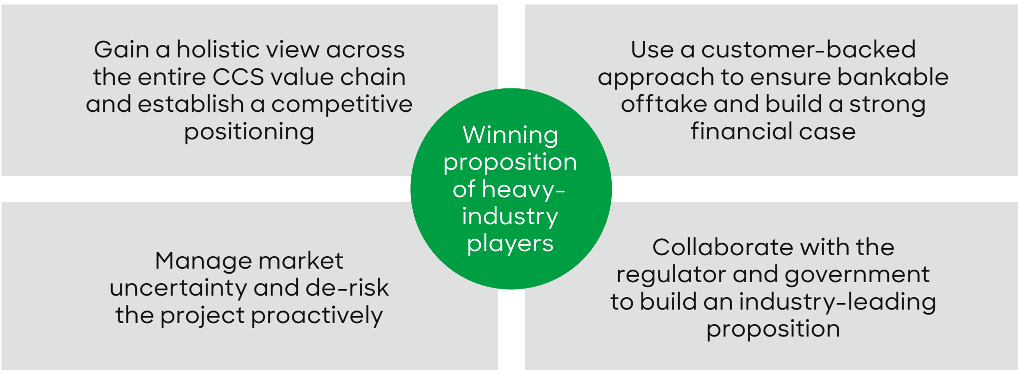
3.2/ Recommendations for industry players

These recommendations synthesize insights from successful projects and address the challenges identified in our industry interviews. ▶ AA

AA Energy-intensive industry players face both challenges and opportunities with decarbonization via CCS

Call to action to energy-intensive sectors

Recommendation



Source: Roland Berger

ESTABLISH COMPETITIVE POSITIONING

The CCS landscape is evolving rapidly, with costs declining, regulations tightening, and early movers capturing advantageous positions. Companies should invest in continuous learning through active engagement in industry events and working groups, assigning dedicated personnel to track technology developments, regulatory changes, competitor movements, and infrastructure developments. Regular exchange with peers, suppliers, and customers reveals practical implementation challenges and partnership dynamics that published sources cannot capture.

Identify your winning value proposition based on realistic assessment of your ambition and capabilities. Companies with high-concentration CO_2 streams and facilities in supportive regions have natural advantages. Those serving sustainability-focused end markets have clearer revenue pathways than commodity producers. The value proposition extends beyond project economics to corporate positioning – for some, CCS is about capturing green premiums and building expertise; for others, it's defensive, avoiding penalties and preserving social license. Honest capability assessment should determine whether to build internal expertise, partner with experienced players, or wait for market maturation.

Review objectives periodically through formal annual cycles to reassess alignment with corporate strategy and validate economic assumptions. These reviews should explicitly consider whether to accelerate, maintain pace, or slow investments based on changing conditions in carbon prices, green premiums, competitor movements, and regulatory developments.

MANAGE MARKET UNCERTAINTY PROACTIVELY

CCS projects face uncertainties that cannot be eliminated but can be managed through scenario analysis, diversification, and risk mitigation. Apply robust scenario analysis that extends beyond financial modeling into strategic decision-making, informing the process of how to structure investments for flexibility. For energy sourcing – the 70% driver of operating costs – evaluate multiple approaches with different risk profiles, choosing options that provide resilience across scenarios for electricity prices, process changes, and grid decarbonization rather than simply minimizing first costs.

Build alternatives and diversify provider relationships where scale permits. Companies with multiple facilities should avoid exclusive dependence on single technology providers, transportation operators, or storage sites, balancing the efficiency benefits of standardization against the resilience benefits of diversity. For smaller emitters, evaluate hub participation opportunities that incorporate multiple options across the value chain. Agree on risk appetite internally and with partners before committing, ensuring explicit alignment on acceptable uncertainty, performance tolerances, and appropriate risk allocation.

Identify risk-specific countermeasures for regulatory, technology, and operational uncertainties, then calculate residual risks after mitigation. If residual risks exceed organizational tolerance even after countermeasures, restructure the project, seek additional risk transfer mechanisms including government support, or decline to proceed.

USE A CUSTOMER-BACKED APPROACH TO ENSURE BANKABLE OFFTAKE

Revenue uncertainty represents one of the most significant risks in CCS business cases. Engage potential customers early to understand their decarbonization commitments, timeline pressures, and premium willingness, moving beyond general sustainability statements to specific offtake agreements that provide bankable evidence of demand. The automotive industry exemplifies validated demand, with major OEMs announcing green steel commitments with specific volumes and timing. Producers who secure long-term offtake agreements before building CCS systems face far less revenue risk than those hoping demand materializes.

Synchronize CCS deployment with customer development timelines. Moving too fast creates stranded assets; moving too slowly allows competitors to capture advantageous relationships. Automotive OEMs face compressed timelines, with substantial green procurement targeted by 2030, while construction markets have longer, more varied timelines. Build strategic partnerships that provide revenue certainty through long-term agreements, potentially involving upfront capital contributions or offtake guarantees in exchange for preferential access. Emphasize reciprocal value creation rather than optimizing each transaction – flexible arrangements that share both upside and downside build more resilient partnerships than rigid contracts that fail when circumstances change.

COLLABORATE WITH REGULATORS AND GOVERNMENT

While companies can make CCS work through careful project selection and risk management, deployment pace and scale depend critically on regulatory frameworks. Establish communication channels with government bodies and provide regulators with concrete information about decision-making processes, cost drivers, and technical constraints that may not be visible from policy perspectives. Follow regulatory changes in real time across relevant jurisdictions, monitoring not just final regulations but proposals and consultations that signal future directions, then translate these changes into business implications.

Participate proactively in regulatory discussions through consultation responses and working group participation, offering specific suggestions for improvement rather than generic opposition. Support stable, predictable policy mechanisms even when less generous than alternatives, building credibility with regulators and coalitions with other stakeholders. Help shape industry norms and standards through participation in technical committees and standards development organizations, contributing operational insights to ensure standards reflect practical reality rather than theoretical ideals that prove unworkable.

3.3/ Call to action for regulators

While companies bear responsibility for executing CCS projects successfully, regulators and governments create the conditions that determine whether deployment occurs the scale and pace necessary to achieve climate objectives. There are six key priorities policymakers must focus on to create investable conditions. ▶ AB

AB Stable regulatory environment and clear focus on decarbonization are essential for successful development of CCS projects

Key asks for regulators

Support requirement	Impact	Ease of implementation
1 Create a stable regulatory environment	●	◑
2 Foster predictable and investable market	◕	◔
3 Enable globalization of carbon abatement	◕	◔
4 Define incentives and risk-sharing mechanisms	◕	◔
5 Develop framework for liability sharing	◕	◔
6 Foster public trust and institutional readiness	◕	◔

Source: Desk research, interviews with market participants, Roland Berger

1. CREATE A STABLE REGULATORY ENVIRONMENT

Policy stability emerges as the single most important factor enabling CCS investment, as companies require confidence that regulatory frameworks will persist over 15-to-20-year project lifetimes. Governments must develop dedicated CCS roadmaps integrated into broader climate strategies that specify which sectors should deploy CCS, what volumes are targeted, and explicit timelines – providing certainty that investments will be recognized as legitimate pathways rather than opening the door to future policy reversals.

Credible commitment mechanisms may include multi-year contractual protections, automatic sunset provisions requiring explicit action to terminate rather than automatic expiration, and clear sectoral targets with interim milestones enable investment decisions that pure political commitments cannot achieve.

2. FOSTER PREDICTABLE AND INVESTABLE MARKETS

CCS deployment requires market mechanisms providing predictable revenue streams for captured CO_2, with carbon pricing implemented to create investment certainty rather than price volatility that prevents long-term commitments. Hybrid approaches combining market mechanisms with price management tools – such as carbon price floors establishing minimum levels alongside published long-term price trajectories – offer promising middle ground between pure market efficiency and the predictability necessary for investment.

Carbon Contracts for Difference (CCfDs) can bridge viability gaps by guaranteeing minimum returns through paying the difference between agreed strike prices and market carbon prices, with Germany's pilot program demonstrating how competitive auctions with declining strike prices and limited contract durations provide certainty while limiting fiscal exposure and maintaining pressure for cost reduction. Standardizing CO_2 measurement, reporting, and verification (MRV) across jurisdictions through internationally recognized frameworks would substantially reduce transaction costs and enable efficient market functioning, particularly for cross-border activities, though standards must balance rigor against practicality to avoid making marginal projects uneconomic.

3. DEVELOP FRAMEWORK FOR LIABILITY SHARING

Unclear liability allocation ranks among the top barriers to CCS deployment, as banks and investors require certainty about who bears consequences when storage fails, transportation incidents occur, or CO_2 losses happen during decades-long operations. Clear liability frameworks should allocate responsibility based on control and expertise: Emitters bear capture performance liability, transportation operators bear pipeline safety and integrity liability, and storage operators bear reservoir performance liability during operational periods (20-30 years), with government assumption of very long-term stewardship liability (50-100+ years) becoming necessary since no private entity can credibly commit to century-long monitoring and no insurance market can provide such coverage.

Cross-border and cross-jurisdictional liability issues require international agreements or regional protocols addressing which laws apply when incidents occur, how liability is allocated between parties in different countries, and whether financial guarantees are mutually recognized – with frameworks enabling insurance market development through regulatory clarity that allows actuarial risk pricing and product structuring.

4. DEFINE INCENTIVES AND RISK-SHARING MECHANISMS

Early CCS projects require policy support to bridge gaps between costs and revenues, with incentive design substantially affecting both fiscal efficiency and deployment effectiveness through transparent eligibility criteria that allow companies to determine qualification without extensive regulatory consultation. Enhanced support for first-of-a-kind installations recognizes their learning benefits and infrastructure development, enabling subsequent projects – through higher initial incentive rates with published phase-downs, dedicated funding for pioneer technologies, or competitive allocation based on the highest learning potential – creating urgency through time-limited premiums rather than allowing indefinite deferral. OPEX tax credits like the US 45Q (providing credits per ton stored) offer advantages over pure capital subsidies by creating continued performance incentives, sharing volume risk between companies and government, and better aligning with CCS economics where operating costs from energy consumption dominate lifetime expenses.

Streamlining permitting through maximum review periods, coordinated multi-agency processes, one-stop coordination bodies, and pre-application consultation can prevent indefinite delays while maintaining environmental protection, with particular focus on incentivizing regional hubs that achieve scale economies through shared infrastructure rather than supporting only isolated projects.

5. BUILD PUBLIC TRUST AND INSTITUTIONAL READINESS

Building social license and institutional capability requires sustained attention to public acceptance campaigns emphasizing CCS's role in decarbonizing hard-to-abate industries rather than positioning it as fossil fuel extension, with balanced information acknowledging both benefits and risks rather than purely promotional messaging.

Transparent communication and meaningful community involvement in project siting and permitting – occurring early when designs can accommodate input – builds trust through clear site selection explanations, geological data disclosure, honest risk discussions, and ongoing monitoring transparency, with independent oversight and economic benefit sharing creating positive local incentives and balancing proximity risks.

Strengthening regulatory institutional expertise through hiring technical specialists, providing CCS-specific training, developing clear guidance codifying best practices, and establishing inter-agency coordination mechanisms should occur before major project deployment rather than attempting to build capability while simultaneously regulating first projects, with international cooperation through organizations like the Global CCS Institute accelerating institutional learning across jurisdictions.

6. ENABLE GLOBALIZATION OF CARBON ABATEMENT

CCS costs varying dramatically across geographies creates opportunities for international cooperation, enabling lowest-cost global abatement through cross-border CO_2 transportation and storage arrangements. Facilitating molecular CO_2 flow across borders requires international frameworks that build on London Protocol amendments, addressing liability allocation, credit recognition, and regulatory oversight, with the Northern Lights project demonstrating how countries with emissions (Belgium, Singapore) could potentially ship CO_2 to countries with abundant storage (Norway, Australia).

Mutual recognition frameworks for regulatory approvals, credit certification, and monitoring standards would reduce transaction costs by allowing one jurisdiction's assessments to be accepted in others when standards are deemed equivalent – similar to pharmaceutical approvals or professional qualifications – covering storage site assessments, MRV protocols, and technology certifications. Compliance market mechanisms that recognize international abatement through carefully designed credit systems with corresponding adjustments to prevent double-counting could accelerate deployment in optimal locations while maintaining environmental integrity, with international coordination on technical standards, verification protocols, liability frameworks, and contractual templates preventing market fragmentation that particularly disadvantages smaller projects.

THE PATH FORWARD

We are entering a decisive period for CCS deployments, where early movers will capture advantages that cannot be replicated later. The 2025-2035 window represents a unique convergence: Costs are declining rapidly but remain high enough for green premiums to provide meaningful revenue, carbon prices are rising but infrastructure is still being established, and customers are willing to pay for differentiation before decarbonized products become commoditized expectations.

The paradox of CCS deployment is that it requires accepting uncertainty while demanding long-term commitment. No amount of analysis will eliminate the regulatory uncertainty, social acceptance variability, or liability ambiguity that make CCS investments challenging. The companies and countries that succeed will not be those that wait for perfect certainty, but rather those that build resilience into their strategies through scenario planning, diversified partnerships, flexible design, and proactive stakeholder engagement.

For regulators, the most impactful intervention may not be increasing subsidy levels but establishing credible long-term frameworks. Our research consistently revealed that regulatory stability matters as much as regulatory generosity for enabling investment – a stable but modest carbon price floor provides more investable certainty than a generous but unpredictable subsidy subject to political reversal, and clear liability frameworks make more projects bankable than vague assurances that issues will somehow be resolved.

The ultimate insight is that CCS is less a technical challenge than an orchestration challenge. Success requires synchronizing actions across companies, regulators, financial institutions, technology providers, infrastructure operators, and communities – each with different incentives, capabilities, and constraints.

The technical components exist and are proven. The economics are increasingly favorable. What remains difficult is aligning these diverse actors around shared timelines, risk allocations, and value distributions that allow complex, multi-decade projects to proceed. The countries and companies that excel at this orchestration – building trust through transparency, creating alignment through fair value sharing, managing complexity through clear governance, and maintaining momentum through consistent commitment – will lead the CCS era.

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