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Decarbonized & Sustainable Industry
World Summit
November 3–5, 2026



DS Industry
November 3, 2026

Industrial CCUS: keys to maturing projects and make sound decisions

Technologies Track - CO_2 capture and utilization in industry

Arturo Basurto - Sustainable Industry Business Manager - Sener

Sener Group

70 years of success **transforming the world** by challenging the boundaries of technology









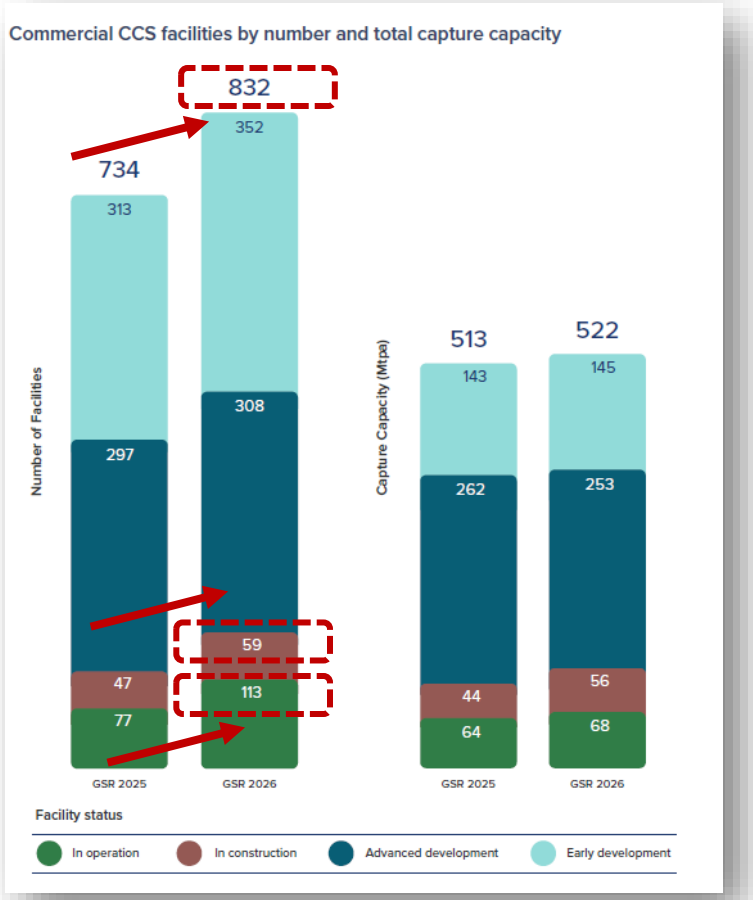


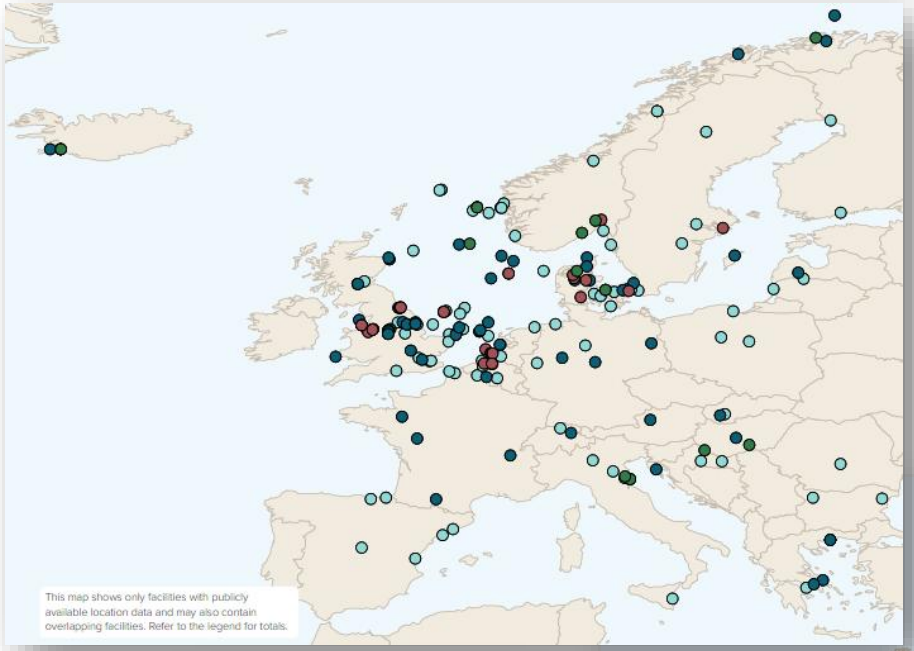
Founded in 1956, ***Sener*** *was the first privately owned engineering firm in Spain.*

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CCS is advancing — the next challenge is turning development into delivery

Worldwide





Facility status	
Early development	139
Advanced development	83
In construction	21
In operation	15

832
Projects: Total number rises by 13% year on year

113
Projects operating globally

266
CO_2 transport and storage projects: 32% of total projects

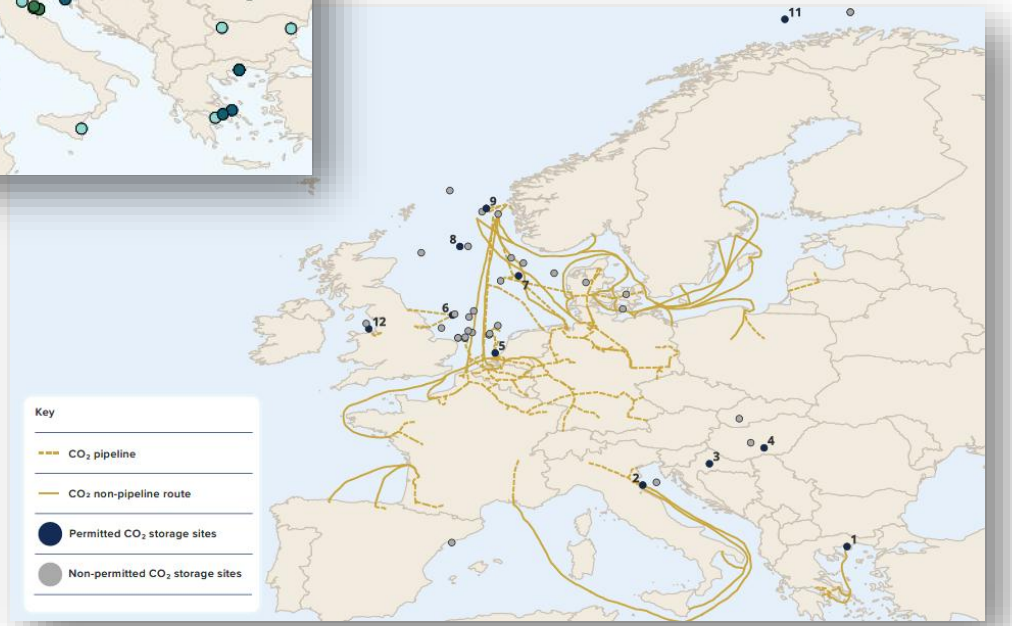
>400 Mt
CO_2 captured and permanently stored since 1996

GLOBAL STATUS OF CCS 2026
SUSTAINING GLOBAL PROGRESS

Europe:

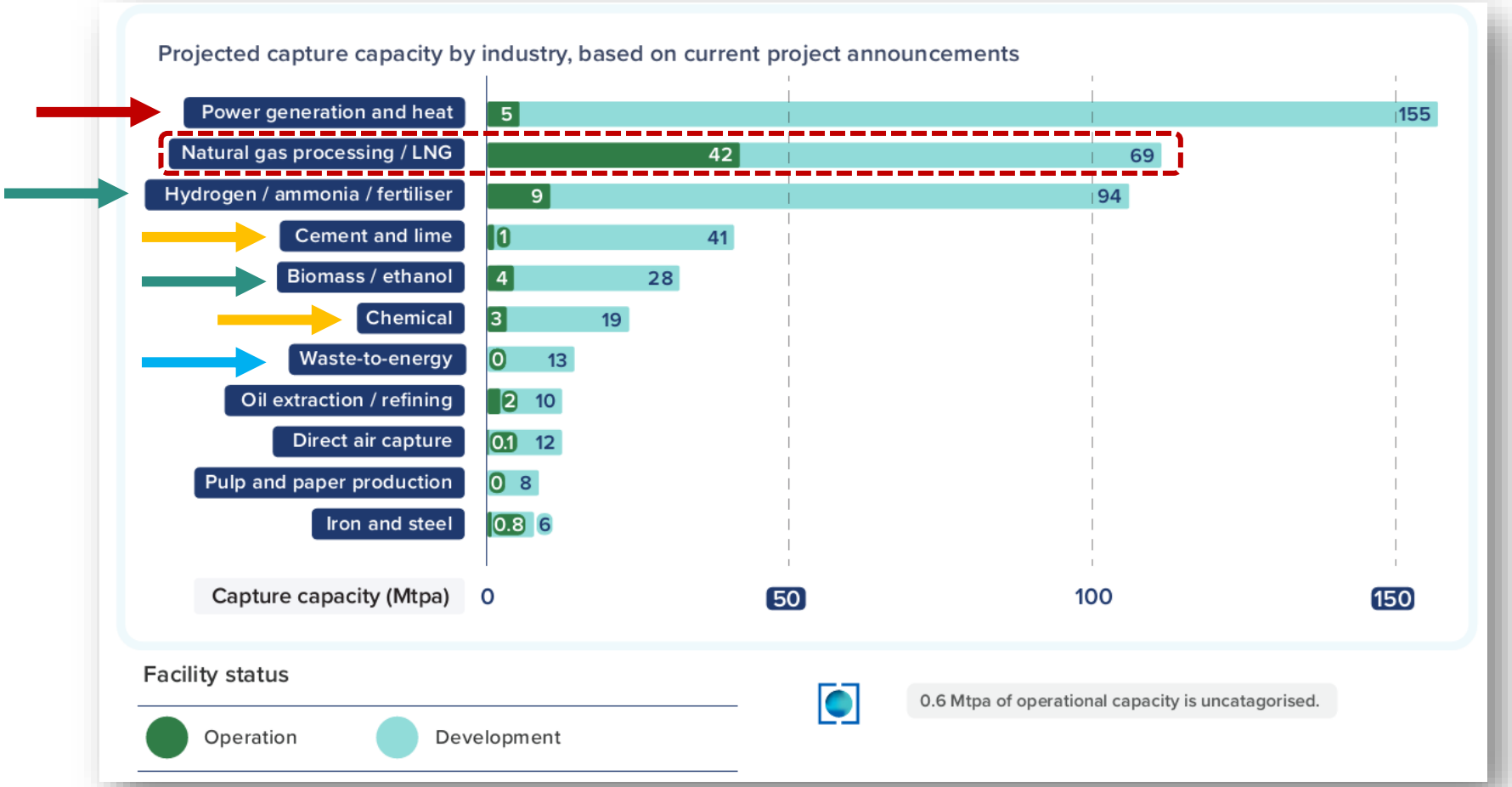
222 of 258 projects still in development — 86%

139 early development + 83 advanced development



Planned CO_2 transport routes and storage sites

CCS is moving into new sectors — each with its own integration challenges





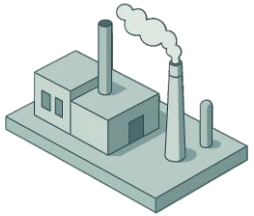
Different gas streams and energy needs

Different site and operating constraints

A tailored approach for each industrial process

Project Phases from the CO_2 Emitter's Perspective

EID: Engineering Investment Decision
F&s: Funding and Support Mechanisms
FID: Final Investment Decision
COD: Commercial Operation Date



CO_2 Emitter Journey

Study Phase

EID

F&S

- **Defining the project:** objectives, scope and development strategy.
- Establishing the **emitter baseline** and **plant constraints.**
- Screening **CCUS pathways.**
- Outlining the **initial business model** and **external enablers.**
- Developing the **preliminary roadmap** and **initiating permitting and funding applications.**

Preparation Phase

FID

- Establishing **project governance** and the **Basis of Design.**
- Selecting the **technologies, licensors/OEMs and integrator engineering team** and **launching the FEED.**
- Defining the **execution strategy** and **preparing for implementation.**
- Advancing **permitting** actions and external approvals, in parallel with engagement of **lenders, grant authorities and local stakeholders.**
- Updating the **business model** and preparing the **execution-phase procurement.**

Execution Phase

COD

- **Overseeing project execution and governance** and ensuring **Owner Engineering** support.
- Coordinating **communication, permitting** closure and **legalization** requirements.
- Preparing and managing the **operation team.**
- **Executing commissioning** and **performance validation.**
- **Implementing CO_2 monitoring, reporting and verification.**

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Screening of technologies	Feasibility study/ Conceptual engineering	Basic engineering/pre-FEED/FEED	Detailed Engineering, Procurement, Construction & Commissioning
8 – 12 months		10 – 12 months	30 – 40 months

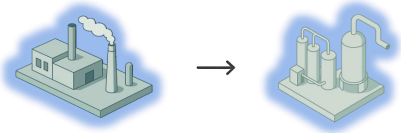
Permitting: 12 – 24 months

Estimated timelines for plants with a CO_2 capacity above 100 ktpa

Progressive project definition, risk reduction and informed decisions

Selecting the right capture solution starts with understanding the plant

Technology-agnostic assessment. Site-specific solutions.



Gas composition & variability · Energy availability · Space & operations · CO_2 delivery requirements

Chemistry-based capture routes

- **Amine Absorption**
  - Honeywell UOP
  - slb Capturi
  - FLUOR
  - GEA
  - Linde
  - PENTAIR
  - ANDRITZ
  - Shell / TEN / TECHNIP ENERGIES
  - MITSUBISHI HEAVY INDUSTRIES
  - Air Liquide
- **Hot Potassium Carbonate**
  - Baker Hughes
  - Sumitomo SHI/FW
  - Honeywell UOP
  - capsol technologies
  - ANDRITZ
- **Other Liquid chemical solvents**
  - Baker Hughes
  - novonesis
  - SAIPEM
- **Chemical/Calcium looping**
  - B&W BABCOCK & WILCOX
  - TECNICAS REUNIDAS
  - Sumitomo SHI/FW

Physical capture routes

- **Cryogenic carbon capture**
  - Linde
  - Honeywell UOP
  - CHART
  - Air Liquide
  - TPI TECNO PROJECT INDUSTRIALE — SIAD Group
- **Metal Organic Frameworks MOFs**
  - Svante
  - Nuada
  - novoMOF
- **Physical Solvent Absorption**
  - Linde
  - Honeywell UOP
  - Air Liquide
- **Membrane separation systems**
  - MTR INDUSTRIAL SEPARATIONS
  - EVONIK Leading Beyond Chemistry
  - BORSIG
  - Honeywell
  - Ardent

Process Intensification Concepts

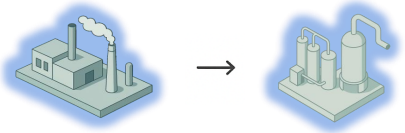
- **Phase-splitting solvent**
  - Axens
- **Rotary Systems**
  - carbon clean
  - Baker Hughes
  - Svante
  - KBR
- **Oxy-combustion**
  - thyssenkrupp
  - Sumitomo SHI/FW
- **Hybrid Separation Trains**
  - Linde
  - Honeywell UOP
  - Air Liquide

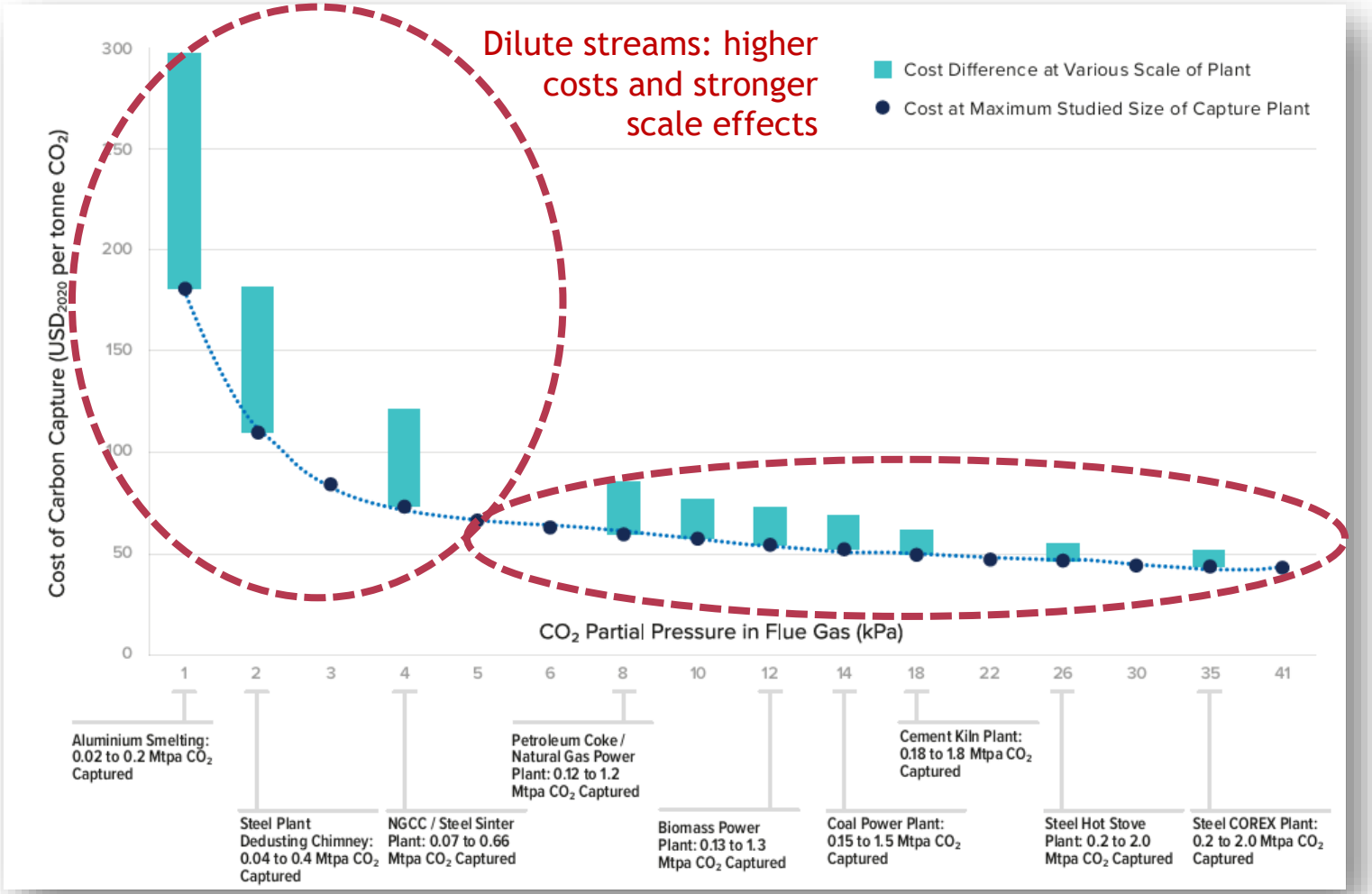
Preparing the existing plant is part of preparing for capture

Illustrative technology landscape — categories may overlap

CO_2 concentration and capture scale influence capture costs

Plant optimization can improve the economics of future capture





Higher CO_2 partial pressure: lower capture costs and less pronounced scale effects

Source: Global CCS Institute, 2021.
MEA-based estimates; costs in USD2020/tCO2.
Indicative trends, subject to study assumptions.

CO_2 quality: aligning requirements across the value chain

Downstream requirements shape capture and conditioning decisions

* Illustrative CO_2 chain



Interfaces: agreed CO_2 quality, delivery conditions, measurement and responsibilities.

Where should purification and conditioning take place?

CO_2 Specification

- **Align CO_2 specifications across the value chain:** translate transport, intermediate storage and final storage or use requirements into practical quality specifications, delivery conditions and clear responsibilities at each interface.
- **Assess impurities and their combined effects:** evaluate how CO_2 composition affects flow assurance, corrosion, materials selection, safety and environmental performance under the expected operating conditions.
- **Optimize purification and conditioning across the chain:** determine which treatment steps belong at the emitter, shared hub facilities or export terminals, coordinating investment and responsibilities to minimize total CAPEX and OPEX while meeting specifications.

Flow Assurance

Two-phase flow, impurity solubility, hydrate formation

Ship materials / design

Transport conditions, sizing and material selection

Pipeline materials / design

Cracking, ductile fracture

Regulatory requirements

Materials / chemical reaction

Material integrity, acid formation and corrosion

Well integrity

Compatibility with well materials and storage formation; injectivity

Measurements

Accuracy and frequency

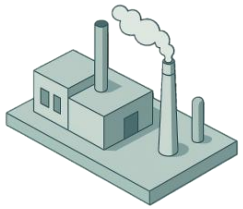
HSE

Impact of impurities on health & environment

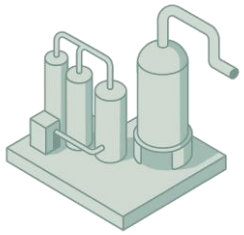
Reaching FID requires more than capture technology and CAPEX support

Enabling the CCUS ecosystem through mechanisms that reduce uncertainty and share risks

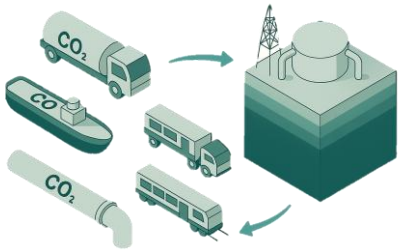




Emitter



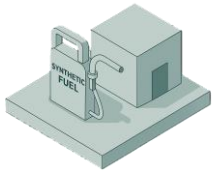
Capture & Conditioning



Logistics



Permanent Storage



Use

Carbon value and commercial revenues

- **Avoided EU ETS allowance costs**, assessed under long-term carbon-price scenarios.
- **Certified carbon removal revenues** from eligible biogenic CO_2 capture and permanent storage.
- **CO_2 sales under long-term offtake agreements**, including supply to synthetic fuel production.
- **Demand and potential price premiums** for low-carbon industrial products.

Public support for investment and operation

- **Investment grants**, including the EU Innovation Fund, Spain's industrial decarbonization PERTE and other national schemes.
- **Operating support**, including competitively awarded payments for CO_2 capture and storage.
- **Carbon contracts for difference**, helping bridge the cost gap and reduce exposure to carbon-price uncertainty.
- **Compatible support mechanisms and aligned timelines**, providing clarity before investment decisions.

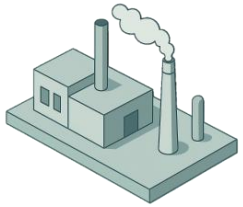
Shared CO_2 infrastructure and industrial hubs

- **Aggregation of CO_2 volumes from nearby emitters**, creating economies of scale where technically and economically justified.
- **Shared transport, conditioning and terminal facilities**, connecting emitters to storage or utilization.
- **Coordinated capacity development and phased expansion**, aligned with emitter demand and downstream availability.
- **Regional and cross-border connections**, expanding access to viable storage and utilization options.

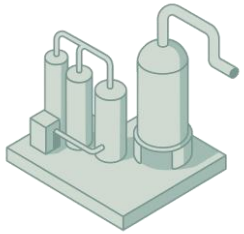
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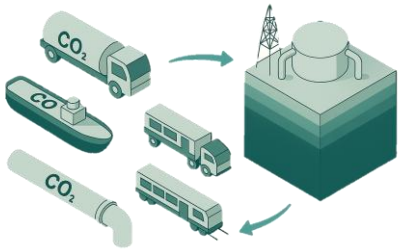




Emitter



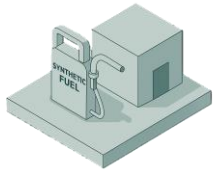
Capture & Conditioning



Logistics



Permanent Storage



Use

Competitive and reliable energy supply

- **Timely access to electricity and heat**, with adequate grid capacity and suitable supply conditions.
- **Energy integration and heat recovery**, reducing additional energy demand and operating costs.
- **Competitive and predictable energy costs**, supported by reliable supply arrangements over the project's operating life.

Commercial commitments and risk allocation

- **Compatible contractual commitments** on CO_2 volumes, quality, capacity, start-up dates and availability.
- **Predictable commercial terms**, including transport and storage tariffs and price-adjustment mechanisms.
- **Clear responsibilities and remedies** for delays, interruptions and off-specification deliveries.
- **Balanced allocation of remaining risks**, supported where appropriate by guarantees, insurance or public risk-sharing mechanisms.

Regulatory certainty and public trust

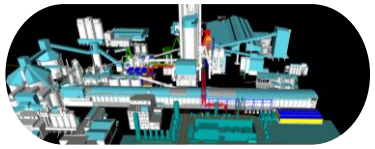
- **Clear and predictable regulation and permitting**, including workable cross-border arrangements.
- **Consistent CO_2 accounting, certification and verification**, with clear recognition of climate benefits and safeguards against double counting.
- **Early stakeholder engagement and transparent communication**, addressing safety, local impacts and community concerns.

Reaching FID requires a viable business model, balanced risk allocation and aligned public and private commitments

Sener's recent project experience across the CCUS value chain

Practical insights from Study Phase and Preparation Phase services

Molins Sant Vicenç dels Horts - MOSUSOL-NetCO₂



- **Sener Scope:** Conceptual Engineering + Support with with funding and grant applications.
- **Tech:** Polysius Oxyfuel + Linde ASU+CPU.
- **Capture capacity:** ≈1 $MtCO_2$/year.
- **Public support:** Selected for EU Innovation Fund funding - 2025 Call.

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- **Sener Scope:** Conceptual Engineering + Support with funding and grant applications.
- **Tech:** Air Liquide **Cryocap™ FG**.
- **Capture capacity:** ≈0,7-1,1 $MtCO_2$/year.
- **Public support:** €200 million awarded under Spain's industrial decarb. PERTE.

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- **Sener Scope:** Conceptual Engineering + Support with funding and grant applications.
- **Tech:** Linde **HISORP® CC**.
- **Capture capacity:** ≈0,78 $MtCO_2$/year

Terresis Zubiri (Navarra); MAGNESIA PLANT



- **Sener Scope:** Pre-FEED Engineering.
- **Tech:** Capsol HPC.
- **Capture capacity:** ≈0,33 $MtCO_2$/year

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ANALYSIS OF CO_2 SPECIFICATIONS REQUIRED FROM EMITTERS FOR MAJOR CCUS HUBS IN SPAIN

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FEASIBILITY STUDY + CONCEPTUAL ENGINEERING FOR A CO_2 TERMINAL AT AN LNG FACILITY IN SPAIN

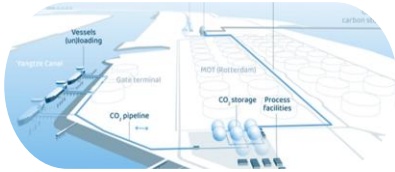


aeb amsterdam AURORA PROJECT – CO_2 CAPTURE AT WTE (AMSTERDAM)



- **Sener Scope:** FEED Engineering.
- **Tech:** SLB Capturi.
- **Partners:** Sener + SLB Capturi + Acciona.
- **Capture capacity:** ≈0,5 $MtCO_2$/year

Vopak Gasunie CO2NEXT PROJECT – LIQUID CO_2 TERMINAL (ROTTERDAM)



- **Sener Scope:** FEED Engineering.
- **Concept:** LCO_2 reception from ships and barges, intermediate storage in pressurised spheres, and onward transport to offshore storage via the Aramis pipeline.
- **Design throughput:** 5.4 $MtCO_2$/year in Phase 1, expandable to 10 $MtCO_2$/year.
- **Storage capacity:** 48,000 m^3 in Phase 1, expandable to 80,000 m^3.

CEMEX Rüdersdorf - CO2LLECT

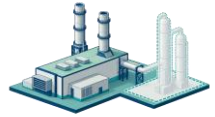


- **Sener Scope:** Conceptual Engineering + Support with funding and grant applications + Pre-FEED + FEED Engineering (BOP + Railway Infrastructure).
- **Tech:** Linde **HISORP® CC**.
- **Capture capacity:** ≈1,3 $MtCO_2$/year
- **Public support:** Selected for EU Innovation Fund funding - 2023 Call.



SUSTAINABLE MULTI-FUEL TANKER — ONBOARD CO_2 CAPTURE

- **Sener scope:** Conceptual Engineering.
- **Vessel capacity:** 5,000 m^3 multi-cargo bunkering tanker.
- **CO_2 concept:** Onboard capture and storage, with provision for future reception of CO_2 captured by other vessels.



CARBON CAPTURE READINESS — CCGT & COGENERATION

- **Sener scope:** Conceptual studies for carbon capture readiness in existing and new-build large-scale power plants.
- **Focus:** Space reservation, flue-gas connections and utility interfaces to enable future capture integration.
- **Locations:** Germany, Netherlands, Saudi Arabia.

Sener’s recent project experience across the CCUS value chain

Practical insights from Study Phase and Preparation Phase services

Lessons learned: building a robust project definition

Early decisions shape integration, operability and future cost



Reliable data and clear interfaces come first

- Consolidate the design basis and responsibilities before advancing engineering.
- Verify existing equipment, utilities and underground services where as-built information is incomplete.

Characterization must reflect real plant conditions

- Assess gas composition, contaminants and variability, including future fuel and feedstock changes.
- Use targeted testing or pilots to assess solvent behaviour, materials compatibility and effluent treatment.





Integration extends well beyond the capture unit

- Address heat recovery, electricity, cooling, water and space constraints as part of the overall design.
- Check equipment references and performance guarantees against the actual process conditions.

Operability and CO_2 delivery requirements belong in early design

- Define start-up, shutdown, trips and flue-gas bypass arrangements, supported by dynamic simulation where needed.
- Align CO_2 quality and delivery conditions with downstream requirements and intended flexibility.

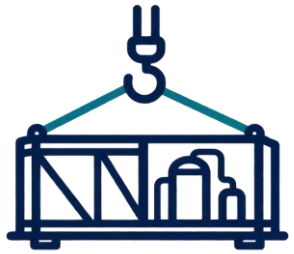


Sener’s recent project experience across the CCUS value chain

Practical insights from Study Phase and Preparation Phase services

Lessons learned: preparing for delivery and investment

Realistic execution plans and economics must develop alongside engineering



Constructability needs attention before execution

- Assess module sizes, transport routes, access, lifting and brownfield interferences early.
- Involve experienced contractors and suppliers during project development.
- Plan construction with the industrial plant in operation, considering access restrictions, tie-ins and shutdown requirements.

Integration and ramp-up risks need realistic allowances

- Allow for design changes, commissioning duration and lower initial availability in unfamiliar applications.
- Reflect these risks in schedules, contingencies and the business model.





Economics must cover the complete operating chain

- Include integration and utilities, scale effects, consumables and supplier dependencies.
- Account for transport/storage charges, CO_2 losses and realistic carbon-value scenarios.

Permitting and stakeholder coordination are project work

- Engage authorities, infrastructure partners and communities early.
- Clarify permitting requirements, MRV and CO_2 specifications, drawing on shared international experience.




*Illustrative project rendering
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Putting integration into practice
A tailored capture solution starts with the reality of the existing plant

Decarbonized & Sustainable Industry

World Summit
November 3–5, 2026

Thank you.
Let’s move forward together



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