CARBON LIMITS

Some challenges and opportunities for CCUS deployment in Europe – key results of some of our recent fact-based projects

September 2022 - Paris

Gaëlle Cauchois – Associate Director
Carbon Limits, Oslo, Norway

Agenda

CARBON LIMITS

1. Gap between developed storage space and the storage needs of capture projects
2. Gap between funding requirements for CCS and announced available public funding in the coming years
3. Some opportunities for cost reduction

Will there be enough storage sites developed to meet the demand?

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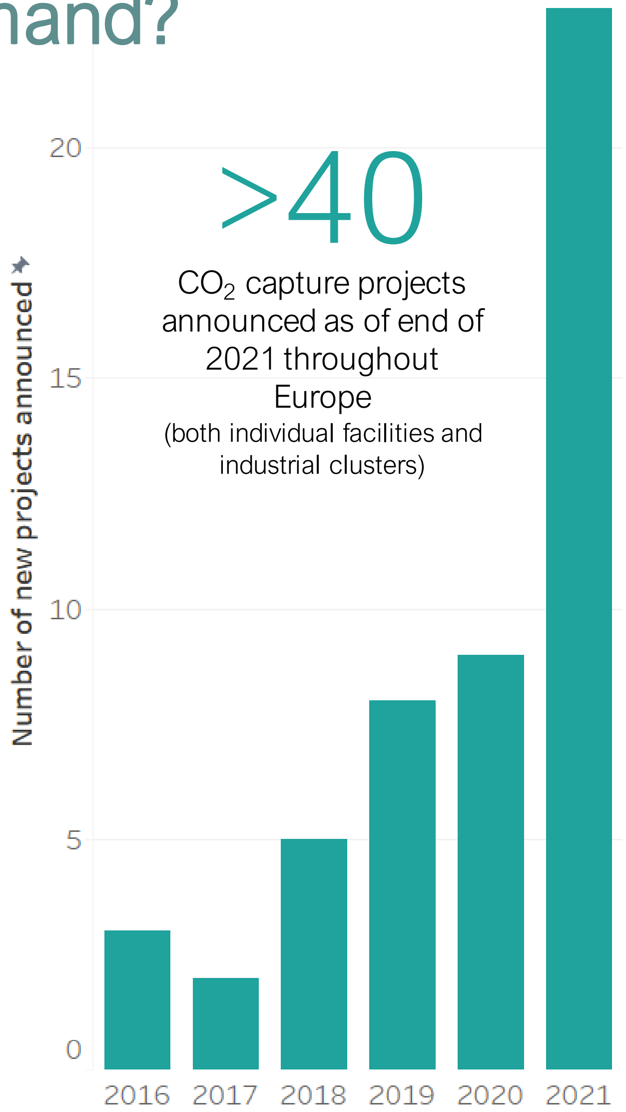


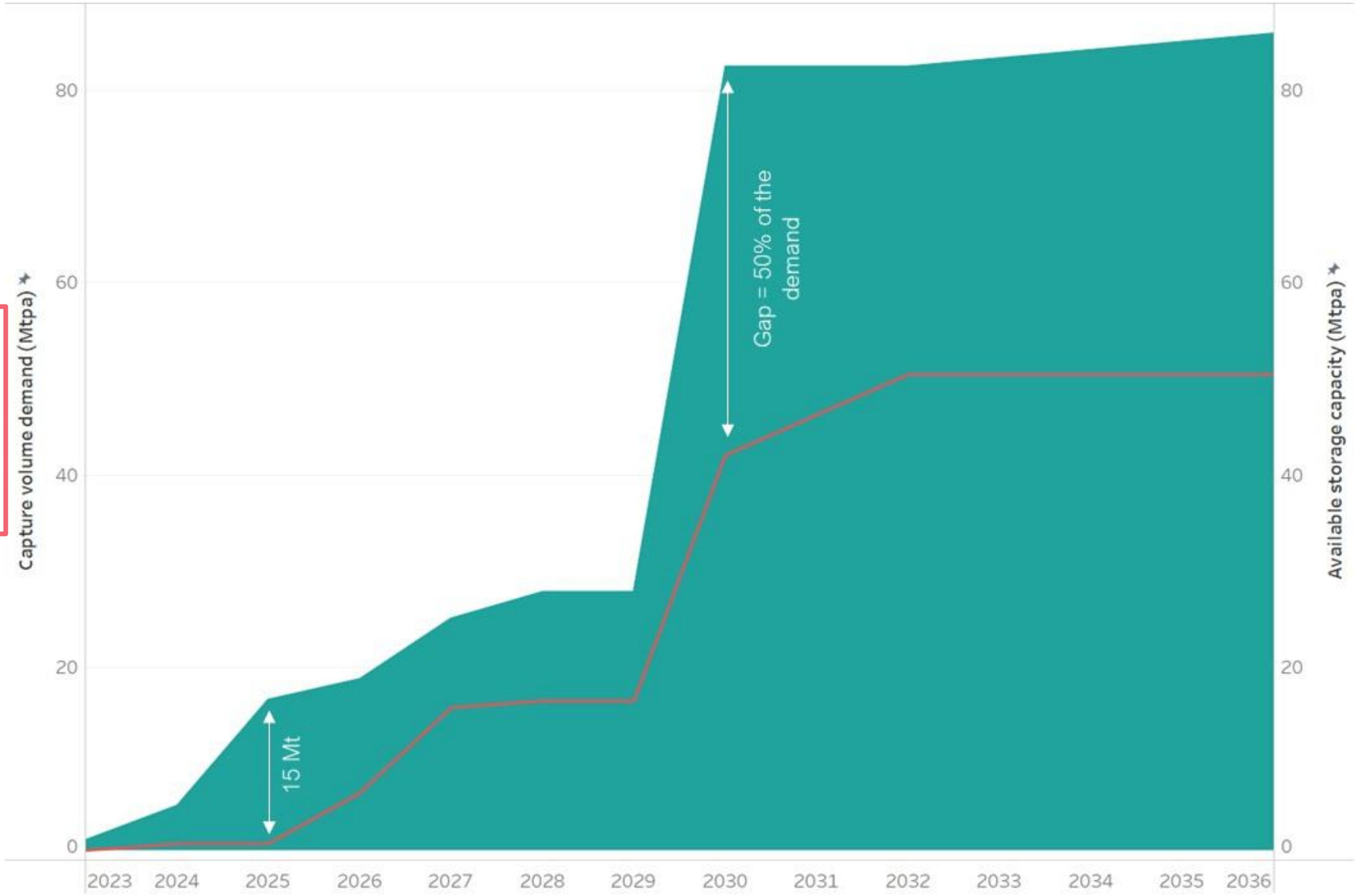
- To effectively avoid the CO_2 captured to be emitted to the atmosphere, the CO_2 needs to be permanently stored in geological formations
- Some carbon utilization technologies can also lead to permanent CO_2 storage but
  - some uncertainties remain around the effectiveness of some of these solutions and
  - the volumes which could be permanently stored are relatively limited and would not allow to achieve current carbon reduction targets
- Therefore, in parallel to or together with the capture projects, several CO_2 storage projects are being developed, but will these be sufficient to cover the storage demand?

CATF Project Database

In theory, enough storage capacity in Europe but …

… it takes time to develop a storage site and CO_2 storage space availability (as currently announced) lags behind capture demand for the foreseeable future and most notably in the short term

Need to develop additional storage sites allowing for open access to significant long-term storage capacity



Carbon Limits Analysis
Recent announcements such as Errai storage site are not taken into account (a potential 4 -8 Mt/y .- start up date not published for now)

More storage sites should be developed

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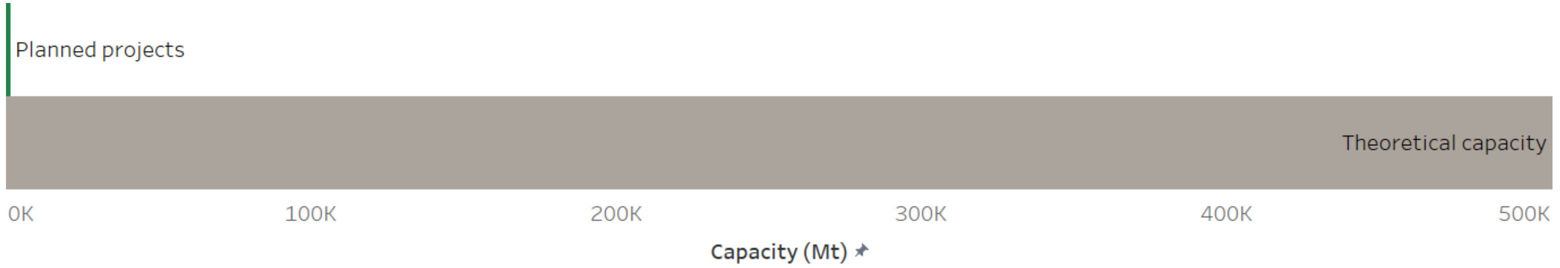

507 ~ 100[+]

Gt CO_2

Theoretically* sufficient geological CO_2 potential in Europe
(onshore and offshore)

Years-worth of CO_2 emissions in the European Union at 2019 levels

*Effective storage capacity is lower than theoretical potential due to the identification of flaws in geological structures and potential competition with other surface or subsurface activities

- Several additional projects will be commissioned as some countries, such as Norway, the UK and Denmark, have opened up new offshore CO_2 storage licenses. As these areas are still at an early phase of analysis, it is not yet possible to provide an estimate of the CO_2 storage potential that will be available in those additional sites.
- Given the current development time for storage projects, these might not be available in time to match capture ambitions. With experience, it might become possible to optimize the storage development process and help meet the capture demand.

European Commission, CO2StoP – Assessment of the CO_2 storage potential in Europe, 2015, https://ec.europa.eu/energy/studies_main/final_studiesassessment-co2-storage-potential-europe-co2stop_en and Geological Survey of Denmark and Greenland for CATF, EU Geological CO_2 storage summary, October 2021

CCS is an essential technology for achieving net zero targets by 2050, but CO_2 storage capacity must be available to meet demand which is only likely to grow further.

This will require coordinated, long-term planning from governments and industry, investment in geological characterization, and a streamlining of processes needed to develop new storage sites.

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CCS costs, carbon price considered for the analysis

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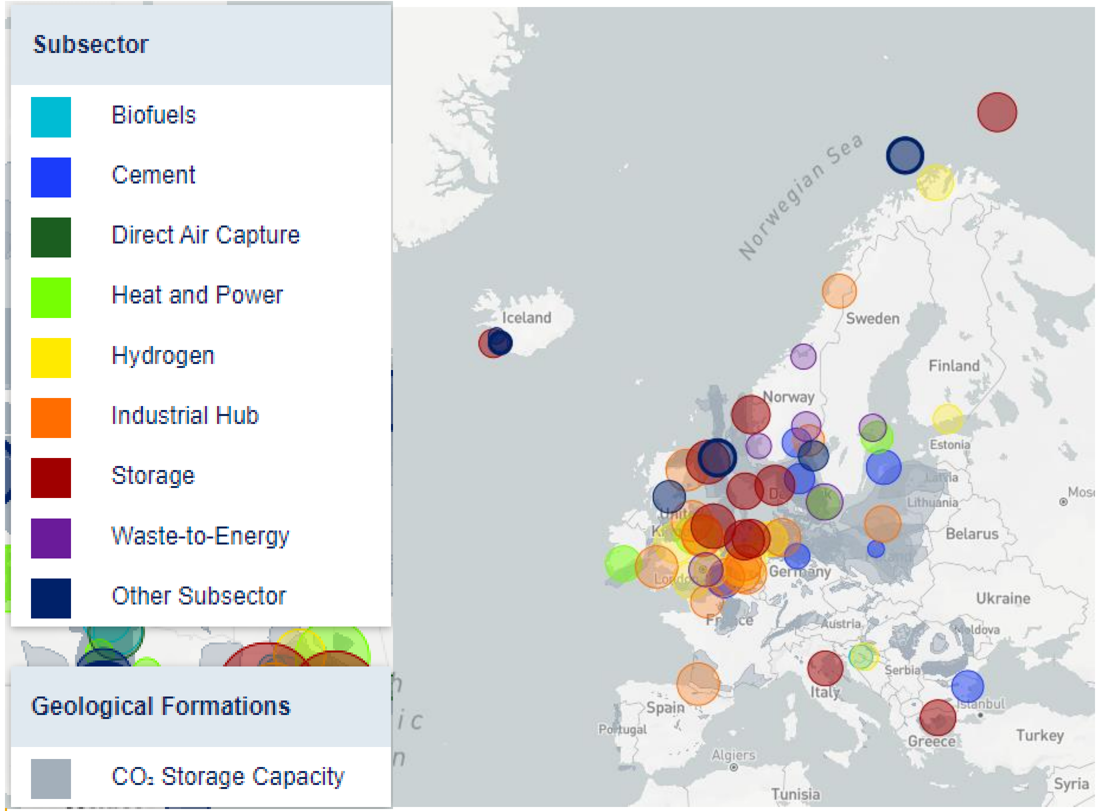
CATF project database



Assumptions

Cost of CCS	Sectors	2021	2030
Low estimate	Hydrogen	93 EUR/tCO_2	48 EUR/tCO_2
Medium estimate	Hubs/clusters/mixed sources, cement	118 EUR/tCO_2	61 EUR/tCO_2
High estimate	Waste-to-energy, iron and steel, refinery, power	143 EUR/tCO_2	74 EUR/tCO_2
Carbon Price		60 EUR/tCO_2	93 EUR/tCO_2 then 5%increase /year

3 years construction
20 years operation

Funding requirements estimated based on Net Present Value calculations considering carbon price as a revenue when CO_2 is not emitted (cost avoided). The required funding reflects the investment which is not recovered by carbon price.

Projects with a positive NPV, meaning they are directly profitable projects, were excluded from the analysis as their returns should allow them to recover initial investments.

CL assumptions based on IEA, discussion with storage projects and https://www.spglobal.com/platts/en/market-insights/latest-news/coal/120320-analysts-see-eu-carbon-prices-at-eur56-eur89mt-by-2030

Funding available considered in the analysis*

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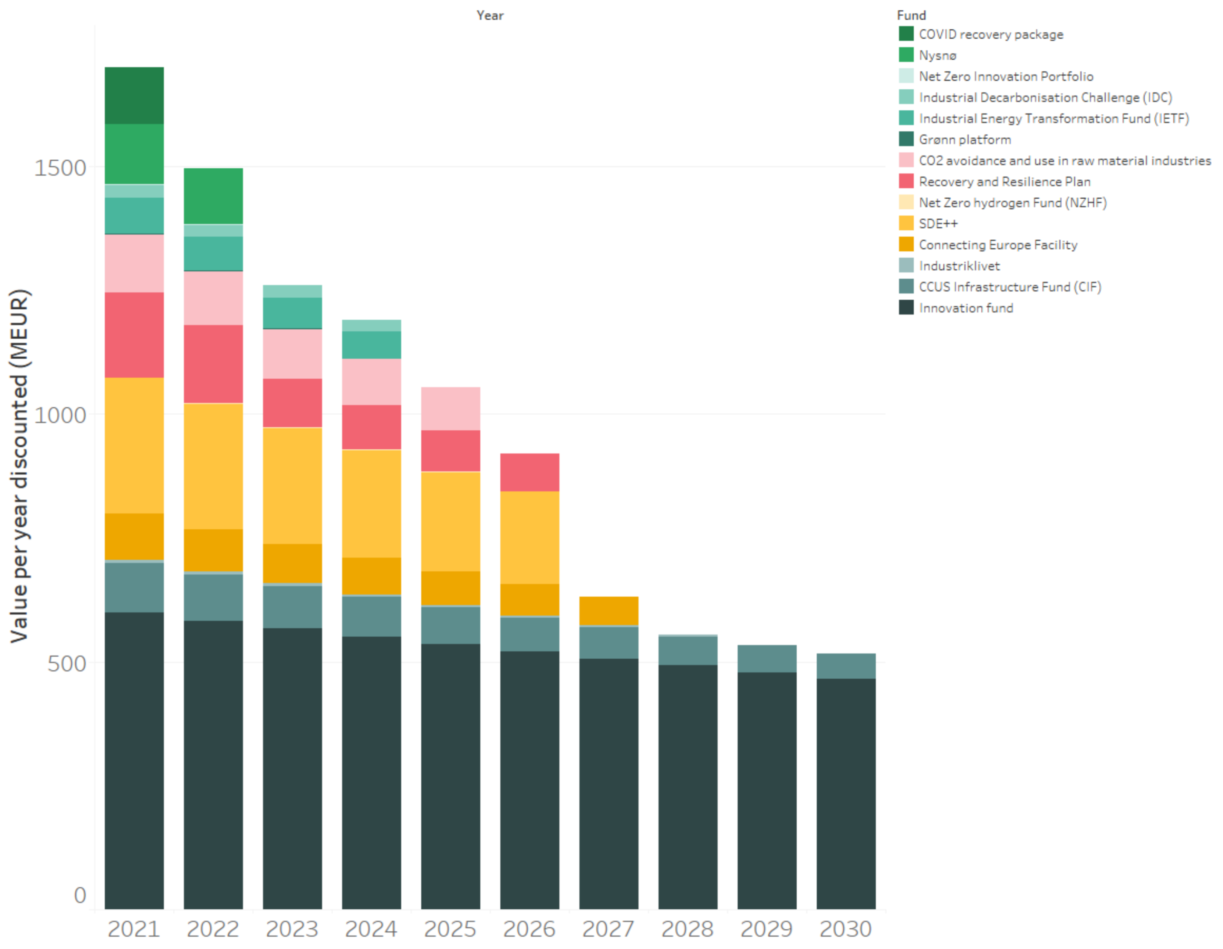


Some additional funding have been announced since the analysis (increase of the innovation fund + additional national funding in Denmark for example)

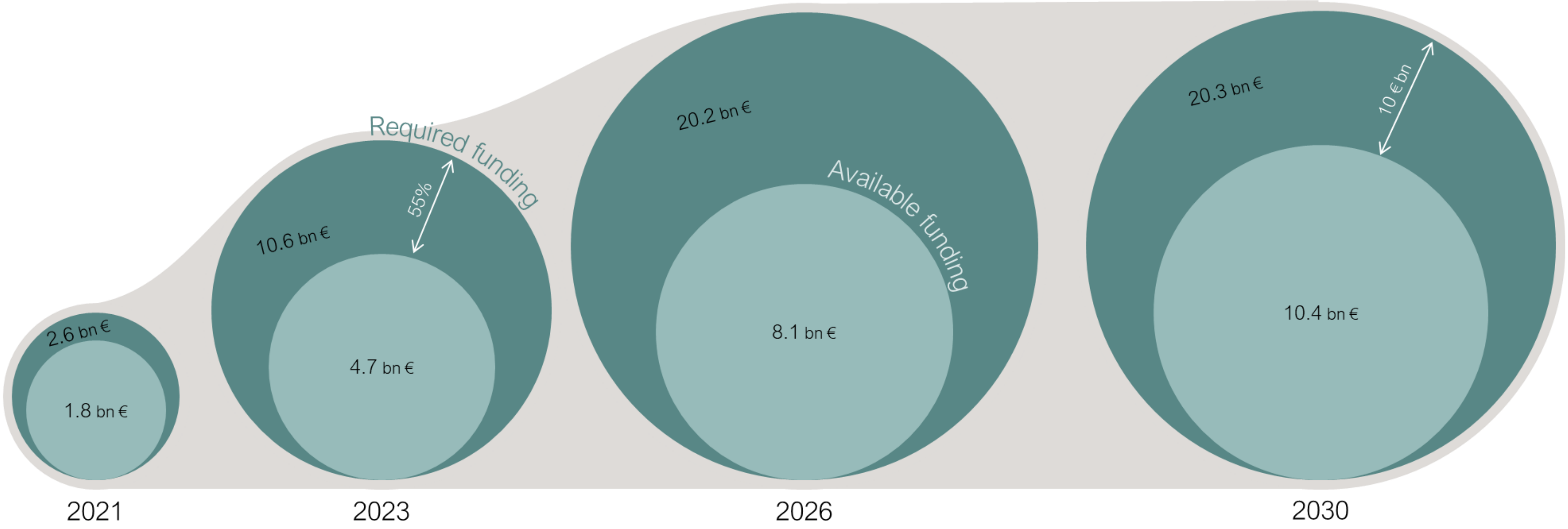
In the first call for large scale projects, the Innovation Fund attributed to CCS amounted to 778 MEUR for 4 projects (BECCS Stockholm - SE, K6 Program - FR, Kairos at C - BE, SHARC - FI)

In the second call, 4 CCS projects were pre-selected for grant preparation (Coda Terminal, IS – ANRAV, BU - GO4ECOPLANET, PL – CALCC, FR) The grant values per project have not been disclosed yet.

* Analysis done in January 2022

Potential gap between funding requirements for CCS and announced available public funding in the coming years

Gap between CCS ambitions and available funding



Announced European and national funding for carbon capture and storage will not be sufficient to support those projects which are unable to recover their capital and operational costs by relying on the carbon price alone.

Note: this analysis does not make the distinction between countries

1. Early movers take the most risk but contribute to the strongest learning effects and should therefore be encouraged with appropriate funding mechanisms. This should be considered when establishing CCS deployment plans at country levels, to provide the correct support and prioritize the most promising emissions reduction opportunities.

2. Funding targeting specifically CCS needs to be further developed, along with other policy mechanisms, positively impacting their profitability and providing companies with the long-term outlook necessary for decision-making. As projects develop, governments might decide to direct support to individual projects.

3. In addition, as technology costs and carbon prices evolve, companies and investors might see increased financial opportunities in CCS, along with the environmental benefits it provides.

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3 Some opportunities for cost reduction

1. Support the development of shared infrastructure – hubs
2. Study the possibility to reuse the existing oil and gas infrastructure if not relevant anymore for their primary purpose

More than 18 hubs projects considered in Europe as of 2022

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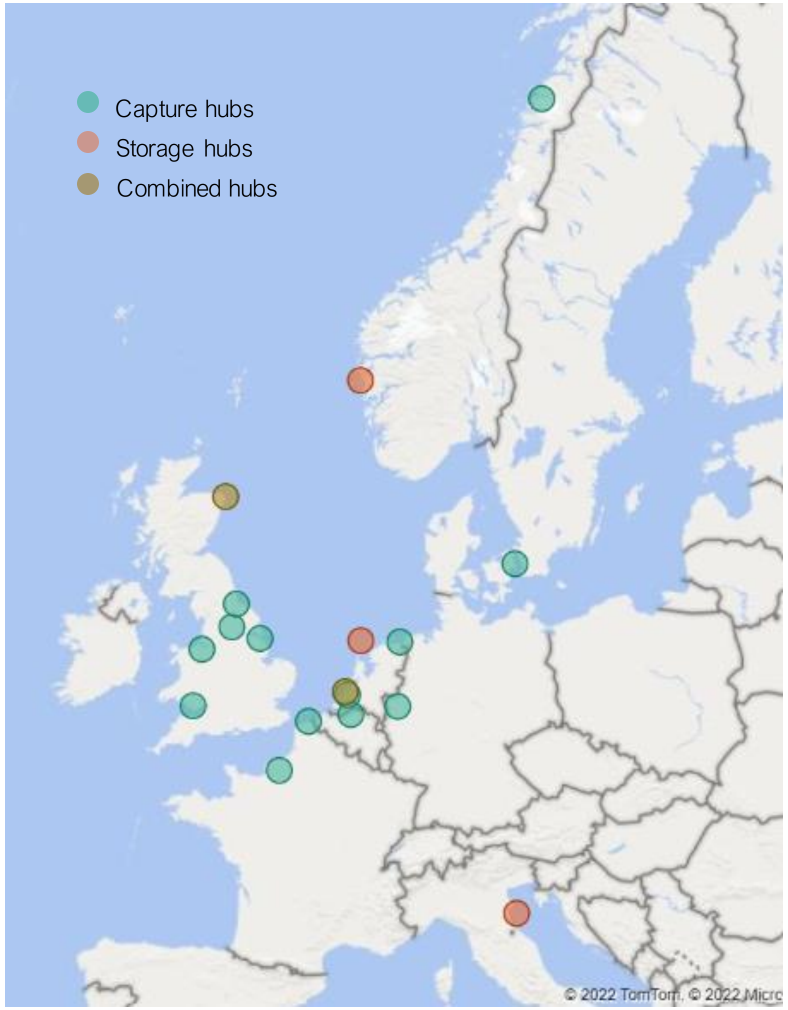
CCS/CCUS hubs in Europe



Country – Hub name/type

Country	*Hub name*	*Type*	*CO_2 sources*	Status
NETHERLANDS	Porthos	Combined	Refineries, H_2, imports	Advanced development
NETHERLANDS	Aramis	Storage	Steel, chemicals, cement, refineries, waste	Early development
NETHERLANDS	H-Vision	Capture	Refineries, H_2	Early development
NETHERLANDS	H2M Magnum	Capture	Power, H_2	Feasibility study
NORWAY	Northern Lights	Storage	Cement, waste, H_2, biomass, steel, refineries	Advanced development
NORWAY	CO2HubNordland	Capture	Aluminum, lime, cement, silicon, ferromanganese, steel	Feasibility study
UK	Net Zero Teesside	Capture	Power, H_2, fertilizer	Advanced development
UK	Zero Carbon Humber	Capture	H_2, steel, power, cement, ethanol	Advanced development
UK	Acorn	Combined	Gas, power, H_2, import	Advanced development
UK	H21 North of England	Capture	Industry	Feasibility study
UK	HyNet NorthWest	Capture	H_2, refineries, fertilizer, cement, others	Advanced development
UK	South Wales	Capture	Power, H_2, refineries, chemicals	Advanced development
FRANCE	Dartagnan	Capture	Steel, power, aluminum, ferromanganese	Advanced development
FRANCE	Axe Seine	Capture	Chemicals, ammonia, refinery, petrochemical, waste	Feasibility study
DENMARK	C4	Capture	WtE, CHPs	Feasibility study
ITALY	Ravenna	Storage	Power, H_2, cement, steel, fertilizer, glass	Early development
BELGIUM	Port of Antwerp	Capture	Power, chemicals, petrochemicals	Feasibility study
GERMANY	H2morrow	Capture	H_2	Feasibility study

Advanced development | Early development | Feasibility study

Re-Stream showed strong potential for transport cost reduction (53% to 82%) involving reuse of pipelines compared to new build options

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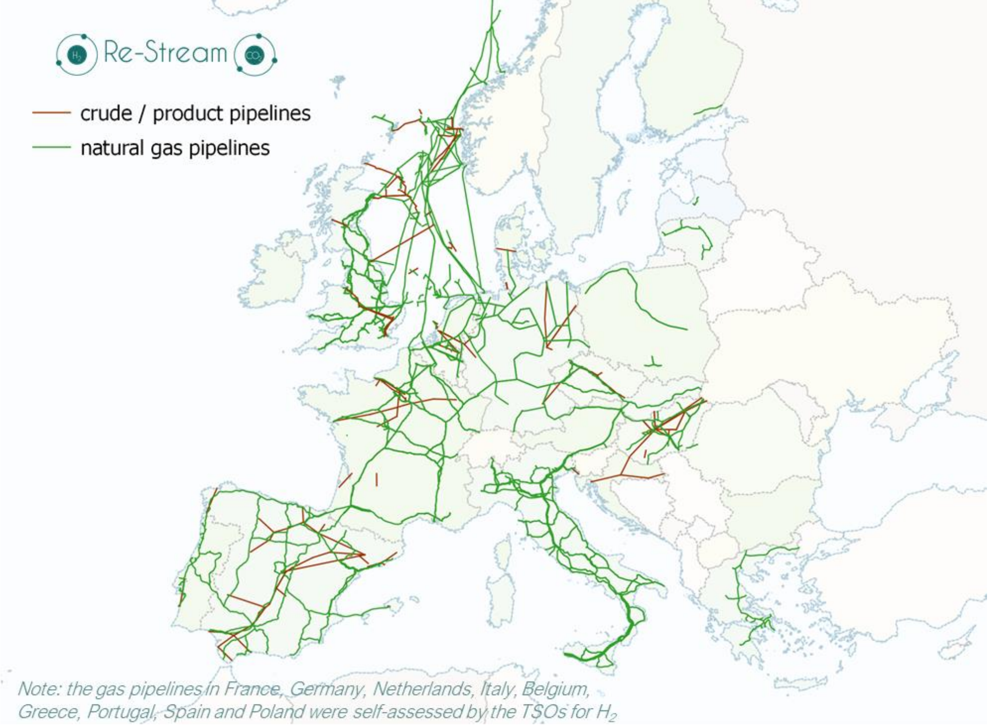
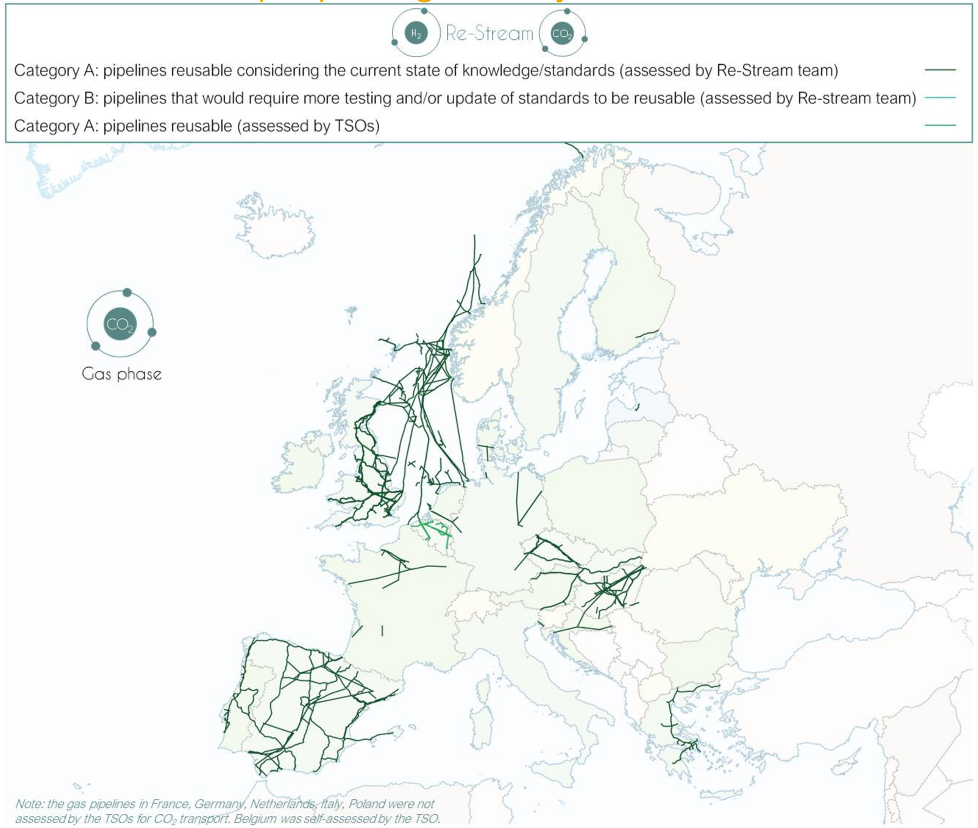
Data could be analysed for ~58,000 km pipelines
(+24,200 km assessed by operators themselves as suitable for H_2 reuse)

50% total offshore pipeline length
30% onshore oil and gas pipelines length



No showstoppers identified for transporting CO_2 in the gaseous phase in existing onshore and offshore pipelines at screening level

Actual repurposing is subject to individual tests



Those cost reductions are of particular importance in the initial phases of development of CCS and will help achieve the EU GHG emissions reduction goals in a cost-efficient way.

Thank you for your attention

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Location of announced CCS projects by type and capacity as of January 2022

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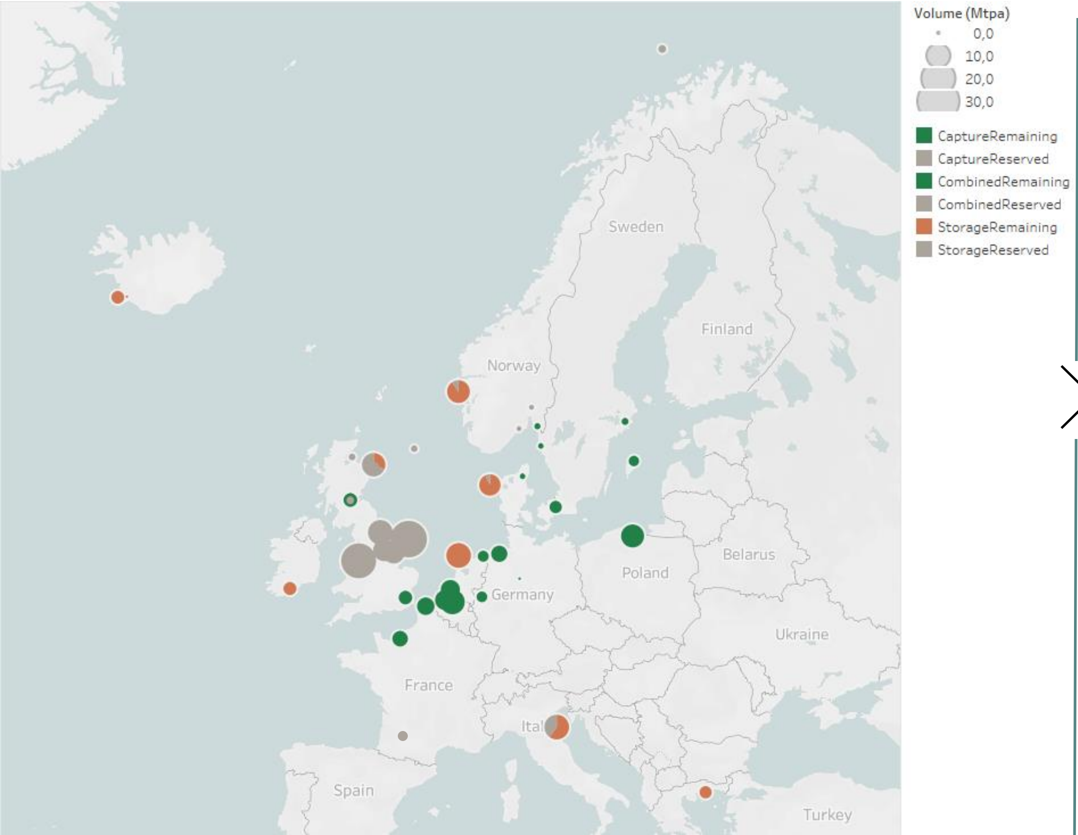

Important disparities between countries

North Sea	An important share of the offshore potential Large majority of planned storage projects and volumes *(UK, Dutch, Danish and Norwegian continental shelves)*
Greece, Iceland, Ireland, and Italy	Oversupply of storage in 2032. But successful development of the storage sites is likely to be contingent on the sourcing of locally captured CO_2.
Countries with the most storage capacity planned	Tend to also have important capture ambitions and, aside from Norway and Denmark, are not expected to have additional storage space if all capture projects materialize.
E.g., Belgium, France, Germany, Poland and Sweden	No geological storage capacity, do not allow onshore CO_2 storage on their territory or need to further characterization of storage formations. Currently no large-scale storage projects announced despite ambitions for capture projects → need to secure storage space in other countries, at least in the near term.

Distance over which the emissions need to be transported to an available storage site might alter the timeline or even relevance of a project and encourage facilities to find alternative decarbonization solutions.

Innovation fund allocation to CCS projects

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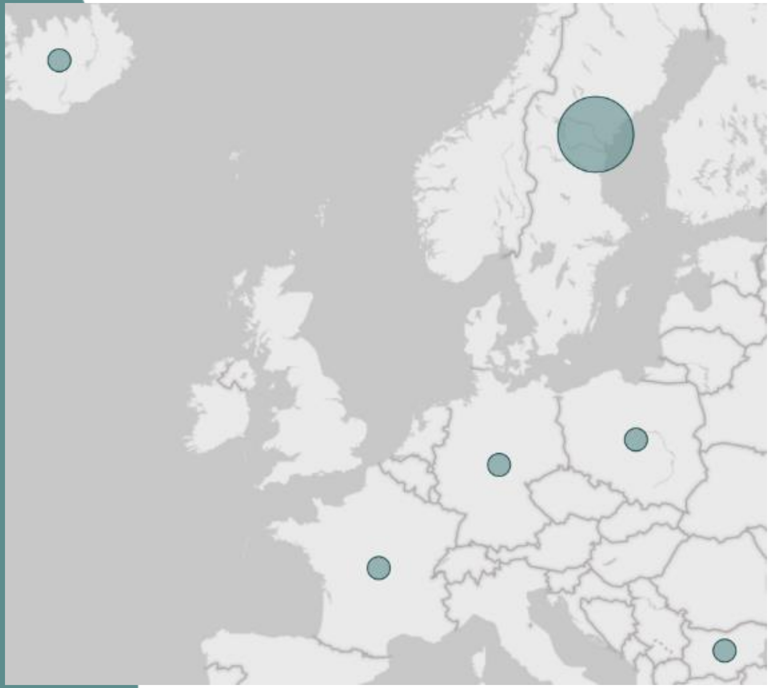
Over €1.8 billion invested in 17 large-scale innovative clean-tech projects including CCU and CCS projects



Project's name	Location	Description
Carbon2Business (C2B)	Germany, Holcim's Lägerdof cement plant	To produce synthetic methanol using a second-generation oxyfuel carbon capture process at a cement plant. It will capture over 1 $MtCO_{2eq}$ annually.
AIR	Sweden	To convert CO_2 residue streams renewable hydrogen and biogas to methanol.
HySkies	Sweden	To build a large-scale facility to produce synthetic sustainable aviation fuel, using CO_2 captured at a Combined Heat and Power (CHP) plant.
Coda Terminal	Iceland	To build a highly scalable onshore carbon mineral storage terminal with an estimated overall storage capacity of 880 $MtCO_2$
ANRAV	Bulgaria, Devnya cement plant	To capture CO_2 at a cement plant and store it permanently in offshore depleted gas field in the Black Sea through an onshore and offshore pipeline system. It has the ambition to be the first full-chain CCUS project in Eastern Europe.
GO4ECOPLANET	Poland, Kujawy cement plant	To capture CO_2 at a cement plant, liquefy, transport by train and storage in offshore sites
CalCC	France, Hauts-de-France (Dunkirk area)	To capture CO_2 emissions from exhaust gases, produce during lime production, transport by pipeline in dense phase, liquefy, ship and store then in geological formations. This will annually store 610 $ktCO_2$.

EU invests €1.8 billion in clean tech projects (europa.eu)