HERCCULES

full CCUS chain demonstration

13/06/2024

Infrastructures for the transport and storage Examples of projects sites in Europe

Roberto Ferrario / ENI

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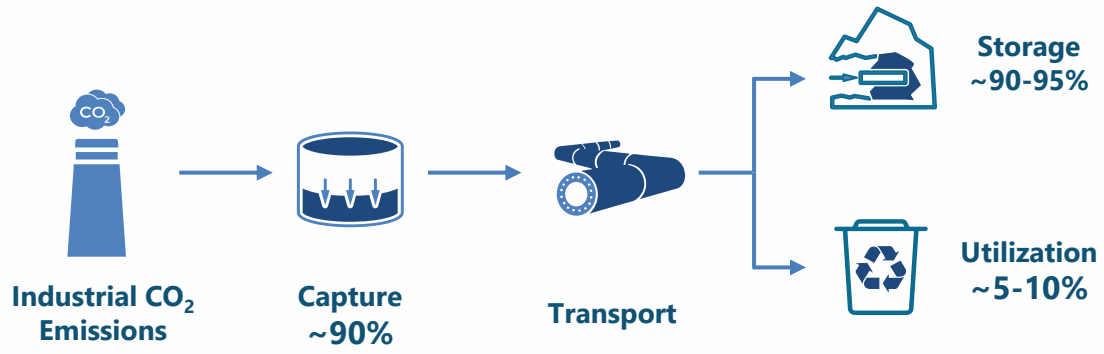
CCUS as a key decarbonization lever

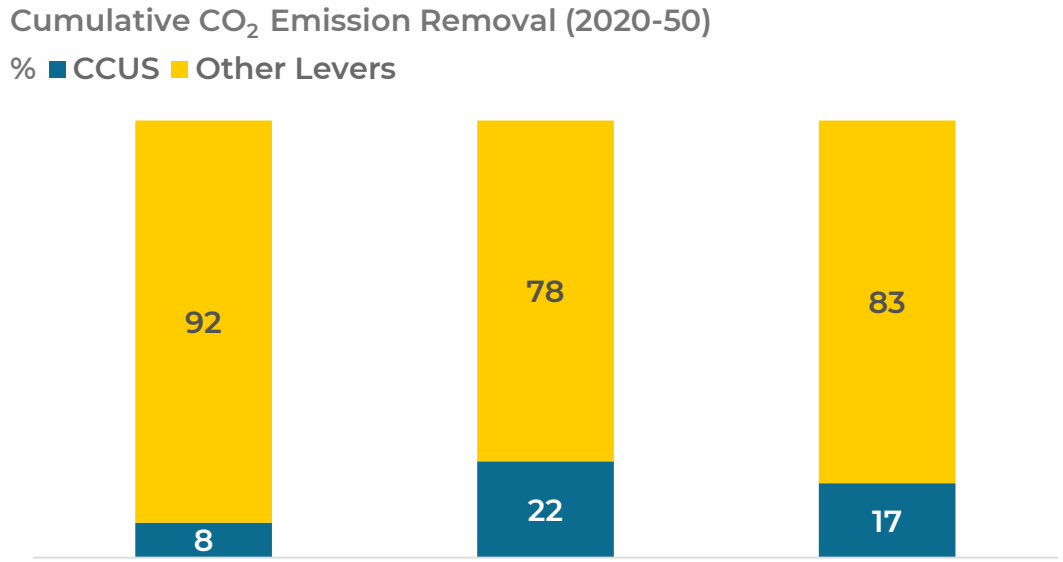
CCUS relies on mature technologies, capitalizing on past experiences and valuing existing assets. It has a relevant role in international decarbonization scenarios.

The CCUS Process



- **Inevitable for the HTA sectors** (e.g., Iron and steel, cement, chemicals) due to the impossibility of reducing emissions from production processes.
- Most effective and efficient process for the industry:
  - **Time and Costs**: reduced impact on existing processes and lower costs than other levers
  - **Higher CO_2 volumes** avoided
- It allows to abate **over 90% of the emissions.**

CCUS contribution in the different decarbonization scenarios



Annual Storage by 2050

IEA	IRENA	IPCC
6040 $MtCO_2$/year	7000 $MtCO_2$/year	7100 $MtCO_2$/year

IEA A Global Pathway to Keep the 1.5 °C Goal in Reach (2023)
Eni Analysis based on data from **IRENA** World Energy Transition Outlook 2023
Eni Analysis based on data from **IPCC** AR6 scenarios <1.5°C (2022)

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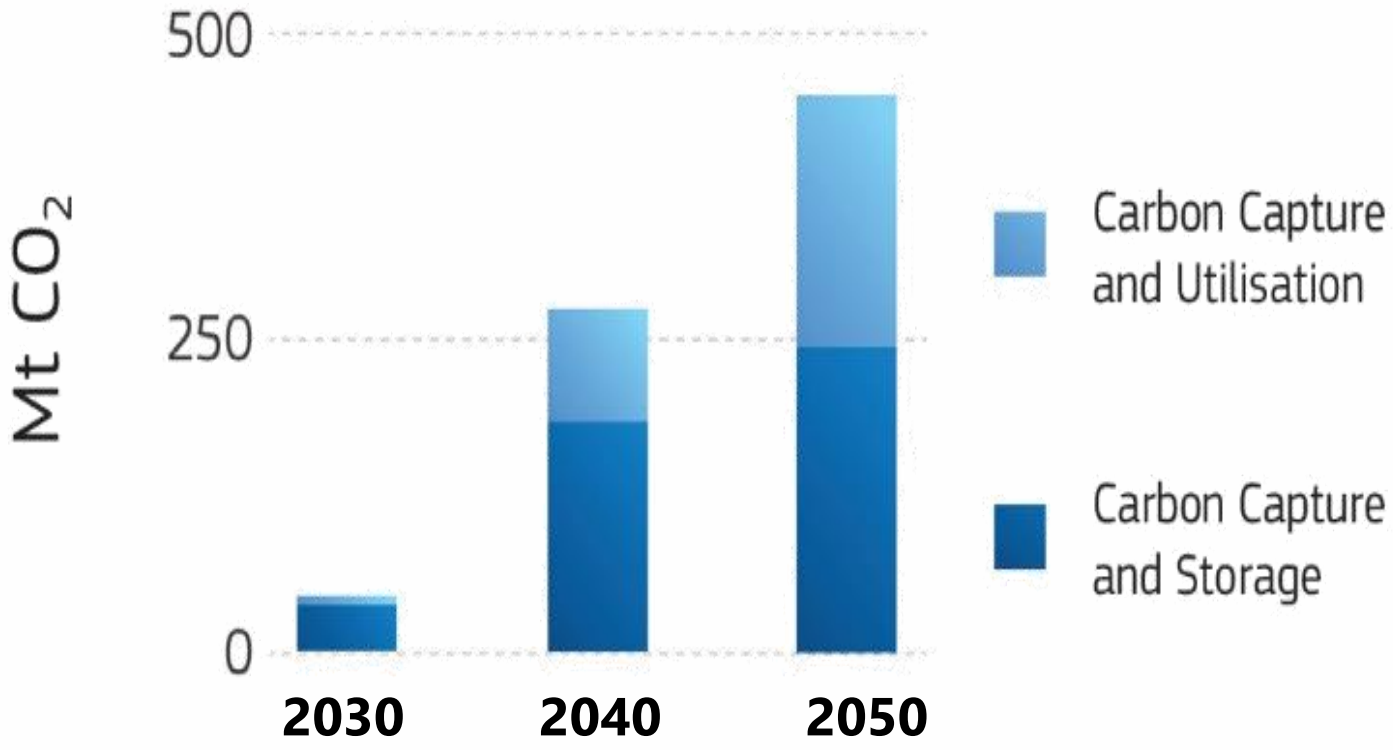
Europe Carbon Management Strategy - targets

- **2030:** >50 MTPA
- **2040:** 280 MTPA (80 Utilization)
- **2050:** 450 MTPA (200 Utilization)



3 pathways

- **Storage:** avoid new emissions
- **Removal:** removing CO2 from the atmosphere
- **Utilization:** substitute fossil-based carbon in synthetic products or fuels

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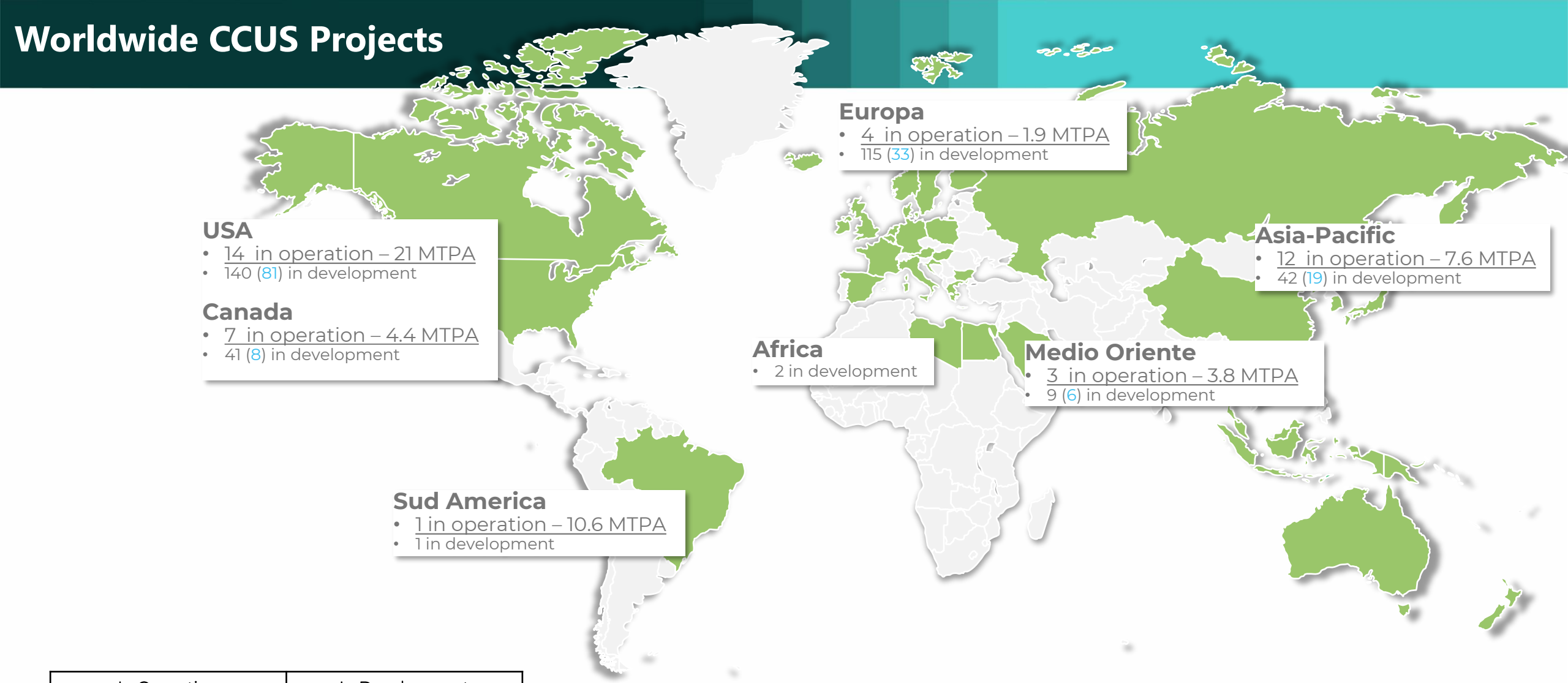
Worldwide CCUS Projects



USA
- 14 in operation – 21 MTPA
- 140 (81) in development

Canada
- 7 in operation – 4.4 MTPA
- 41 (8) in development

Europa
- 4 in operation – 1.9 MTPA
- 115 (33) in development

Asia-Pacific
- 12 in operation – 7.6 MTPA
- 42 (19) in development

Africa
- 2 in development

Medio Oriente
- 3 in operation – 3.8 MTPA
- 9 (6) in development

Sud America
- 1 in operation – 10.6 MTPA
- 1 in development

In Operation	In Development
41 CCUS Projects	351 (147) CCUS Projects

Based on data from the Global CCS Institute - Status Report 2023
In brackets, projects under construction or in an advanced stage of development

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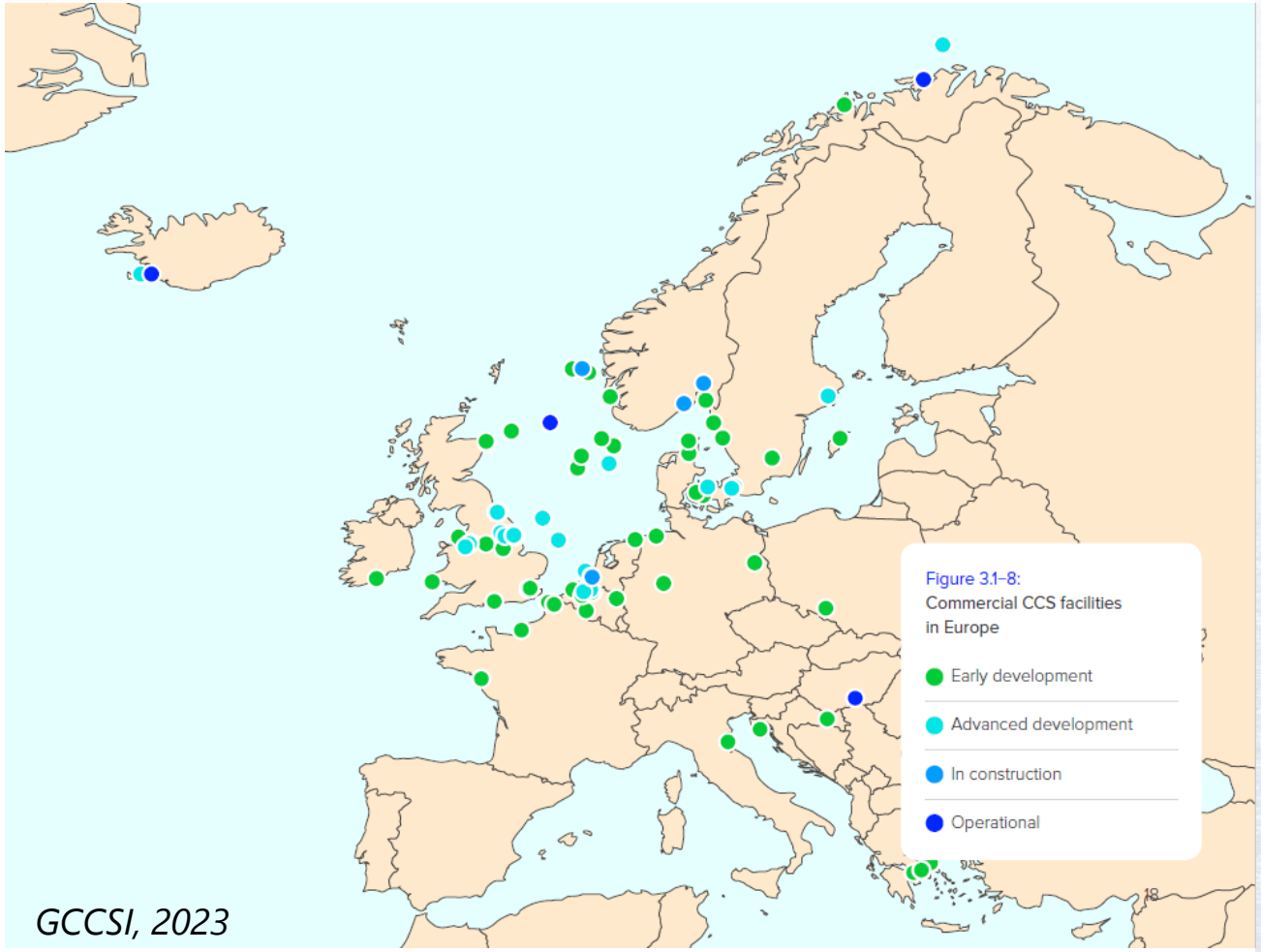
CCUS Projects in Europe Growing at a Rapid Rate

35 CO2 transport and storage (T&S) projects under development, mainly located in northern Europe



GCCSI, 2023

119 CCS projects in operation in Europe

63% 63% growth in projects in various stages of development or operation compared to 2022

2024 The launch of Northern Lights, the first "open-source" project for the transport and storage of CO2 and Ravenna phase 1, is expected in 2024.

Source: Global Status of CCS 2023

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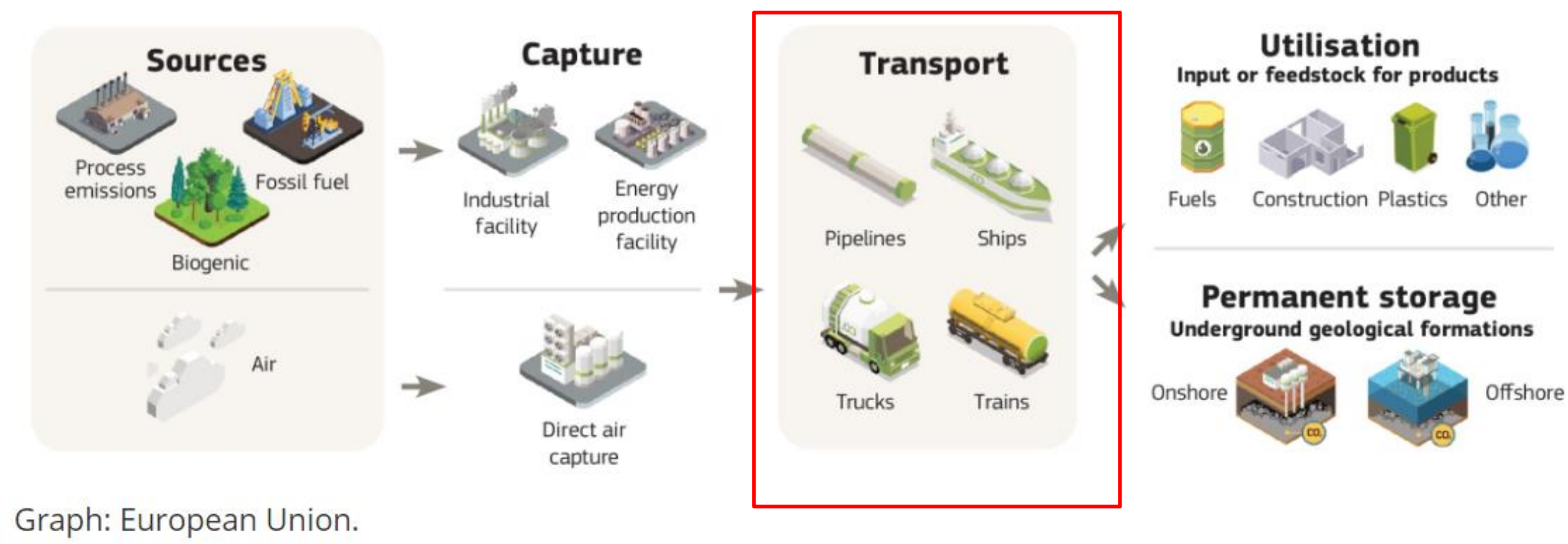
Europe Carbon Management Strategy - infrastructure



Graph: European Union.

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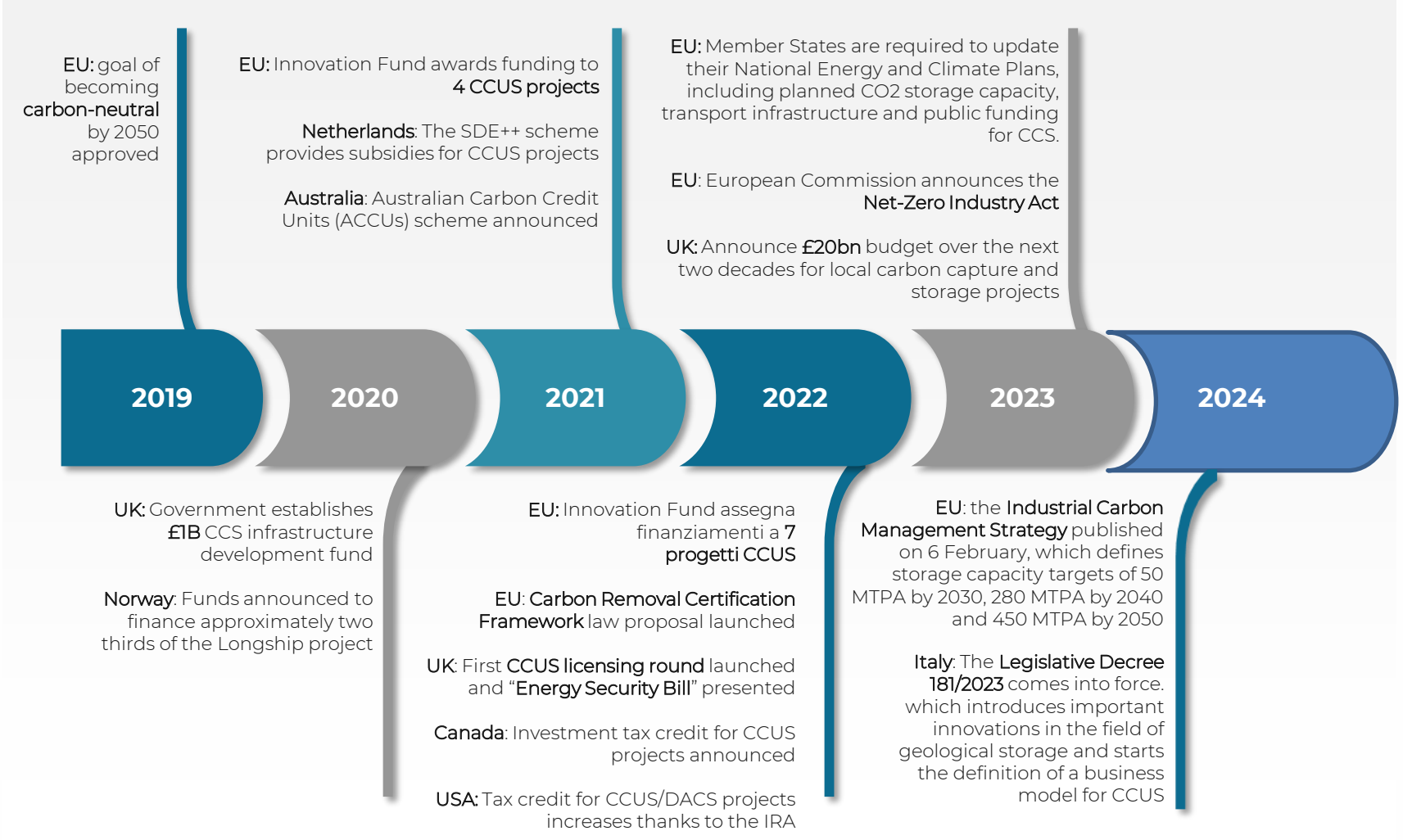
Growth of CCUS

Government policies and development of funds and financing



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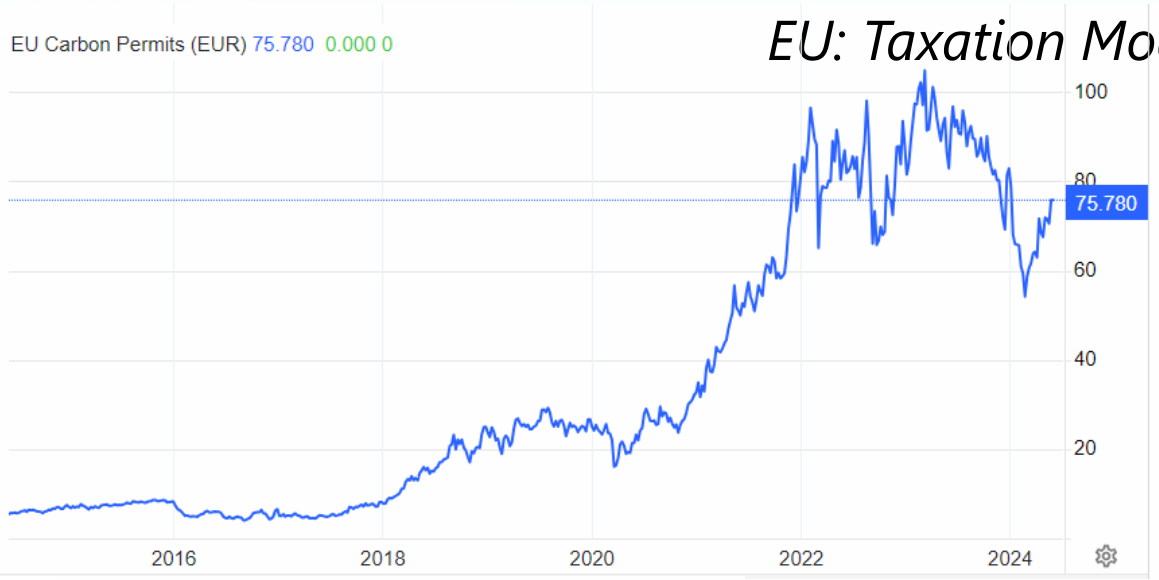
Types of governmental approaches to promoting CCUS

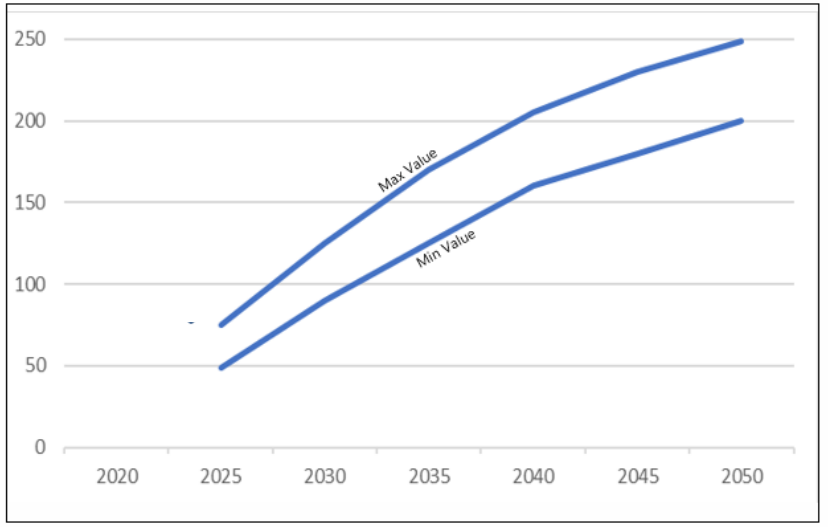
USA: Incentive Model

ACTIVITY		BEFORE IRA (IN $ PER TONNE OF CO_2)	AFTER IRA (IN $ PER TONNE OF CO_2)
Geological storage of CO_2	From power generation and industrial facilities	50	85
	From direct air capture (DAC) facilities	50	180
Utilisation of CO_2	From power generation and industrial facilities	35	60
	From DAC facilities	35	130

Table 2: Increases to the 45Q tax credit from the Inflation Reduction Act of 2022

EU: Taxation Model





Directive strengthened in 2023 to meet EU climate objectives.

Both increases in ETS price and reduction in the number of free allowances assigned to emitters are expected.

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Support mechanisms: CfDD - SDE++

Main category	Subcategory	2020 CO_2 Reduction	2020 Subsidy intensity (€/tCO2)	2022 CO_2 Reduction	2022 Subsidy intensity (€/tCO2)
Renewable electricity	Wind	0.06	38	0.03	156
	Solar (roof)	0.33	67	0.12	65
	Solar (field)	-	-	0.09	160
	Solar (water)	0.31	86	-	-
Renewable heat (CHP)	Biomass	0.08	111	0.3	171
	Geothermal (deep)	-	-		
	Geothermal (shallow)	-	-	0.58	141
	Solar Thermal	0	129	0	207
Renewable Gas	Biogas	0.04	164	0.19	210
Low CO2 heat	Aquathermal energy	-	-	0.03	284
	Electric boilers	0.17	109	0.21	164
	Waste heat	0.03	61	0.03	178
	Heat pumps	0.09	120	0.02	165
Low CO2 production	CCS	2.34	48	3.13	135
	CCU	-	-	0.24	137

Source: Netherlands Enterprise Agency (RVO)

SDE++ is the Dutch incentive program for the energy transition, with funds allocated on a competitive basis.

CCUS projects participated in 2020 and 2022.

CCUS was the leading technology in terms of emissions avoided and among the most competitive in terms of cost per ton avoided for the taxpayer.

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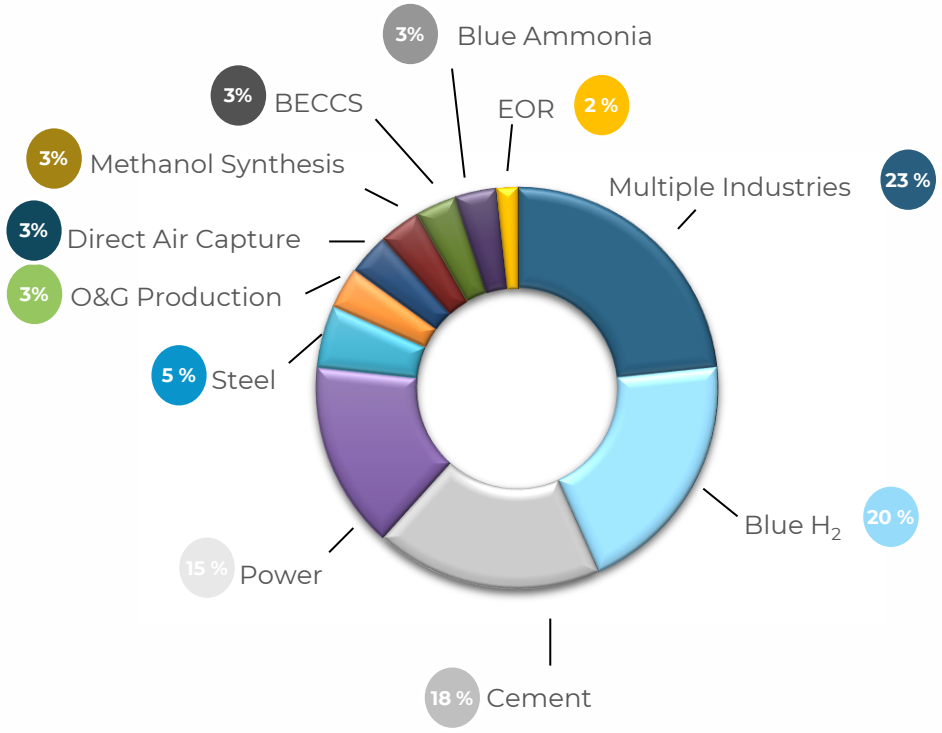
Support mechanisms: EU Innovation Fund

- Funded by the EU ETS
- Provides financial support through grants for deploying innovative technologies
  - includes CCS facilities to meet net-zero commitments and the energy transition



Distribution of CCUS projects by sector

23 CCUS Projects Awarded

2021
- 4 CCUS projects selected out of 7 total
- Received ~70% of total funding (~780M€)

2022
- 8 CCUS projects selected out of 16 total
- Received ~60% of total funding (~1B€)

2023
- 11 CCUS projects selected out of 41 total
- Received ~42% of total funding (~1.5B€)

CCUS is also supported by other European funding programmes:

- CEF for transport & aggregation and storage infrastructures of the Projects of Common Interest (PCI)
- Horizon Europe, for CCUS projects in the research and development phase.

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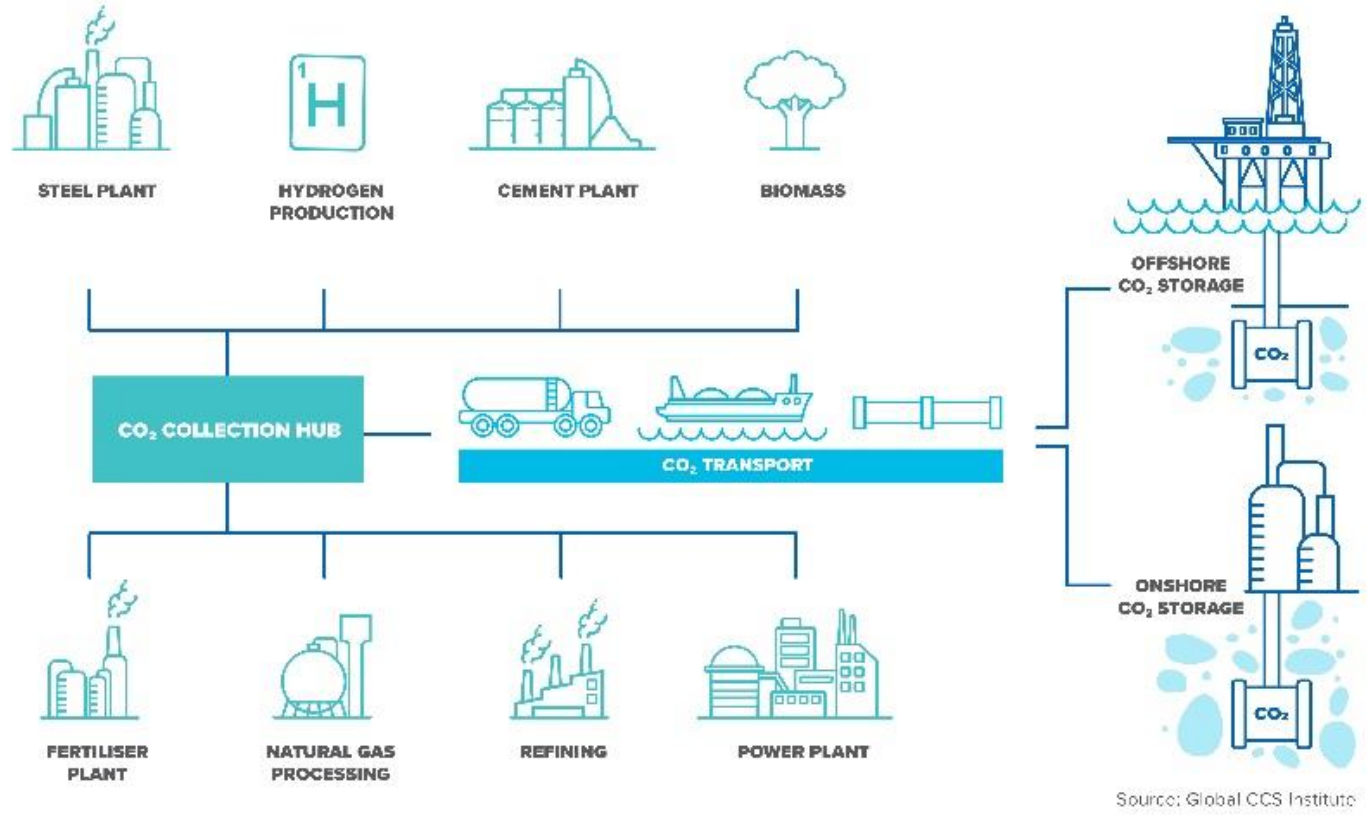
Types of Transport and Storage and Infrastructure

CCUS Hub Concept



CCUS hub and cluster network. Credit: Global CCS Institute

Benefits

- Effectively promotes the large-scale application of CCUS
- Established in industrial areas where large emitters are located, with positive impact on local economies and employment
- Shared infrastructure benefits from economies of scale
- Will likely attract additional carbon emissions-intense industries seeking a CO_2 management solution

Challenges

- Requires large upfront investments for T&S infrastructure
- Many actors involved along the value chain require significant coordination effort and increase interface risks

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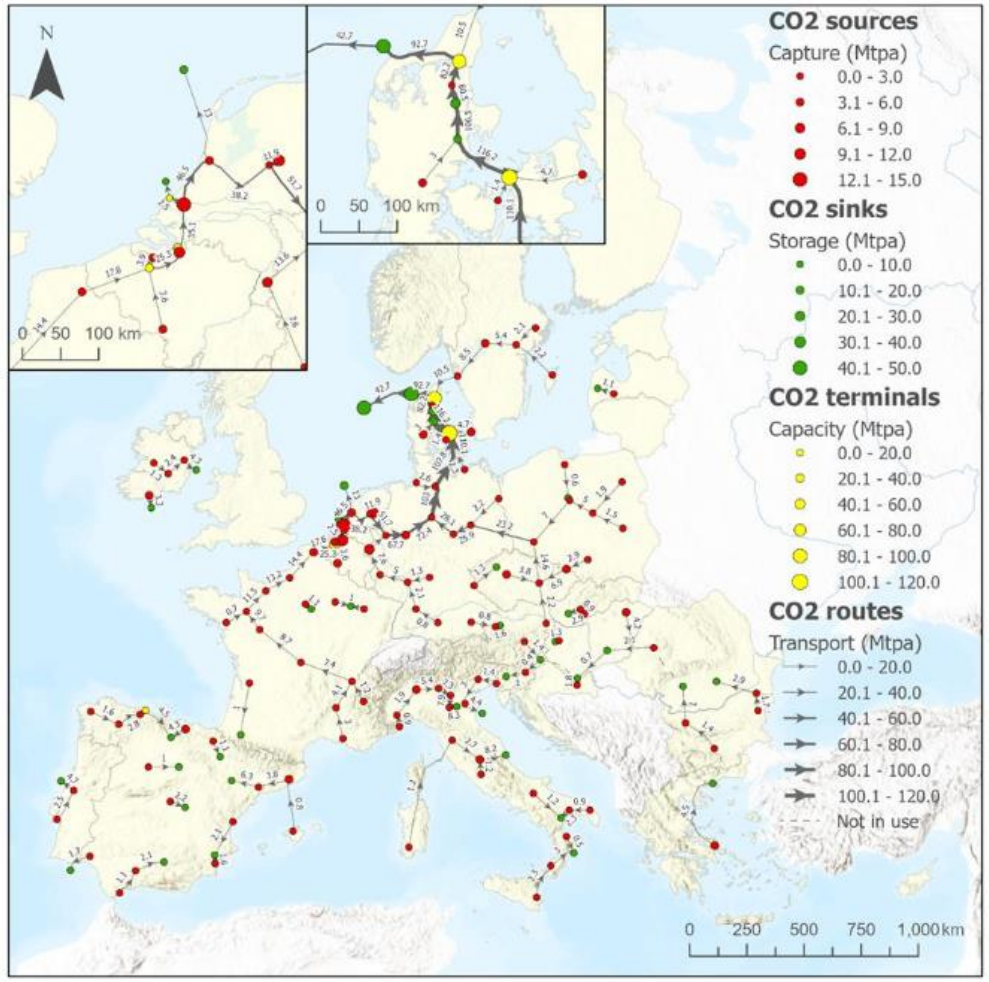
Potential transportation infrastructure in Europe



Source: JRC, 2024

- CO2 transport infrastructure is a crucial factor and key enabler of the successful large-scaled deployment of CCUS
- Figure on the left shows an example of a potential future CO2 transport network in 2050
    - Based on 8 scenarios from the EU Joint Research Centre
- Future European CO2 transport network could reach a length of 6 700-7 300 km by 2030
    - Might extend to between 15 000 and 19 000 km by 2050
- Requires investment of between EUR 9.3 billion and EUR 23.1 billion
- Extent and cost of network can be reduced by developing storage capacities in regions where current capacities are insufficient (e.g. southern and eastern Europe) to avoid transporting CO2 over long distances

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Opportunities for CO_2 Transport by Ship in Europe

The European Commission aims to store at least 50 million tonnes of CO_2 by 2030.

Shipping will play a crucial role in Europe for the development of carbon capture and storage.

1 million tonnes of CO_2 can be transported per year

by a 20,000-tonne cargo liquified ship with a one-week round trip

Current projects under development could transport up to

39.5 million tonnes of CO_2 per year by 2030

Future European storage sites compatible with ship transport could exceed

50 million tonnes of CO_2 storage

26 storage projects identified

could use shipping to transport CO_2

European policymakers should support the development of CO_2 transport by ship for

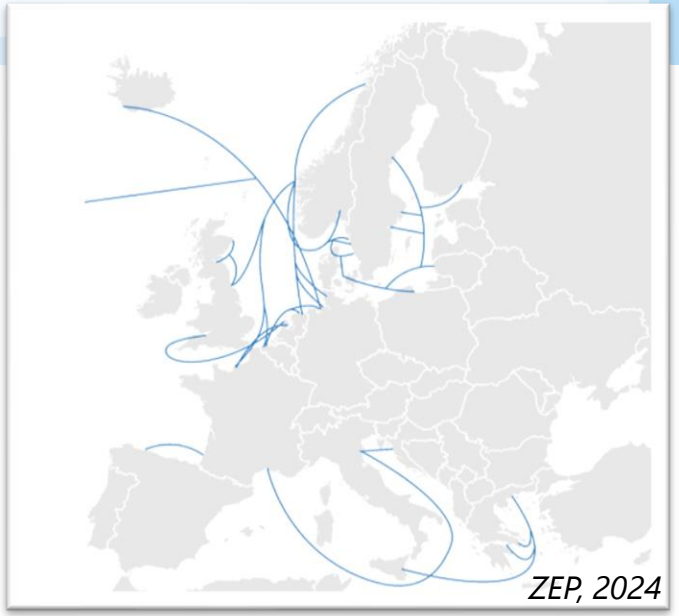
industrial decarbonisation

Key recommendations for European countries

- Incentivise funding and remove barriers to cross-border CO_2 transport by ship in EU and UK ETS systems.
- Provisionally apply Article 6 amendment of London Protocol with the International Maritime Organisation and sign bilateral agreements where needed.
- Support more research into a multimodal CO_2 transportation model to include ships, barges, trains and trucks.

IEA: Estimate of ~$30/ton CO_2

Potential CO_2 Shipping Routes Identified



ZEP, 2024

HERCCULES full CCUS chain demonstration

Funded by the European Union

Projects of Common Interest (PCI)

- Initiated in 2013, PCIs represent projects recognized as pivotal for enhancing the energy infrastructure interconnectedness across the EU.

Project	Description
Aramis	Cross-border T&S from emitters near the Rotterdam harbour with pipeline transport to Dutch continental shelf.
CO2 TransPorts	Establish infrastructure to facilitate large-scale CCS from Rotterdam, Antwerp, and North Sea areas.
ECO2CEE	Open-access cross-border CO2 T&S project with storages sites in Denmark, Norway, Netherlands, and the UK.
Bifrost	CO2 transport and storage project with offshore storage in DK from emitters from Denmark, Germany, and Poland.
Callisto	Development of multi-modal CO2 hubs in the Mediterranean storing CO2 emissions from France and Italy.
CCS Baltic Consortium	Cross-border CO2 transport via rail between Latvia and Lithuania with a multi-modal liquid CO2 terminal based in Klaipeda.
Delta Rhine Corridor	Pipeline transport from Ruhr area in Germany and the Rotterdam area in the Netherlands emitters to offshore storage off Dutch coast.
EU2NSEA	Cross-border CO2 network developed between Belgium, Germany, and Norway to also collect CO2 from Denmark, France, Latvia, the Netherlands, Poland, and Sweden, with storage on the Norwegian continental shelf.
GT CCS Croatia	Construction of CO2 pipeline transport infrastructure in Croatia and Hungary, with underground storage in Hungary.
Norne	Transport infrastructure in Denmark onshore and possibly offshore storage, emitters primarily from Denmark, Sweden, Belgium, and the UK will transport CO2 to Denmark via ship.
Prinos	Offshore CO2 storage for emissions from Greece, by pipeline, and from Bulgaria, Hungary, Cyprus, Greece, Italy, and Slovenia by ship.
Pycasso	Transport and storage of CO2 in an onshore storage site in southwestern France, with industrial emitters from France and Spain.
Northern Lights	CO2 cross-border connection project between several European capture initiatives (among others Belgium, Germany, Ireland, France, Sweden) transporting CO2 by ship to storage on the Norwegian continental shelf.
Nautilus CCS	CO2 emissions from Le Havre, Dunkirk, Duisburg, and Rogaland areas captured and transported by ship to various sinks in the North Sea.

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Selected Examples of Eni CCS Projects

Ravenna CCS

Ph 1 - 2024
25 KTPA of CO_2

Ph 2 – 2027
4 MTPA of CO_2

Exp – after 2030
16 MTPA of CO_2

Ravenna CCS

- Important CCS Hub in Southern Europe and Mediterranean
- Supports decarbonization of industrial clusters in Italy & Mediterranean – storage site for the PCI Callisto
- Transportation network being developed to receive CO_2 both via pipeline and shipping
- Strong interest from nearby and international emitters, including beneficiaries from Innovation Fund
- Over 20 feasibility studies in collaboration with national and international industrial emitters
- Over 500 MTON of CO_2 total capacity
- Phased expansion of injection up to 16Mtpa after 2030

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Callisto - Mediterranean CO_2 network

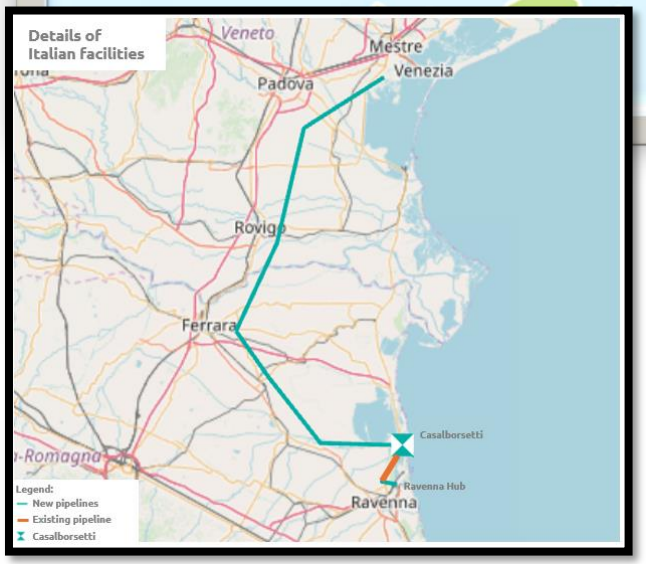
Project selected in the 2023 PCI and PMI Union List

TEN-E Thematic Area: Cross-border CO2 Networks
Member States: France, Italy
PCI Promoters: AL (also Coordinator), ENI, SNAM and 16 other industrial partners

Development of CCS infrastructure:

CALLISTO Mediterranean CO2 Network aims to create an “open access” **multimodal CO2 hub** in the Mediterranean, supported by **dedicated onshore infrastructure**, with the aim of enabling the decarbonization of various clusters of industrial emitters through capture, aggregation, transport and permanent storage of CO2.

Expected commissioning dates: 2027 (Italy) and 2029 (France)



128 Mt of CO2 to be avoided in 23 years of activity
Increase from 2 to 6.4 Mtpa within the first 6 years of operation

CO2 from France and Italy, with the possibility of extension to other industrial areas in France and other Mediterranean countries

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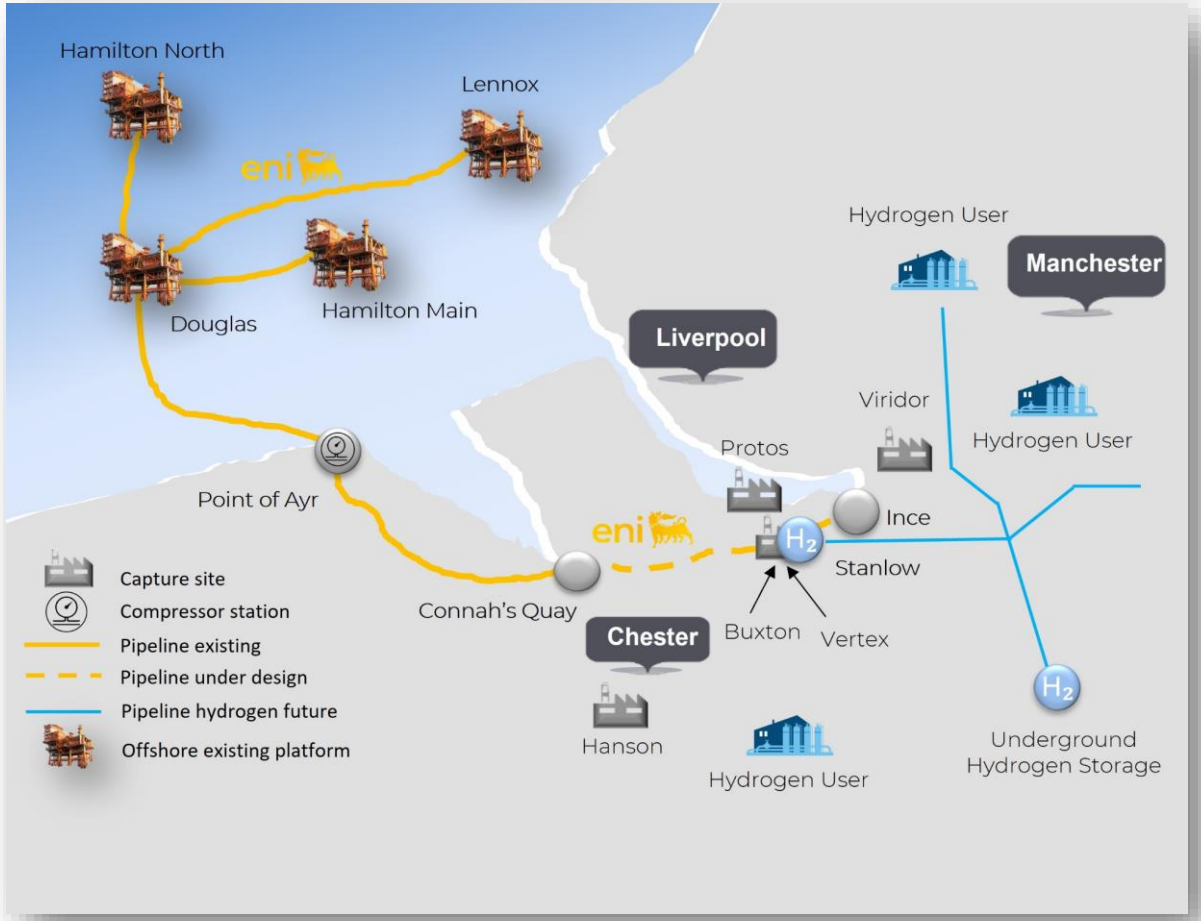
Hynet North West

Phase 1 - 2027
4.5 MTPA of CO_2

Phase 2 – after 2030
10 MTPA of CO_2



- Selected as one of the two Track 1 projects in 2021
- 5 emitters have been selected for Track 1 development
- Over 21 MoU signed
- Total storage capacity of 200 MTON of CO2
- Injection capacity of 4.5 MTPA of CO2 for Phase 1 and 10 MTPA for Phase 2
- Strategic project for the UK: 30% storage capacity and 40% Blue Hydrogen Production

Waste-to-Energy: Viridor, ENCYCLIS (More than energy from waste)

Hydrogen: VERTEXHYDROGEN

Lime & Cement: Hanson HEIDELBERGCEMENT Group, TARMAC A CRH COMPANY

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Conclusions

- EU committed to achieving economy-wide climate neutrality by 2050 (limiting global warming to 1.5 °)
- CCUS is one of the key decarbonization levers
- Uneven distribution of storage opportunities across Europe
- CO2 transport and storage infrastructure (pipeline/ship) is the key enabler common to all pathways
- Public support and definition of business model important to kick start CCUS developments largely due to high upfront costs

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> THANKS FOR YOUR ATTENTION