CLEAN AIR TASK FORCE

September 2025

Europe Transport & Storage Cost Tool Methodology

Summary

1. Tool update
2. Emitters
3. Storage hubs
    - Planned
    - Widespread
4. Transport model
    - Pipelines
    - Rail
    - Shipping/ coastlines
    - Inland waterways
5. Levelized cost of transport
6. Data

Introduction

CCS cost tool update

- Assess multi-modal CCS transport in Europe
- Consider near-term and long-term storage availability
- Model least-cost paths for individual point source emitters

Emitter data

EU emitter data was taken from the European Environment Agency's European Pollutant Release and Transfer Register (PRTR), using data updated in December 2024.

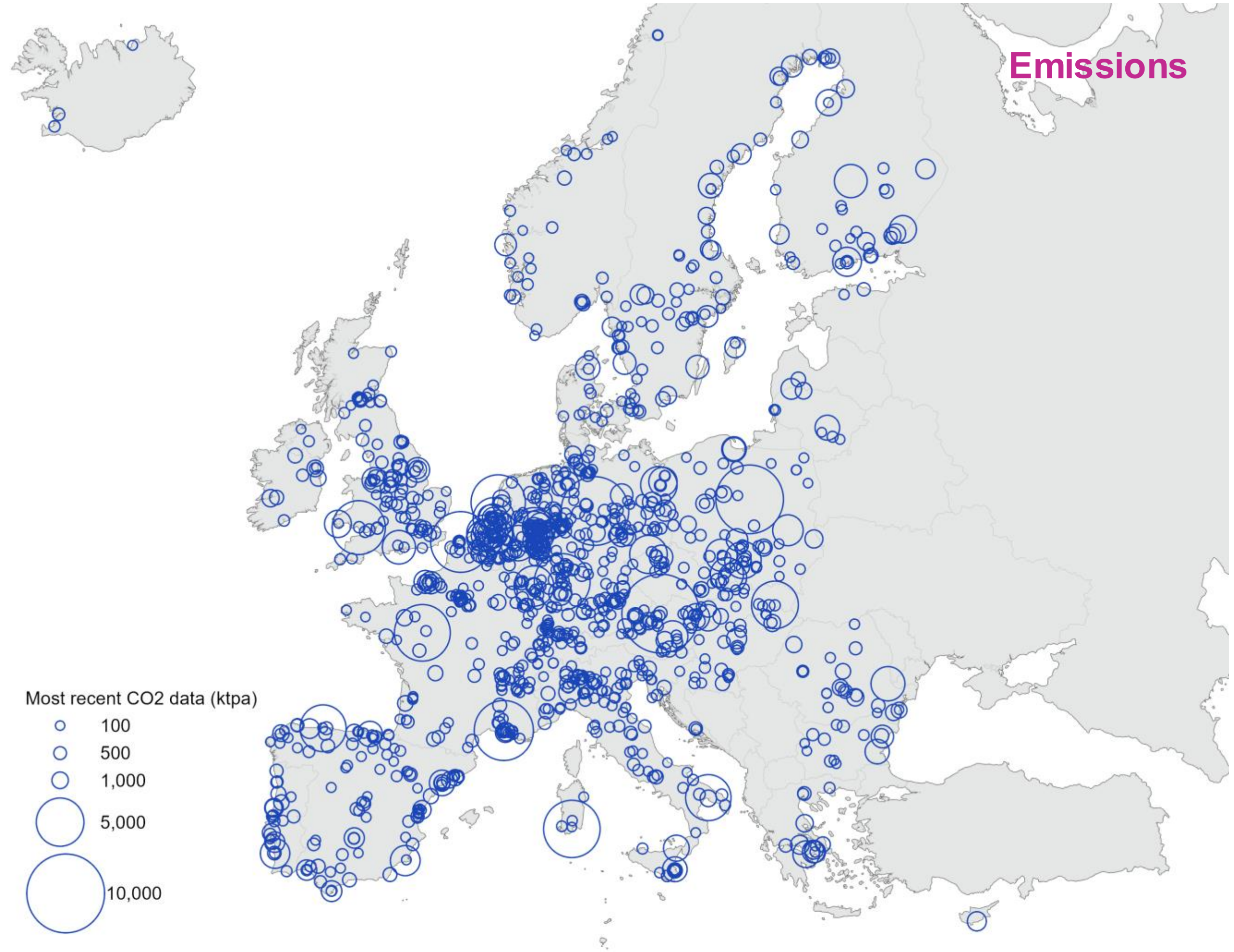
UK emitter data was taken from the UK Pollutant Release and Transfer Register (PRTR).

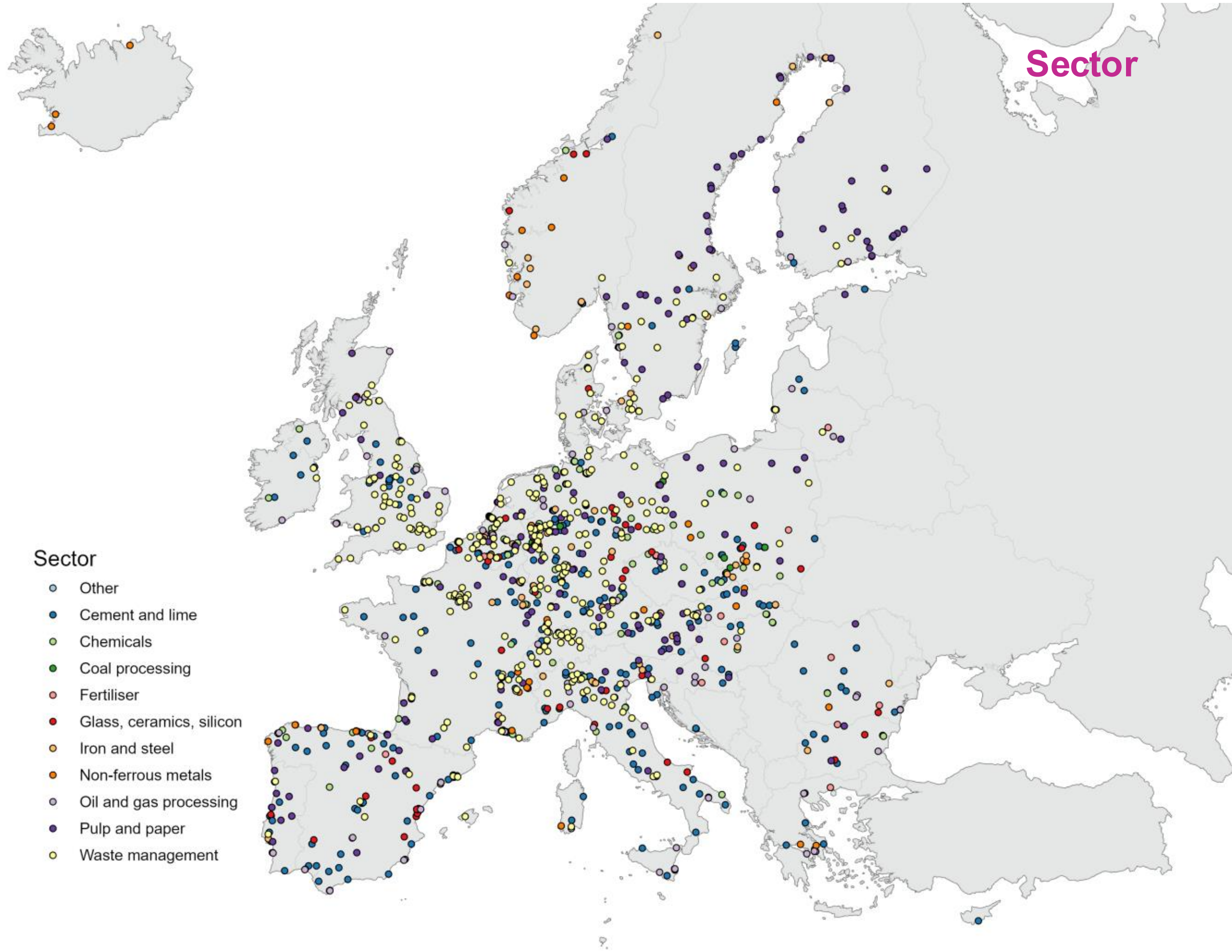
Norway emitter data was taken from Norsk Utslipp.

Emitters declaring emissions in any year since 2019 were included, with the last declared value used for each source (this is 2022 for most operating sources).

Industrial emission sources of 100 ktpa and greater in the following EU sector codes were included in the analysis: 1a,1d,1e, 2a-e, 3a-g, 4a-e, 5a-c,6a-b. This covers oil refining, gas processing, chemical industries, iron and steel, non-ferrous metals, cement and lime, waste incineration, and pulp and paper.

Map of emitters





Hub identification: Planned hubs

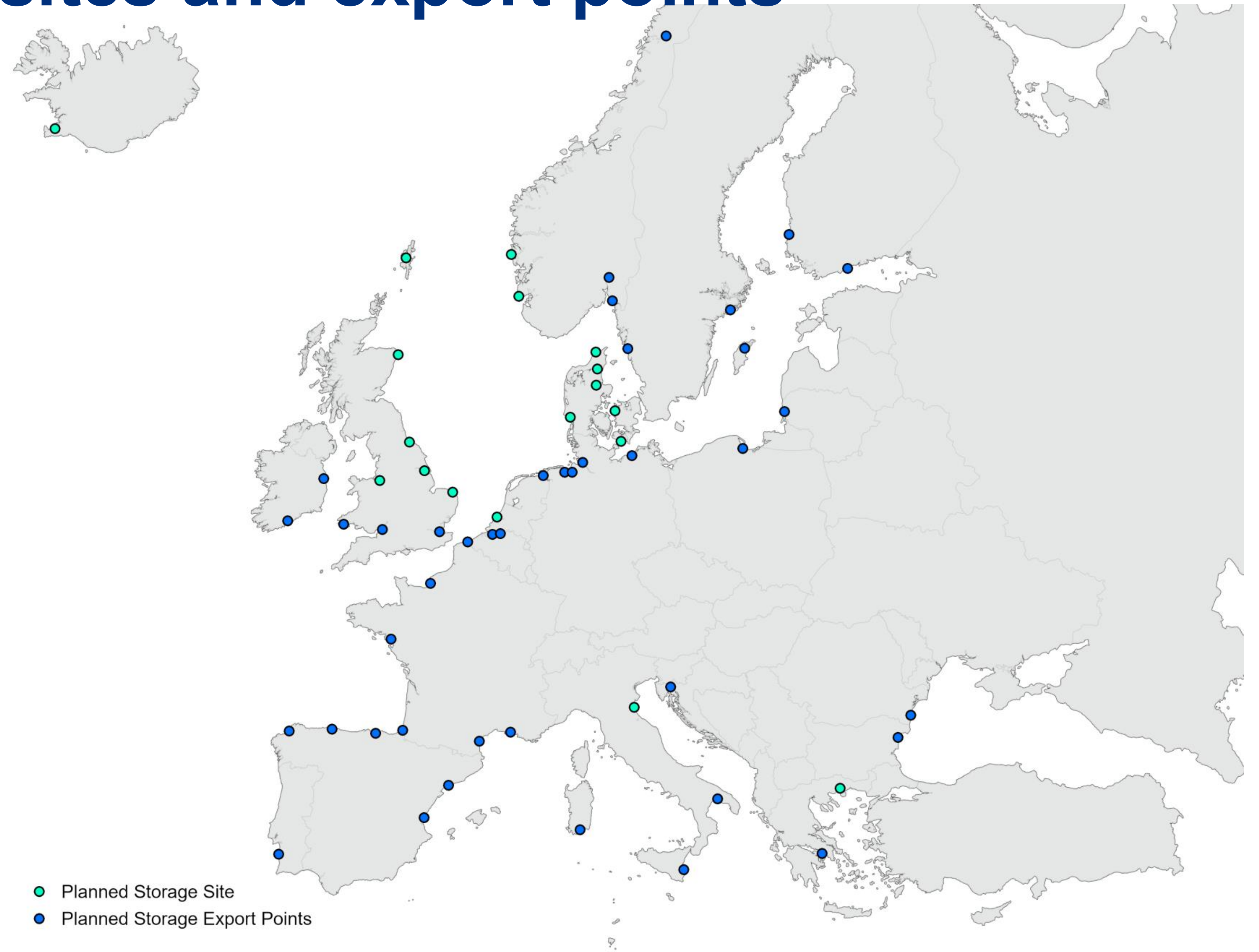
Publicly announced storage hubs in Europe were identified, using CATF project tracking data. For the 'Planned hubs' scenario, this excludes some smaller, onshore storage sites which are primarily associated with one or two local emitters, in order to focus on large storage sites with plans to collect emissions from multiple sources.

These storage sites are largely offshore, so each is associated with an onshore collection point.

Some onshore collection points were also designated CO_2 ship import points, where such terminals are planned. The two onshore storage sites considered are also associated with CO2 ship import points.

CO_2 ship export points were identified based on publicly announced plans – in particular, current and proposed Projects of Common/Mutual Interest for CO_2 networks. For Ireland and Croatia, likely export ports were selected in the absence of announced plans (Dublin, Cork, Rijeka).

Planned storage sites and export points



Note: For offshore storage sites, the associated onshore collection point is shown.

Hub identification: widespread storage

Additional storage hubs under the Widespread Storage scenario are based on the following sources for each Member State. Where a suitable sedimentary basin, saline aquifer, or 'trap' formation is identified, a representative point (or points for larger areas) are selected.

Austria: Four storage sites identified by the CO2 transport network study commissioned by the Austrian Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology.

Bulgaria: Seven saline aquifers identified in the EU Geocapacity project.

Croatia: The proposed Bockovac storage project and four saline aquifers identified by the Geocapacity project.

Czechia: The CO2Spicer storage pilot project, and three sedimentary basins identified in the EU Geocapacity project.

France: Announced early-stage projects in the Paris Basin, South-West Basin and a storage site in the South-East Basin identified under the 'Strategy CCUS' Horizon project.

Germany: Five representative locations across four regional saline aquifers identified by Knopf and May (2017).

Greece: Two storage sites in Macedonia identified by the 'Pilot Strategy' Horizon project.

Hungary: The announced 'Danube Removals' storage project in the Pannonian Basin and five other locations based on saline aquifers identified in the Geocapacity project.

Hub identification: widespread storage

Italy: Large-capacity saline aquifers identified in Donda et al. (2011).

Lithuania: Three saline aquifers identified in Malik et al. (2024).

Portugal: An offshore storage site identified by the 'Pilot Strategy' Horizon project.

Poland: Storage sites identified by PGI's CO2 storage atlas.

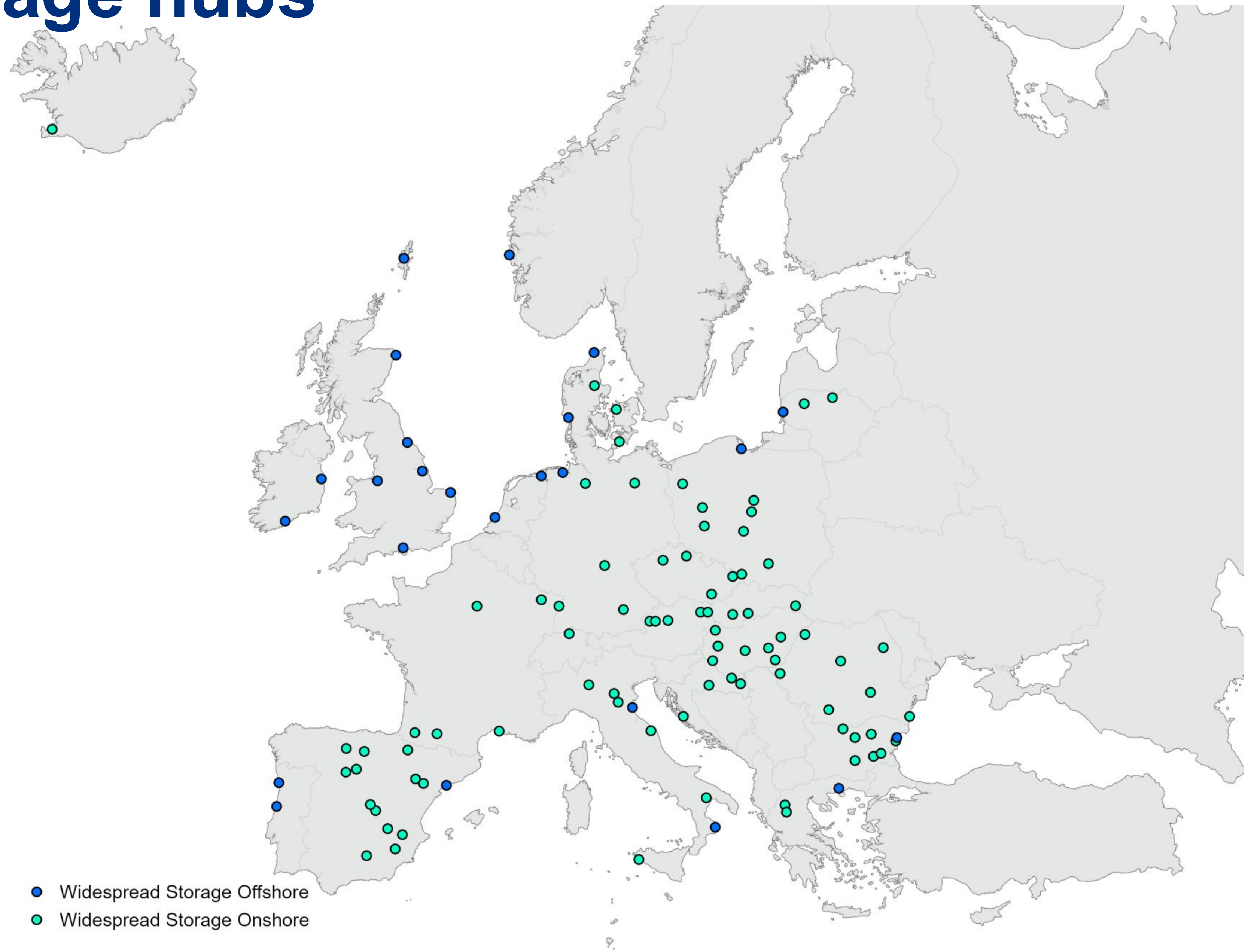
Romania: Two storage sites in the Southern Carpathian Foredeep and five other promising sedimentary basins identified by the EU Geocapacity project.

Slovakia: The proposed Engas CO2 storage site in the Pannonian Basin and two other saline aquifers identified in the EU Geocapacity.

Spain: Suitable saline aquifer traps identified in Martinez del Olmo (2019), using data from the Spanish CO2 atlas (ALGECO2 project).

Switzerland: The Upper Muschelkalk basin, identified as a potential storage site in Swiss potential for geothermal energy and CO2 storage

Widespread storage hubs



Note: For offshore storage sites, the associated onshore collection point is shown.

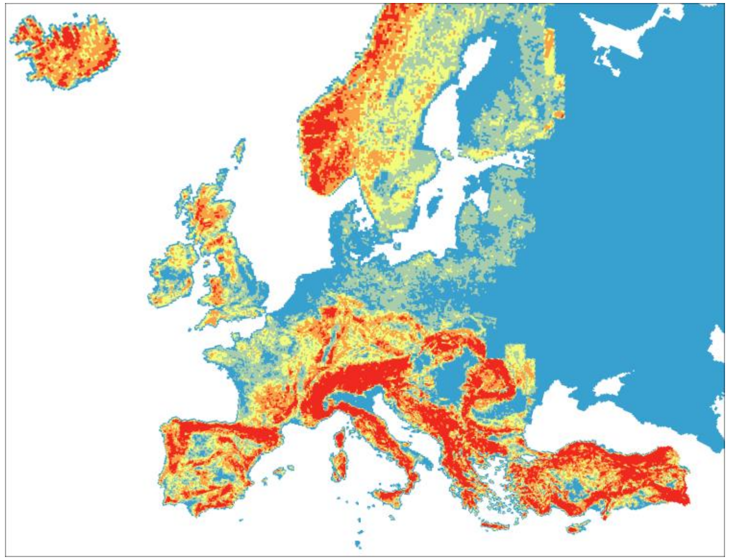
Modeling transport connections

An optimal path is modelled between each emitter and the nearest storage point for pipeline, shipping, barge, and rail. To develop the model, (1) a "cost surface" is created for each mode of transportation to represent the factors or combination of factors that affect travel between a source (emitter) and sink (storage site) over a given area (2) Accumulated distances are calculated between each sink-source pair and (3) the most efficient, least-cost path is determined. The analysis is done at the 10 km spatial scale.

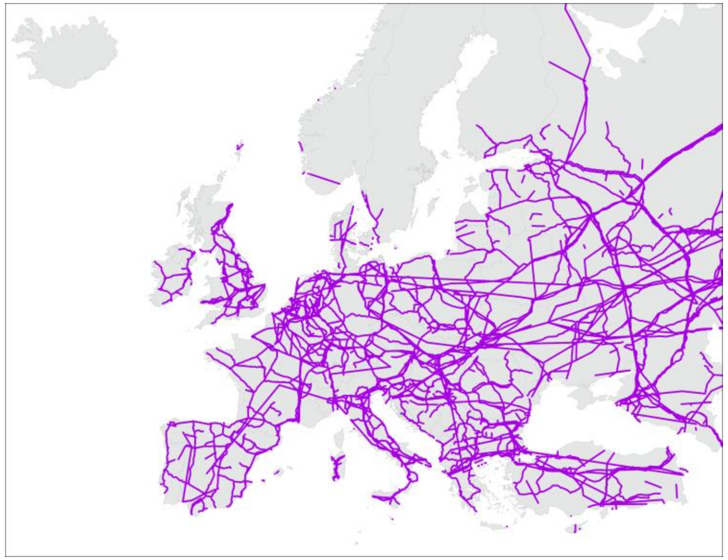
- For pipelines, existing rights-of-way for oil and natural gas pipelines and terrain slope are considered.
- For shipping, only those emitters within 3 km of the coast are evaluated.
- For barge and rail, any emitter within 3 km of the existing rail network and navigable waterways are analysed. Only waterway networks of class V and higher (allowing for barge transport) are considered.

Weighted cost surface

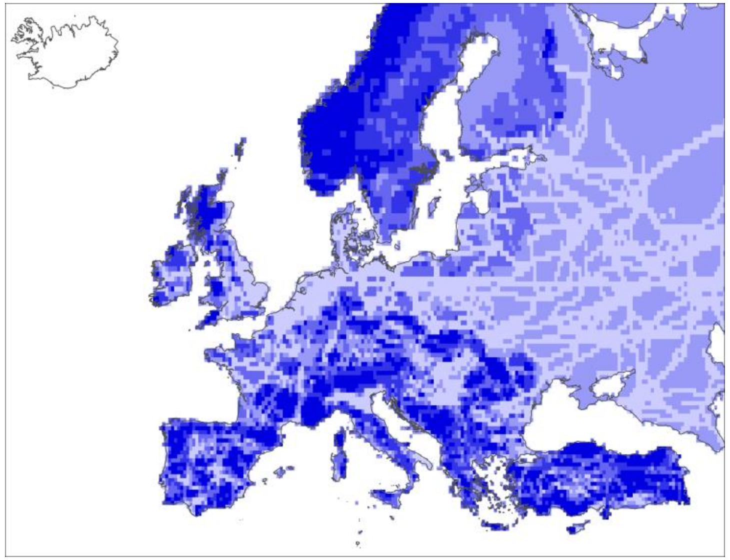
Example of how the cost surface is created for pipelines.



+



=



Terrain slope

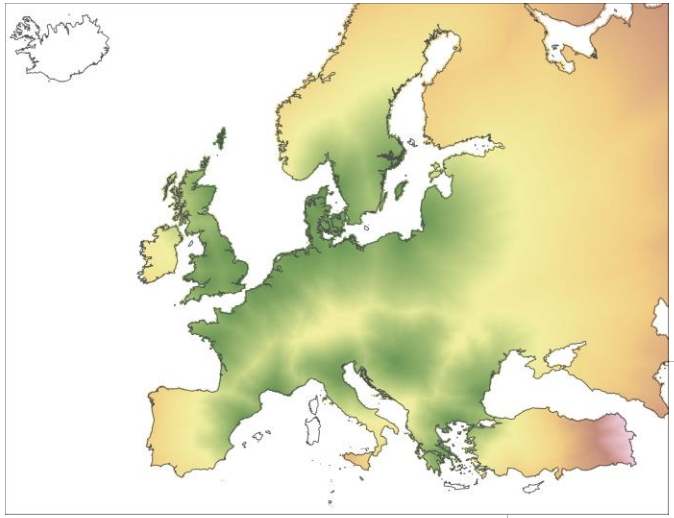
Oil and gas pipelines ROWs

Weighted cost surface

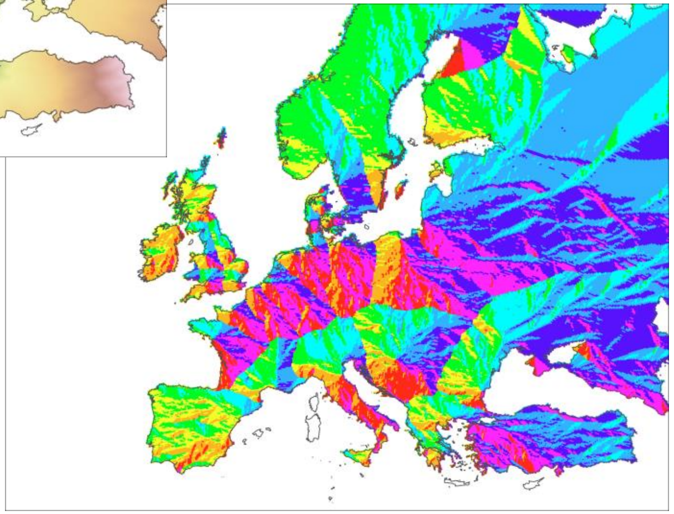
Lower "cost" area (light blue), higher "cost" area (dark blue)

Optimal path analysis

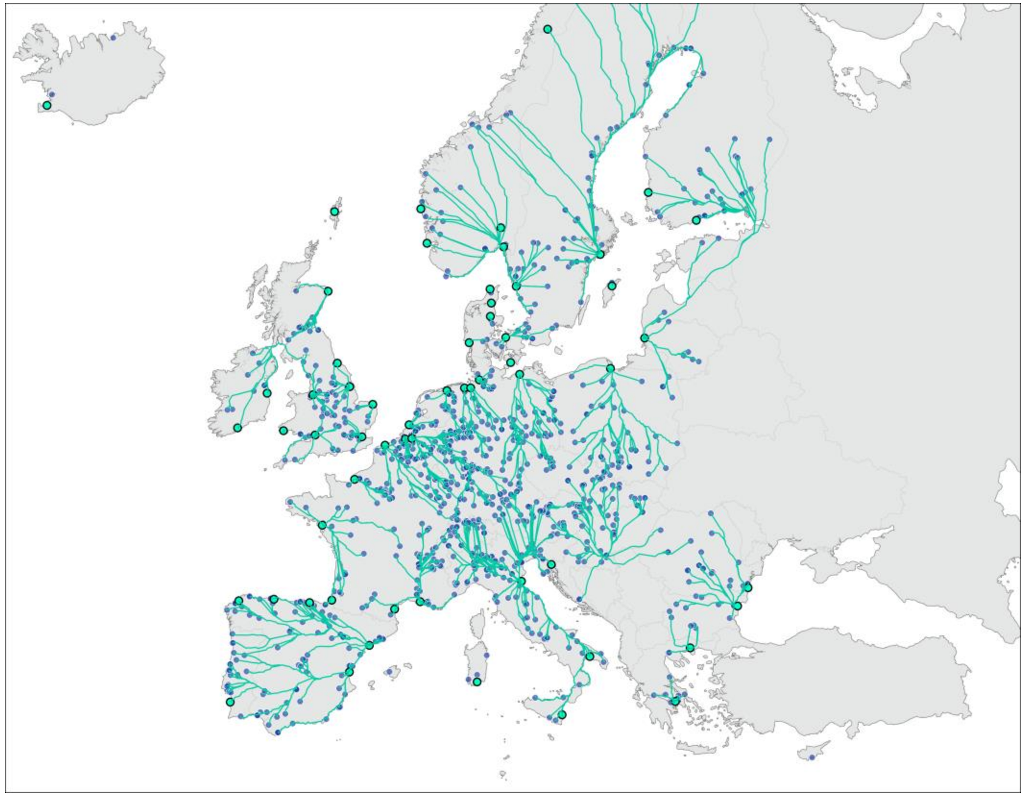
Example of how distance accumulation based on the cost surface is used to determine optimal paths for pipelines.



Distance accumulation: considers straight-line distance, cost distance, and true surface distance.



Backlink raster: defines the direction or identifies the next neighbouring cell (the succeeding cell) along the least accumulative cost path.

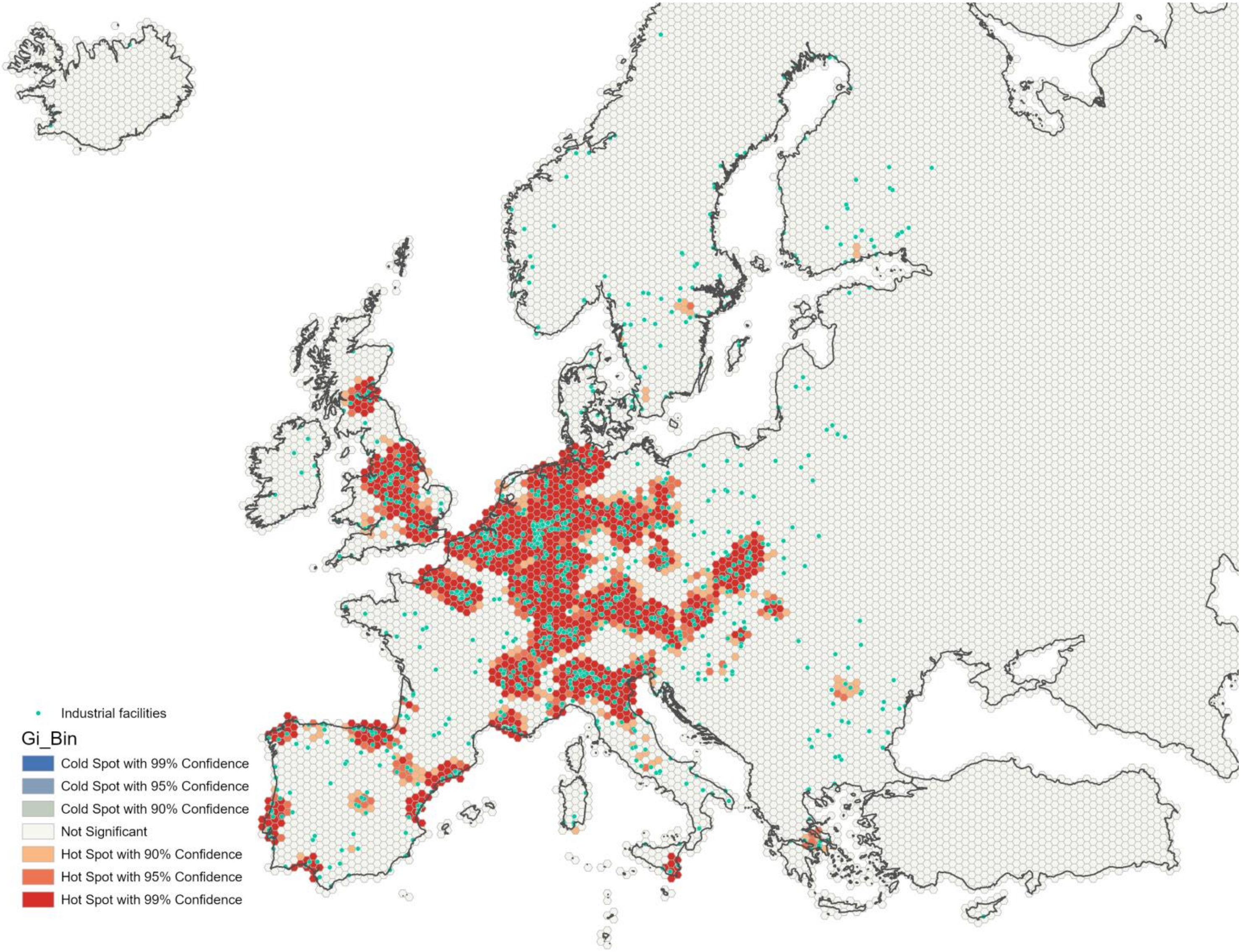


Least-cost paths

Cluster analysis: identifying industrials corridors

High-opportunity industrial regions are identified using the Getis-Ord statistic (Gi*), which measures statistically significant spatial clusters of high values (hot spots) and low values (cold spots).

For this analysis, hot spots indicate areas of significant industrial concentration.



Levelised cost of transport calculation

Transport costs

The levelised cost of CO_2 transport (LCOT) for pipelines, barge, and rail are calculated using an updated version of the Excel model published by Sievert et al. (2025) (Supplementary Information). This model uses data from the research literature and stakeholder consultation to derive LCOT for each transport mode as a function of mass of CO_2 transported and distance transported.

The model was updated to 2024 euros, using inflation data from the European Central Bank. A further 1.5% inflation was applied over the financial lifetime of the infrastructure. Electricity costs were also updated to the EU average non-household prices for 2020-2024.

Coastal emitters also consider transport via medium pressure ship, using a cost equation published in Oeuvray et al. (2024), adjusted to 2024 euros and modified to include a receiving terminal cost (based on Sievert et al. (2025)).

These models generate costs for each emitter and transport mode using: total CO_2 emissions at each point source and the path length (for each transport mode) to the nearest storage hub or export hub.

Costs of CO_2 compression (pipeline) and liquefaction (rail, barge, and shipping) are added to the total transport cost.

Levelised cost of transport calculation

Hub costs

A cost is derived for each storage hub based on the cost of onshore/offshore storage and including any transport between the onshore collection site and offshore storage site. Transport costs are calculated using the Sievert et al. (2025) model and the announced, first phase annual capacity of the storage site.

A shipping cost is derived for each export hub using Sievert et al. (2025), assuming low-pressure shipping of 1 Mt/year, and the distance to the nearest storage hub with import capability. The storage hub cost at this destination is combined with the shipping cost to derive a total transport and storage cost for each export hub. Port-to-port shipping distances are taken from sea-distances.org. Shipping fuel costs are based on LNG prices at Rotterdam, obtained from shipandbunker.com.

Levelised cost of transport calculation

Additional considerations

The total cost of transport is calculated between each emitter and its nearest export hub or storage site by pipeline, rail, barge (where possible), and ship (for coastal emitters).

For rail and pipeline, the cost to the second nearest hub is also calculated, as well as the cost to the nearest onshore hub (if available). This allows potentially further afield but lower cost hubs to be considered.

For emitters located in cluster 'hot spots' (see slide 14), pipeline costs are based on a minimum CO_2 volume flow of 1 Mtpa, assuming larger, shared pipelines would be built in these areas. Emitters located outside these areas use pipeline costs based on their actual annual CO_2 emissions.

The combined transport and storage cost for each viable transport mode is compared for each emitter and the lowest cost route selected. Pipeline routes are then excluded from this comparison for the 'no pipeline' scenario.

CATF

Levelised cost of transport calculation

Other input assumptions

Cost of compression: €15/t (Clean Energy Technology Observatory, 2024)

Cost of liquefaction to low pressure: €17.5/t Roussanaly et al. (2021)

Cost of liquefaction to medium pressure: €16.5/t Roussanaly et al. (2021)

Cost of liquefaction to LP from pipeline pressure: €4.7 Roussanaly et al. (2021)

Cost of liquefaction to MP from pipeline pressure: €3.5 Roussanaly et al. (2021)

Cost of storage (onshore): €15/t (based on upper end of CETO (2024) and stakeholder consultation)

Cost of storage (offshore): €30/t (based on upper end of CETO (2024) and stakeholder consultation)

Cost of CO_2 terminal (used for MP shipping case only): €3.1/t. Based on Sievert et al. (2025)

Other data sources

Sources:

Infrastructure

- Ports: Eurostat GISCO
- Railways: EuroGlobalMap, OpenRailwayMap
- Waterways: UNECE Blue Book
- Oil and Gas Pipelines: Global Energy Monitor
- Simulated CO2 Network: JRC
- Land use/Land cover: Eurostat GISCO

Sinks: CO2SToP

DEM/ Slope: Eurostat GISCO