

Requirements for a CO₂ infrastructure in Germany – Achieving climate neutrality in the cement, lime and waste incineration sectors

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Cement and lime production as well as waste incineration belong to sectors with long-term unavoidable CO₂ emissions. Even if every effort is being made to reduce CO₂ emissions here, a significant amount of CO₂ will remain, which cannot be avoided by technologies for efficiency and switch to alternative fuels and materials. In order to still achieve the climate targets in Germany and the European Union and not to jeopardise local industrial value creation, there is no way around the capture of these unavoidable CO₂ quantities with subsequent storage and utilisation (CCS/CCU) in these areas.

CCS/CCU needs the transport of CO₂ from the source to the sink. This requires a CO₂ infrastructure, which must be developed quickly and pragmatically, because timely deployment and CO₂ emission avoidance at scale is of essence. For industrial plants in the EU Emissions Trading Scheme (EU ETS) in particular, the annually decreasing volume of CO₂ allowances is the key indicator for the pace of required decarbonisation. If the current legal framework continues, no new CO₂ allowances will be issued around 2040. Conversely, this means that EU ETS plants will have to operate in a largely climate-neutral way by then. In order for CO₂ capture to function on time, investment decisions need to be taken now and a CO₂ infrastructure must be established by the mid-2030s at the latest.

A new VDZ study (Fig. 1) presents the expected, unavoidable CO₂ generated in Germany in the cement, lime and waste incineration sectors. They currently emit around 65 Mt of biogenic and fossil CO₂ per year. Conventional reduction measures will reduce these emissions to around 58 Mt CO₂ per year by 2045. This amount of remaining CO₂ can only be avoided by capturing it with subsequent storage or utilisation. Various processes are currently being tested in the cement industry on a pilot and demonstration scale in cement plants in Germany; further projects on an industrial scale are already being planned (Fig. 2). Similar projects have been announced in the lime industry and in waste incineration plants.

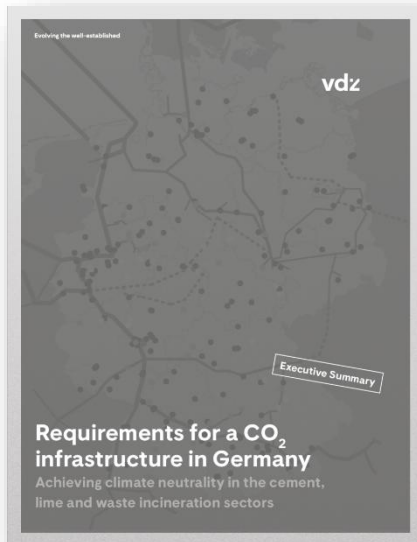


Figure 1: New VDZ study about CO₂ infrastructure in Germany published

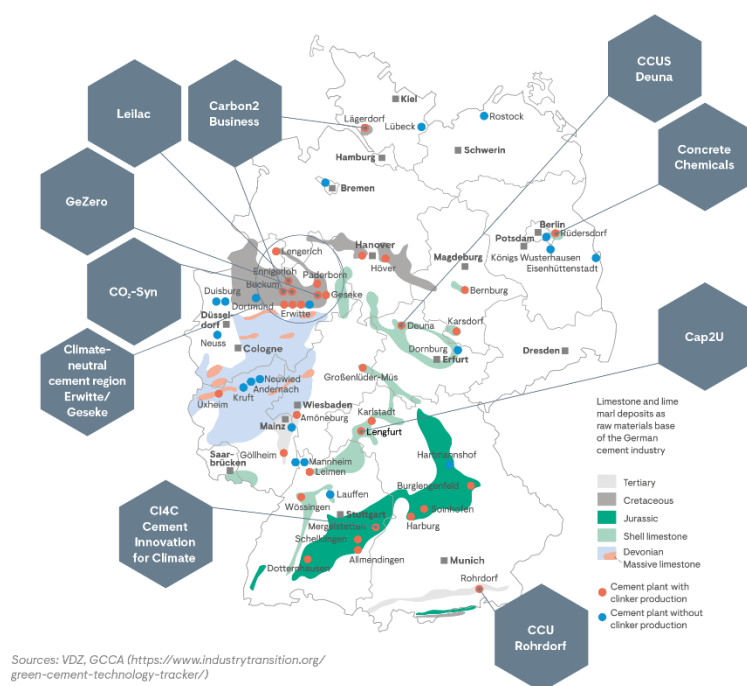


Figure 2: CO₂ capture in the cement industry – examples of projects in Germany

Based on the geographical distribution of emissions from the CO₂ sources in the three industrial sectors, in Germany around ten clusters can be derived with CO₂ emissions of 2 to 7 Mt CO₂/a each (Fig. 3). These serve as the basis for modelling the infrastructure requirements. Other comparatively small CO₂ sources in these sectors, which were located outside these clusters, and additional CO₂ quantities from neighbouring countries expected for transit to the north were integrated in the analysis of transport volumes.

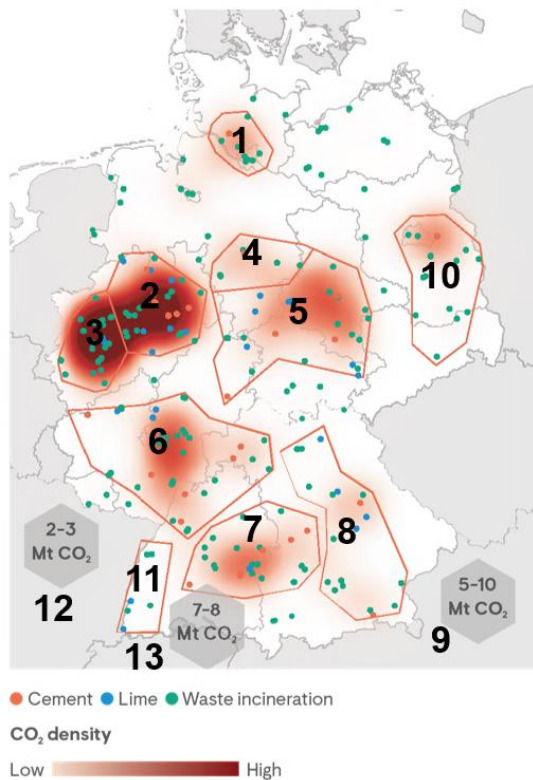


Fig. 3: CO₂ clusters in Germany

Prospects for a CO₂ transport in Germany

The VDZ study looks at multimodal CO₂ transport by pipeline, rail or ship. In the medium and long term, the majority of CO₂ transport will have to take place via pipeline in view of the expected volumes. In certain cases, trains and possibly ships will also play a role, as the analysed scenarios show.

The question of access to a future CO₂ infrastructure is decisive for the choice of the transport option. If one compares the geographical distribution of the sites in the three sectors with the infrastructure projects for CO₂ transport that are currently planned or announced, the following picture emerges from the analysis:

Almost all cement and lime industry sites are located at a distance of around 50 kilometres from the corridors for CO₂ pipeline networks that have been suggested to date. This also applies to a large number of waste incineration plants. Therefore, a connection to a pipeline appears possible for the majority of CO₂ sources (Fig. 4).

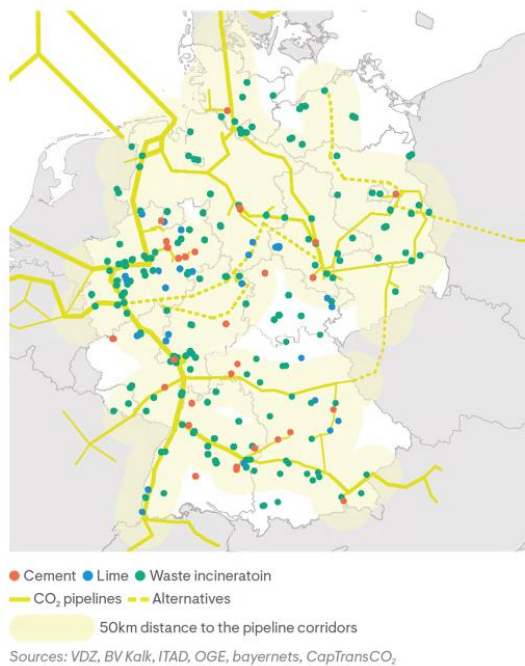


Figure 4: CO₂ pipeline network and connection of the sources

In general, CO₂ transport by rail is also possible. Many cement and lime plants have a railway siding, but this is not sufficient as a prerequisite. Among other things, a loading infrastructure has to be set up, railway sidings expanded and, if necessary, upstream sections of track have to be upgraded. In addition, reloading the CO₂ at the transfer points to the sink involves a great deal of effort, meaning that this option is only possible in certain cases.

Transport by inland waterway only seems conceivable at very few locations that are close to larger waterways or already have a harbour connection. In addition to the necessary expansion for CO₂ transport, factors such as high and low water levels must also be taken into account.

For CO₂ exports from corresponding hubs on the coast to geological CO₂ storage sites under the North Sea, transport by sea-going vessel will play a greater role, at least until offshore CO₂ pipelines are available to a sufficient extent.

CO₂ storage and utilisation

In addition to transport, the required capacity of CO₂ sinks is a key factor for the rapid development of CO₂ capture over time. An evaluation of currently planned and published storage projects shows that by 2030, an annual storage capacity of around 30 Mt CO₂ can be expected within the EU and over 50 Mt CO₂ in Europe as a whole¹. By 2038, the currently known projects indicate annual storage capacities of just under 50 Mt CO₂ in the EU and around 140 Mt CO₂ in Europe as a whole.

¹ EU, Norway, Iceland, UK

The focus for storage is on the continental European North Sea coast of Denmark, the Netherlands and the Norwegian and British North Sea (Figure 5). At the same time, CO₂ storage projects are also being developed on land, e.g. in France, Denmark and Poland. In the future, onshore storage options will be available at significantly lower costs than offshore storage. Due to growing demand and new regulation, it can be assumed that the expansion of storage capacities in Europe will continue to accelerate. The utilisation of existing former gas fields in Central Europe for the temporary storage of CO₂, as planned in Austria, for example, can represent a transitional solution for locations for which a pipeline connection will not be established until later.

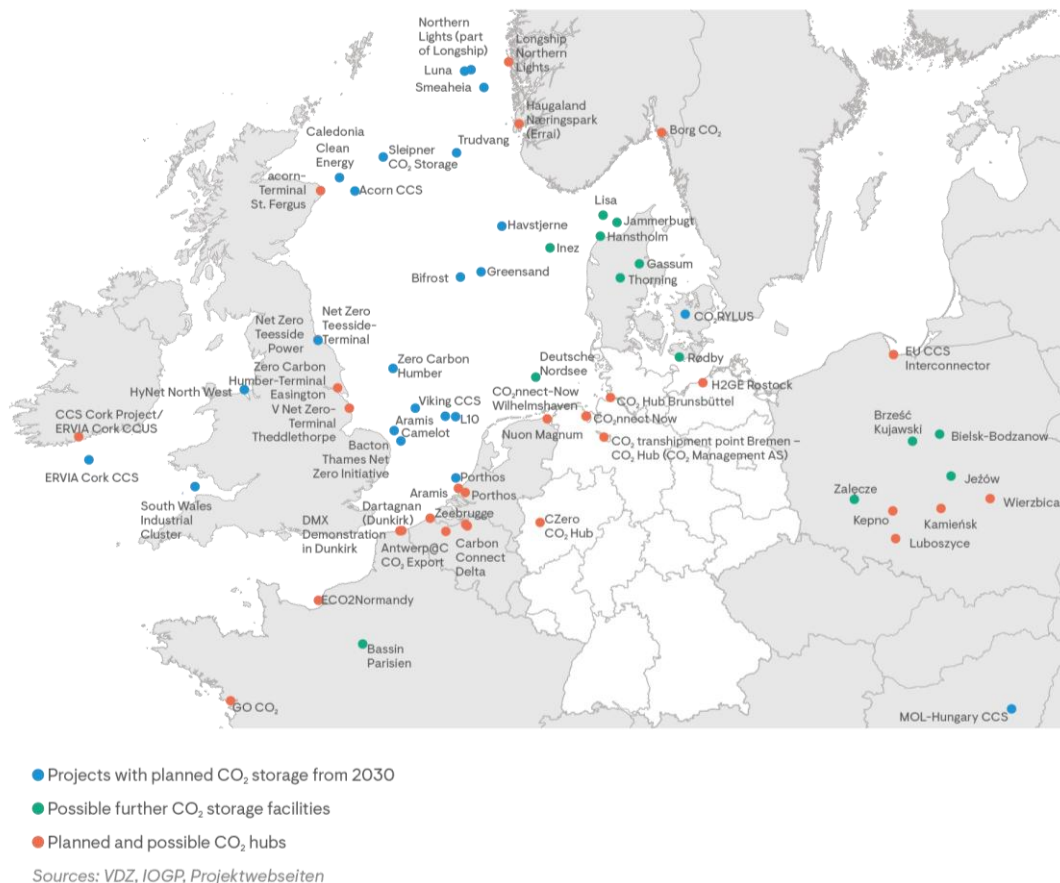


Figure 5: CO₂ storage facilities and hubs in Europe

There is also considerable CO₂ storage potential under the German North Sea. According to a research project by the Geomar Institute in Kiel, Germany's offshore CO₂ storage potential is estimated to be in the order of 1.9 to 10.4 Gt. An annual storage capacity of around 20 Mt CO₂ is estimated initially and significantly more in the medium term. In addition to CO₂ storage sites under the seabed, there are also geological formations under the German mainland that are generally suitable for CO₂ storage.

Although CO₂ utilisation (CCU) is included in this study, it cannot be explicitly depicted in the infrastructure modelling, because the quantitative, geographical and temporal development of CO₂ demand up to 2045 is still unclear. In addition, it must be clarified how the enormous demand for the required renewable electricity can be met. Overall, this analysis assumes that regional CO₂ utilisation

can already make an important contribution to climate protection before 2045 and that a CCS-oriented pipeline network will also serve as the basis for increasing CCU integration.

CO₂ -infrastructure ramp-up: Scenarios and assumptions

The development of CO₂ transport is modelled on the basis of two scenarios. In the CN2040 scenario, climate neutrality is to be achieved in 2040. In comparison, a second scenario is considered in which the development of the pipeline network is delayed by five years and climate neutrality is not achieved until 2045 (CN2045).

For the CO₂ transport requirement, the captured volumes for the years 2030, 2035, 2040 and 2045 are calculated (Fig. 6). In the CN2040 scenario, infrastructure development in the form of CO₂ pipelines is assumed to begin as early as 2028, with the first sites connected. Compared to the CN2045 scenario, larger quantities of CO₂ can be transported earlier. In CN2045, starting in 2028, CO₂ will initially only be transported by rail. Afterwards, beginning in 2033 pipeline transport will be implemented at a high expansion rate.

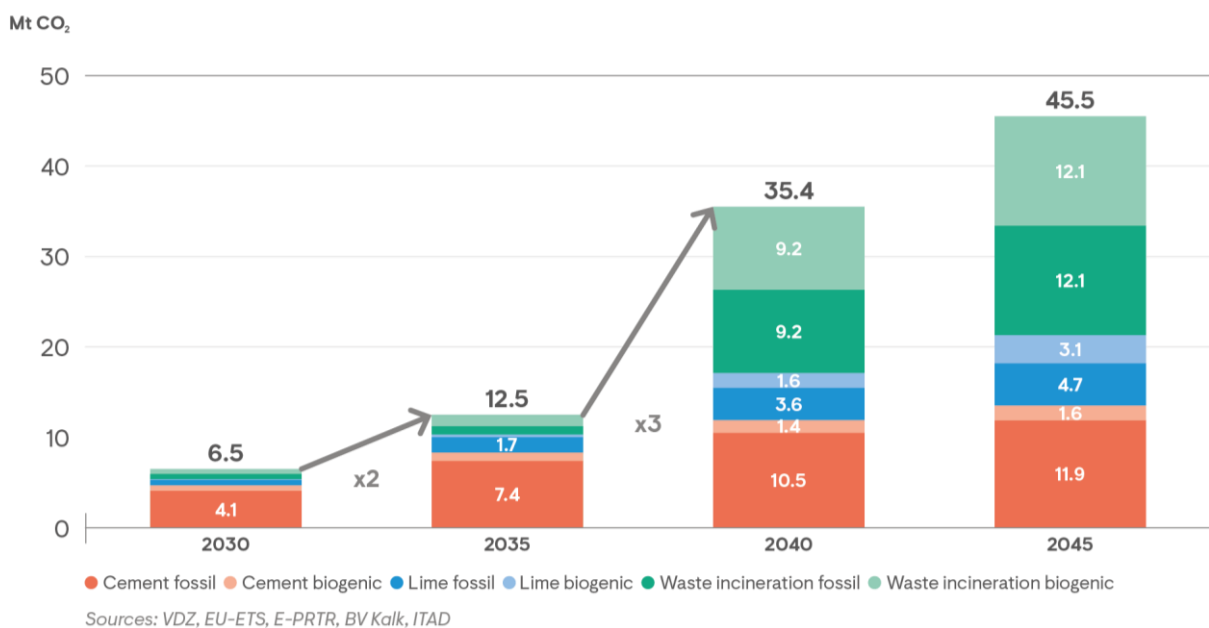


Figure 6: Development of CO₂ capture over time in the CN2040 scenario

Figure 7 shows the main findings of the two climate neutrality scenarios 2040 und 2045. The central CN2040 scenario results in an annual CO₂ transport requirement of around 6 Mt in 2030, around 13 Mt in 2035 and around 35 Mt in 2040. In 2045, this will rise to 45 Mt in Germany. Additionally, there will be volumes of 15 to 20 Mt CO₂ per year for transit from the neighbouring countries of Austria, Switzerland and East of France beginning in 2035.

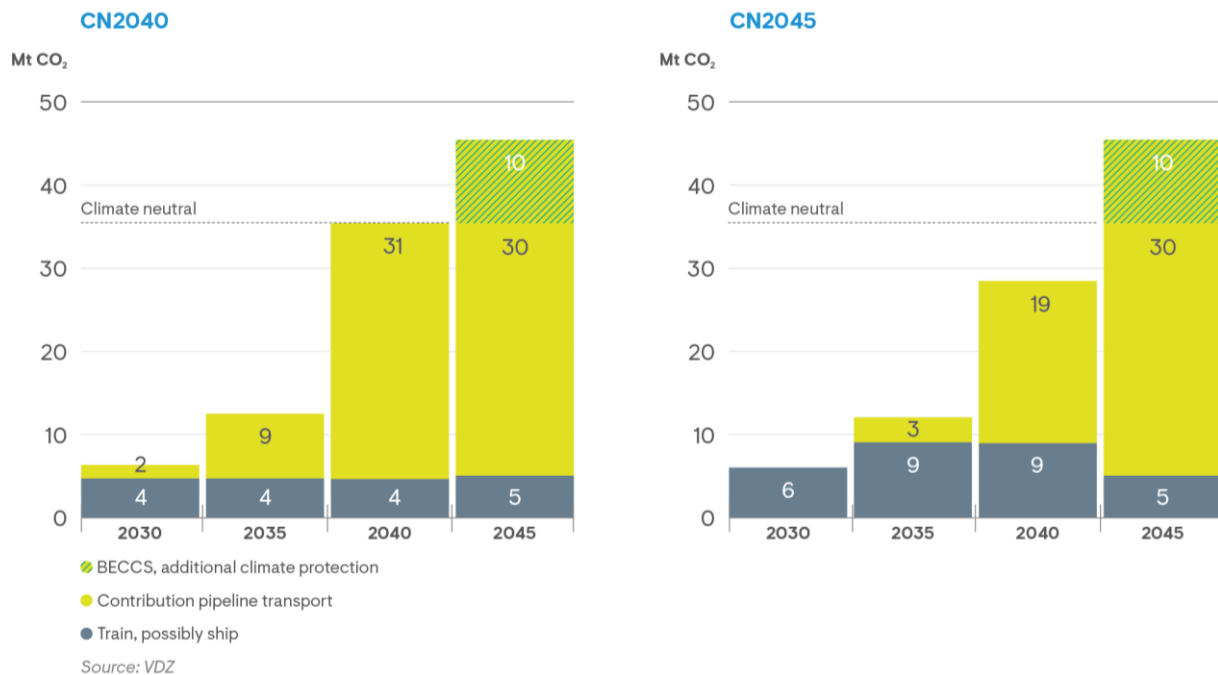


Figure 7: CO₂ transport requirements for pipeline, train and ship transport in the CN2040 and CN2045 scenarios

In total, around 4,800 km of long-distance pipelines and 3,000 annual trips by 20 block trains with tank wagons are required to transport the CO₂. In the CN2040 scenario, CCUS can save cumulative emissions of around 500 Mt CO₂ in Germany over 25 years; this includes around 50 Mt of negative CO₂ emissions from the capture and storage of biogenic CO₂. By 2035 at the latest, all ten identified clusters must be connected to a transport and storage infrastructure.

In the CN2045 scenario, the CO₂ sources are not connected to a CO₂ pipeline network until 2033. Accordingly, the demand for train and ship transport will become almost twice as high as in CN2040 at 9 Mt CO₂ per year. Still, the CO₂ pipeline network will also need to be expanded very rapidly from 2033 onwards. From 2045 onwards, 90 % of the captured CO₂ will also be transported by pipeline in this scenario, with the proportion transported by train and possibly by ship decreasing accordingly. The removal of biogenic CO₂ from the co-combustion of sustainable waste-derived biomass also enables a negative emissions contribution of 10 Mt CO₂ per year after 2040.

Investment requirements and costs

The investment required to build the 4,800 km long CO₂ pipeline network identified in this study is estimated to be around EUR 14 billion. Applying this to the estimated cumulative CO₂ capturing and transport volumes by pipeline of around 415 Mt CO₂ from sources in Germany until 2047 in the CN2040 scenario results in calculated costs of around EUR 35 per t CO₂. If the transit volumes

from neighbouring countries are included, these could decrease significantly to around EUR 25 per t CO₂². Even if a direct comparison of transport costs must be made on a site-specific basis, the VDZ study currently expects costs in the range of EUR 35 to 60 per t CO₂ for transport by rail for distances of more than 500 km, including the infrastructure for loading and unloading³. The costs can also be lower for shorter transport distances.

The conditions for the implementation of the infrastructure must now be created quickly, such as the legal framework or a sufficient amount of CO₂ free energy.

Study available for download

If you are interested in a more detailed view on the described scenarios, in how much additional thermal and electrical energy is needed for capturing the CO₂ or what is required for the infrastructure ramp-up in Germany, you can download an English summary of the study at:

<https://vdz.info/co2transport>

The full VDZ study “Requirements for a CO₂ infrastructure in Germany” (in German) is available at:

<https://www.vdz-online.de/co2-infrastruktur>

² Costs for the connection to the transmission grid are not included. The figures relate to onshore pipeline transport in Germany. The operating costs for the pipeline network are considered to be comparatively low.

³ This does not include the conditioning of CO₂ for rail transport at the departure and destination stations.