In accordance with the European Union target of 80-95% reduction in net greenhouse gas emissions for the year 2050 relative to 1990 levels, as well as the 2050 German directive for Net-Zero greenhouse gas emissions, the Helmholtz Initiative for Climate Adaptation and Mitigation aims to provide the innovation and decision-making guidance required to both minimize future emissions and improve societal resilience to the negative consequences of anthropogenic climate change.

While the rapid development of clean energy generation infrastructure, associated with cross-sector energy efficiency improvements and progress of low-carbon technologies such as electric vehicles represent tangible contributions to this goal, a large degree of emissions remain tied to industrial processes at the core of German economic output, notably within refineries, the iron and steel industry and the cement and lime industry.

In parallel to searching for low-carbon process alternatives, or utilisation scenarios for tough-to-decarbonise emissions, the case for underground CO2 storage remains attractive both economically and from a safety point of view [1].

The German onshore territory presents a large potential for carbon storage owing to a number of stratigraphic layers presenting favourable storage characteristics (depth, thickness, porosity, as well as surrounding rock properties) with considerable geographical extent.

A significant aspect in establishing cost-effective carbon networks that are engaging for both the public and industrial partners is the creation of advantageous organisational structures that take into account viable placement of storage sites, minimal-cost pipeline networks, coherent regional grouping, sensitivity to public concerns, as well as awareness of future emission landscapes.

As a consequence, we propose a national-scale study in which we address the aforementioned constraints to create hypothetical CO2 networks based on varying regional clustering methods, number of storage sites, pipeline scalability costs and underground storage and transport constraints relating to public acceptance.

We make use of recently published graph-optimisation algorithms to ensure we achieve close-to-optimal network structures for each input CO2 sources and storage sites, and usable land space for transport [2].
The geological data used is based on literature work establishing potential CO2 storage sites, as well as a catalogue of faults of which the fault-zone conductivity is not necessarily known [3]. CO2 emission data is taken from the EU carbon trading emitters register and future emission scenarios exclude fossil energy generation.

Our results show that a large diversity of CO2 networks can be envisioned for a 2050 German Net-Zero landscape while still maintaining acceptable regional exclusivity, owing primarily to the large degree of underground storage potential available. One aspect that is not considered is the prospect of trans-national CO2 networks that could benefit both locally certain large isolated point sources close to country borders or more globally through infrastructure economy of scale.

