DISSEMINATION
GENIE

Exploring the route to a climate resilient future

Geoengineering and negative emissions technologies are being debated as possible interventions in tomorrow's battle against climate change. GENIE investigates the risks and benefits of these advanced climate options.

Injecting aerosols into the stratosphere to reflect the sun's radiation, sucking carbon dioxide out of the ambient air with gigantic fans, and sequestering power plant emissions deep underground. Do these measures sound like something taken out of a science fiction novel? They are not. As the concentration of greenhouse gases in the atmosphere continues to rise, scientists and policymakers worldwide agree that new methods must be applied to avoid a future climate catastrophe. Conventional mitigation efforts should be sustained, but they have to be supplemented by a wide range of geoengineering and negative emissions technologies.

The GENIE project

The EU-funded GENIE (GeoEngineering and NegatIve Emissions pathways in Europe) project explores the environmental, technical, social, legal, ethical and policy dimensions of greenhouse gas removal and solar radiation management. GENIE aims to produce a comprehensive scientific assessment for evidence-based policymaking to address climate change and expand the toolkit for a zero-emissions future.

The GENIE project is led by a team from Aarhus University in Denmark, working in conjunction with the International Institute for Applied Systems Analysis (IIASA) in Austria, the Mercator Research Institute on Global Commons and Climate Change in Germany, and the University of Wisconsin at Madison in the USA.

Next, we highlight each consortium member's flagship output from the first half of the project's duration.

Study reveals social perceptions among global public for emerging climate technologies

A new worldwide survey-based study by Aarhus University shows that populations in the Global South support emerging technologies to combat climate change more than the public in advanced economies.

Innovative and even radical approaches to remove carbon dioxide from the atmosphere and reflect sunlight before it reaches the Earth's surface are increasingly acknowledged as potentially indispensable in the run to reach the emission targets dictated by the Paris Agreement. Yet, to be soundly implemented, these methods must resonate with citizenries around the world. In a study just published in *Nature Communications*, Chad M. Baum and colleagues have provided instrumental input to the ongoing discussion of the societal feasibility and desirability of these emerging climate intervention technologies.

By way of nationally representative surveys featuring more than 30 000 respondents in 30 countries, the Aarhus University researchers have examined public perceptions of a diverse set of climate intervention technologies. A central finding is that [publics] in the Global South are generally more supportive of the cutting-edge methods to tackle climate change than their Global Northern counterparts.

According to Baum, a variety of factors explain the finding: "Our results suggest that a range of climate beliefs are important, including how much a person expects to be harmed by climate change or has personal experience with major natural disasters. There is also evidence that the age of the country's population is correlated with support, most of all for solar geoengineering approaches."

The study represents a significant advance in mapping attitudes towards the technologies currently receiving massive attention in the scientific community. It stands out as the first piece of research to encompass respondents from six continents. Additionally, the survey is pioneering in its attempt to examine perceptions across the entire spectrum of methods, ranging from stratospheric aerosol injection to afforestation and direct air capture with storage.

As University Distinguished Professor Benjamin K. Sovacool, a coauthor and principal investigator of the GENIE project, stated: "Until now, researchers have almost exclusively focused on how publics in the US, the UK and Germany view these options to counteract climate change, while populations in Asia, Africa and South America have been overlooked. This is extremely problematic given that most of the world's future climate impacts will befall the Global South, not the Global North."

While the analysis reveals marked differences between the Global South and the Global North, it also attests to common ground. Baum noted: "The groups agreed that afforestation and restoration efforts were most deserving of support. They were also both rejecting a more hands-on policy approach to the development of the technologies. This is interesting because harsh words have been exchanged in academic and policy circles on the necessity of international moratoria on the riskiest technologies or the introduction of a global-level market for carbon credits and offsets. Both consistently received the lowest support in our survey. They instead wanted to see information and engagement campaigns and policies that encourage research and development."

Read more in *Nature Communications*: https://go.nature.com/3TkWP7S

Reconciling differences: scientific models and national inventories

Recognising the significance of effective land management in meeting climate targets, 118 out of 143 countries have incorporated land-based emissions reductions and removals into their nationally determined contributions (NDCs). Differences in defining managed land and human-induced carbon fluxes have led to differences between scientific models and national inventories in estimating land-based emissions. A recent study led by GENIE researchers from IIASA highlighted the importance of reconciling these differences to assess progress toward global climate targets accurately.

IIASA assessed key mitigation benchmarks after aligning emissions scenarios with inventories, finding that achieving the 1.5 °C temperature goal of the Paris Agreement will require earlier net-zero CO_2 emissions, stronger emission reductions by 2030 and significantly lower cumulative CO_2 emissions. The findings underscore the necessity for countries to set distinct targets for land-based mitigation, separate from other sectors, to ensure alignment with global

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climate objectives. They also emphasise the urgency of clarifying national climate goals and enhancing comparability between global models and national inventories.

Read more in *Nature*
https://www.nature.com/articles/s41586-023-06724-y

The State of Carbon Dioxide Removal

GENIE researchers from MCC, IIASA and UWISC have coordinated the flagship publication *The State of Carbon Dioxide Removal*. This report fills an important gap in global climate change assessments: the need for a balanced, independent and rigorous synthesis of the current science on carbon dioxide removal (CDR). The first edition of *The State of Carbon Dioxide Removal* was published in 2023, and the second, updated and expanded edition was published in June 2024. The second edition is authored by dozens of global CDR experts and has chapters on research and innovation, demonstration and upscaling, markets, policymaking, public perceptions, current deployment, Paris-consistent CDR requirements, the CDR gap and measurement, and reporting and verification (MRV). Important contributions are to provide an up-to-date estimate of current CDR deployments, evaluate the 'CDR gap' (the measure of difference between country proposals to deploy CDR versus Paris-consistent requirements) and evaluate the state of CDR technology development and readiness.

Read more
https://www.stateofcdr.org/

Evaluating carbon dioxide removal gaps

Another recent study led by GENIE researchers from MCC has evaluated the 'carbon dioxide removal gap'. This analysis quantifies current national proposals to expand CDR in the NDCs and long-term mitigation strategies. These national proposals are then compared to scenarios consistent with the Paris Agreement's temperature goal (i.e. those that hold warming to 1.5 °C). The study finds a gap between national proposals and Paris-consistent levels of CDR, suggesting that countries need to:

i. strengthen their emissions reductions in the short and medium term;

ii. incentivise further removals on land by supporting afforestation, reforestation and improved forest management; and

iii. promote the innovation, development and upscaling of energy-efficient, scalable and cost-effective novel CDR technologies.

Read more
https://www.nature.com/articles/s41558-024-01984-6

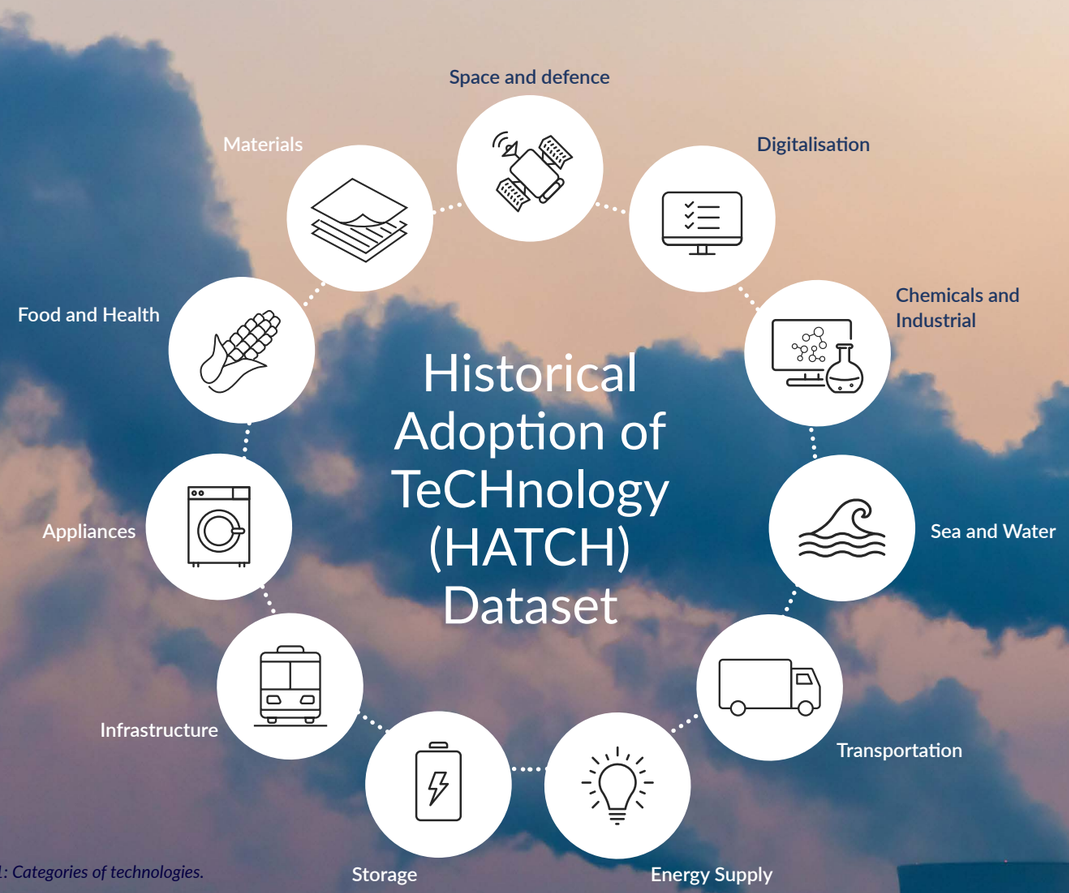

Figure 1: Categories of technologies.

Public perception of CDR technologies

A third recent study led by GENIE researchers from MCC evaluated the attention, sentiments and emotions towards CDR technologies on Twitter for the first time. This article complements other work in the consortium that used survey methods to assess how the public perceives these technologies. The analysis covered 11 CDR technologies alongside five 'solar radiation management' technologies (sometimes also known as 'geoengineering' technologies). Using machine-learning methods to study 1.5 million tweets, the researchers found that attention is shifting from general geoengineering themes towards more specific technology discussions, while conspiracy narratives often coincide with SRM tweets.

Read more
https://www.sciencedirect.com/science/article/pii/S0959378023001310

https://www.researchsquare.com/article/rs-4109712/v1

https://www.nature.com/articles/s43247-024-01365-z

https://www.climateliterature.org/#/project/cdrmap.

Understanding technological growth

To study the growth of different technologies, the GENIE team members at UWISC have created the Historical Adoption of TeCHnology (HATCH) dataset with time series data on over 200 technologies. The HATCH dataset spans a wide array of technologies across different regional scales and periods. This includes, for example, data on small, digital technologies such as cell phones as well as large industrial technologies such as railroads.

Understanding technological growth—how fast different technologies are adopted and to what extent—can help us understand how newer technologies may grow. The growth trajectories that technologies have taken in the past differ; while some have grown quickly, others have grown slowly. Meeting the temperature goals of the Paris Agreement will require the growth of technologies to reduce emissions, so understanding potential pathways for such growth is crucial.

A newly published dataset includes time series data on technology adoption for over 200 technologies:
https://cdr.apps.ece.iiasa.ac.at/story/hatch/

As we consider options to meet temperature goals in the future, it is informative to look at and understand the dynamics and drivers of technological growth in the past. One type of analysis is connecting a historical analogue technology to a more novel technology. Because many carbon dioxide removal (CDR) methods are at an early stage of development (some small-scale operations exist for technologies like direct air capture and carbon sequestration, for example), studying the growth of a historical analogue technology can provide insight into feasible future pathways for the growth of such a CDR method.

Papers that have used the HATCH dataset include:

Nemet, G., Greene, J., Müller-Hansen, F. and Minx, J.C. (2023) 'Dataset on the adoption of historical technologies informs the scale-up of emerging carbon dioxide removal measures', *Communications Earth & Environment*, 4, pp. 1–10. doi: 10.1038/s43247-023-01056-1.

Nemet, G.F., Gidden, M.J., Greene, J., Roberts, C., Lamb, W.F., Minx, J.C., Smith, S.M., Geden, O. and Riahi, K. (2023) 'Near-term deployment of novel carbon removal to facilitate longer-term deployment', *Joule*, 7(12), pp. 1–10, doi: 10.1016/j.joule.2023.11.001.

Edwards, M.R., Thomas, Z.H., Nemet, G.F., Rathod, S., Greene, J., Surana, K., Kennedy, K.M., Fuhrman, J. and McJeon, H.C. (2024) 'Modeling direct air carbon capture and storage in a 1.5 °C climate future using historical analogs', *Proceedings of the National Academy of Sciences*. 121, e2215679121, doi: 10.1073/pnas.2215679121.

GENIE
GeoEngineering and Negative Emissions Pathways in Europe

PROJECT SUMMARY

The EU-funded GENIE project will explore the environmental, technical, social, legal, ethical and policy dimensions of greenhouse gas removal and solar radiation management. GENIE aims to produce a comprehensive scientific assessment for evidence-based policymaking to address climate change, and to expand our toolkit for a zero-emissions future.

PROJECT TEAM

World-leading researchers will integrate insights from social science, engineering and physical science disciplines to provide a comprehensive view of geoengineering, and how they can help with the transition to climate neutrality in Europe and the world. All partners are also leading authors in the current production of reports from the Intergovernmental Panel on Climate Change (IPCC).

PROJECT PARTNERS

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