POLICY BRIEF

DEVELOPMENT OF GREENHOUSE GAS REMOVAL IN AUSTRALIA

A summary of the report on the Australian Academy of Science's roundtable on novel negative emissions approaches for Australia.

- The world needs to remove greenhouse gases from the atmosphere to limit global warming, and Australia can make a major contribution.
- Policy frameworks are in their infancy—globally, and in Australia. Developing greenhouse gas removal capability requires investment, cooperation and regulatory reform to accelerate the development of diverse solutions and explore innovative opportunities.
- Opportunities to support greenhouse gas removal include making it part of the refresh of national science and research priorities and identifying removal as a priority across a range of Australian Government investment vehicles (including the Australian Renewable Energy Agency, National Reconstruction Fund, and Clean Energy Finance Corporation). There should be targets and reporting as part of Australia's nationally determined contributions and annual climate statement.
- Greenhouse gas removal does not diminish the unarguable obligation to reduce emissions.

'Greenhouse gas removal' and 'negative emissions' refer to human activities that remove greenhouse gases from the atmosphere. 'Net negative emissions' occurs when more greenhouse gases are removed from the atmosphere than are emitted.

Discussion on greenhouse gas removal in Australia is in its early stages. The Australian Academy of Science convened a roundtable of experts to help shape Australia's emerging negative emissions conversation and explore the scientific capability, research, collaboration and investment needed to support new breakthroughs in greenhouse gas removal.

GREENHOUSE GAS REMOVAL

Current greenhouse gas removal solutions are insufficient to achieve the scale of removal needed to reach net zero emissions and limit global warming to 1.5°C, and well below 2°C, above pre-industrial temperatures. Removal efforts need to be scaled up. The world currently removes around 2 gigatonnes of carbon dioxide ($GtCO_2$) per year from the atmosphere, with only 0.002 $GtCO_2$/year of this resulting from novel methods.[1] Scenarios that limit global warming involve removing hundreds of billions of tonnes of CO_2 over the century.

Australia has been active in promoting land-based approaches such as afforestation, reforestation and carbon farming. These approaches can only account for part of the large-scale greenhouse gas removal required,

1. Smith, S. M., Geden, O., Nemet, G., Gidden, M., Lamb, W. F., Powis, C., Bellamy, R., Callaghan, M., Cowie, A., Cox, E., Fuss, S., Gasser, T., Grassi, G., Greene, J., Lück, S., Mohan, A., Müller-Hansen, F., Peters, G., Pratama, Y., Repke, T., Riahi, K., Schenuit, F., Steinhauser, J., Strefler, J., Valenzuela, J. M., and Minx, J. C. (2023). The State of Carbon Dioxide Removal - 1st Edition. The State of Carbon Dioxide Removal doi:10.17605/OSF.IO/W3B4Z

necessitating accelerated development of greenhouse gas removal and storage technologies, both existing and novel. Planning to achieve negative emissions requires consideration of a range of future opportunities and options as part of a portfolio of solutions, including innovations from scientific breakthroughs.

The roundtable identified a range of novel greenhouse gas removal and storage approaches, including: direct air capture methods; ocean alkalinity enhancement; technologies that split CO_2 into carbon and oxygen; mineral carbonation; enhanced mineralisation; blue carbon; and using photosynthetic organisms (Table 1).

Table 1: Novel approaches to greenhouse gas removal and storage noted by participants during the roundtable and the pre-roundtable survey. Note that this is not a comprehensive list of all approaches.

Atmospheric greenhouse gas removal

Chemical approaches

- Direct air capture (DAC)
  - Metal-organic frameworks (e.g., CSIRO's Airthena)
  - Solid and liquid sorbents (e.g., amines, amino acid salts and lime-based)
  - Trains that capture CO_2 while travelling between mine sites, to be stored subsequently at mine sites
  - DAC used to accelerate biomass production (e.g., bamboo) with a view to use in cross laminated timber as a large-scale replacement/augmentation for steel structures in buildings
- Electrochemical approaches (e.g., MIT's electro-swing process)
- Ocean alkalinity enhancement
  - Hawaii-based start-up Heimdal's seawater approach
  - Canada-based start-up Planetary Technology's approach, which uses mine tailings, water and renewable energy to extract valuable metals, and produce hydrogen and material that can be used
  - Addition of alkalinity-enhancing substance generated from mine tailings and other waste
  - Electrochemical approaches
- Carbon harvesting technologies
- Zeolites, photocatalysts and iron air salts for methane removal

Biological approaches

- Capture CO_2 via photosynthetic organisms (e.g., bioreactors), using bioengineering and synthetic biology to manipulate biological systems to take up more CO_2
- Methane removal by methane-consuming bacteria
- Use of microalgae to capture carbon followed by protein extraction (for human consumption) and biochar production from the remaining biomass for sequestration to soil
- Ocean farming (e.g., kelp, seagrass) for CO_2 capture
- Soil carbon 'farming' and innovative (regenerative) soil land management methods
- Inorganic soil carbon

Other

- Integrating carbon capture into current structural materials and systems (e.g., building materials can perform a dual role as carbon capture surfaces or retrofitting HVAC systems to provide capture function)

Carbon storage

Geological storage

- Mineral carbonation (*in situ* and *ex situ*)
- Storing CO_2 in certain types of mine tailings
- Geosequestration
  - Basalt
  - Depleted oil and gas reservoirs
  - Deep saline aquifers
- Enhanced mineralisation (also known as enhanced weathering)

Soil storage

- Biochar production from residual biomass in agriculture and forestry for sequestration in soil
- Sediment carbon in mangroves, saltmarshes and seagrass
- Carbon 'farming' and innovative soil management methods that help to preserve the more stable (long-lasting) forms of soil organic carbon

Ocean storage

- Biomass in the ocean (e.g., seaweed that sinks to the deep ocean)
- Blue carbon
- Deep ocean storage

Storage in high value products

- Building materials (e.g., cement production) and polymers

No single greenhouse gas removal approach will be a silver bullet. A mix of different approaches will need to be implemented.

Greenhouse gas removal and storage will have associated co-benefits and trade-offs. Improving holistic assessment of the benefits, risks and limitations of greenhouse gas removal, storage and use is needed to inform decision making. This will ensure that positive impacts and co-benefits are maximised, negative impacts are reduced, and risks are appropriately managed.

Early and sustained engagement with policymakers and communities, particularly Aboriginal and Torres Strait Islander peoples, will be essential to support appropriate approaches to negative emissions portfolios. Building community confidence in genuine benefits and effective risk management is also required to support greenhouse gas removal activities.

Greenhouse gas removal approaches do not permit a slowed effort to reduce emissions—rapid emissions reduction remains essential to achieve any level of temperature stabilisation.

POLICY IS IN ITS INFANCY

Governments globally have net zero targets, which imply the use of greenhouse gas removal, but few integrate it into their climate policies.[1] Policy frameworks to support the development of greenhouse gas removal are in early stages. Developing removal capability requires investment, cooperation and regulatory reform to accelerate the development of diverse solutions and explore innovative future opportunities.

The growing international policy response to negative emissions is focussed on commercialisation and accelerating existing options rather than finding new, highly impactful innovation options. Nations such as the US are **investing** in technologies such as direct air capture. Not only could Australia catch up to other international leaders such as the US and Europe, but a focus on basic research and new greenhouse gas removal opportunities would also make Australia an international leader.

There will be an increasing demand for high-quality CO_2 removal. Greenhouse gas removal is a promising but underexplored area of research.

OPPORTUNITIES TO SUPPORT GREENHOUSE GAS REMOVAL

Given the urgent need for greenhouse gas removal, Australia will need to foster an innovation and regulatory environment to accelerate the development of these technologies and attract private-sector investment. The required mechanisms include strategic coordination, interdisciplinary collaboration, and improved knowledge sharing between research and industry. Regulatory reform is needed to incentivise greenhouse gas removals, particularly distinguishing between reductions and removals and high– and low-quality offsets.

Further interdisciplinary research is needed in some areas, including: the societal aspects of greenhouse gas removal development and implementation; governance; carbon cycle dynamics; impacts of climate change on greenhouse

gas removal capacity; and methods to remove greenhouse gases other than CO_2 (e.g., methane).

Specific opportunities include:

- With elements of the national science and innovation system under review by the government, there is a unique policy window to elevate negative emissions in the Australian policy discourse.
- Greenhouse gas removal could become part of the Australian Government's suite of priorities across investment vehicles like the Australian Renewable Energy Agency, Clean Energy Finance Corporation and the National Reconstruction Fund.
- Establishing a greenhouse gas removal target to provide investment certainty and report on progress in the annual climate statement to parliament.
- As a Party to the Paris Agreement, Australia is required to prepare nationally determined contributions (NDCs) every five years, which outline domestic mitigation efforts that countries aim to achieve. Implementing and monitoring greenhouse gas removal activities could form part of Australia's future NDC.

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