# ANU Climate Change Institute submission

# Technology Investment Roadmap Discussion Paper

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This submission primarily addresses point b) The shortlist of technologies that Australia could prioritise for achieving scale in deployment through its technology investments

In particular the multiple opportunities offered by Negative Emissions Technologies. This submission is complementary to the ANU Energy Change Institute submission.

## Key messages from this submission

Reducing greenhouse gas (GHG) emissions is necessary but insufficient to stabilize climate. Negative emissions (taking greenhouse gases out of the atmosphere), are needed and Australia has a comparatively large role to play over and above reducing our domestic emissions.

We recommend that the strategic national investment includes technologies that capture, use, and store carbon, across the land sector and in industry. This is more than offsetting ongoing emissions but drawing down the stock already in the atmosphere which is a pre-requisite to keep global temperatures well-below 2°C.

Negative emissions technologies are uniquely placed to support jobs growth in regional and rural communities and put Australia at the forefront of research and development. At the same time, we can transform atmospheric carbon into valued products and help Australia meet its international emissions commitments.

## The rationale and need for Negative Emissions Technologies (NETs)

Global temperatures are now more than 1.0°C above pre-industrial levels, predominantly driven by human-caused greenhouse gas (GHG) emissions[1]. The nations of the world came together in 2015 to forge the Paris Agreement, which has two main goals: to keep global temperatures well-below 2°C and, if possible, to 1.5°C. The IPCC Special Report on 1.5°C published in 2018 showed that there was no scenario which achieved the 1.5°C goal which did not include major carbon dioxide ($CO_2$) removal from the atmosphere. The approaches which remove $CO_2$ from the atmosphere are generically termed Negative Emissions Technologies (NET's) although other terms are also used. The situation has become even more challenging since the preparation of that IPCC report, with record GHG emission levels in subsequent years[2] raising the need for NET's and the associated policies, regulation, communication and engagement and R&D.

## The pathway forward for NETs

Many negative emissions technologies are at an early stage of technological development[3]. Experience from around the world shows that pre-emptively identifying (multiple) successful innovations in such a rapidly changing environment is essentially impossible[4]. However, in

[1] IPCC 1.5 Summary for Policymakers
[2] https://www.globalcarbonproject.org/
[3] https://www.nature.com/articles/s41586-019-1681-6
[4] https://www.brookings.edu/wp-content/uploads/2019/12/Coordinatedactionreport.pdf

these early stages where uncertainty is high, governments can greatly increase the chance of successful commercialisation of NETs by creating a consistent and predictable environment for innovation and technological development. A reliable regulatory environment, that successfully balances broad safety nets and dedicated support when specific technologies show promise to meet Roadmap goals (in accordance with conditional technology neutrality[5]), is recommended to leverage private sector investment and innovation.

Strong industrial, regional, or political bases of support are also factor in decision-making[6]. Investment in areas which have clear benefit for specific constituencies is the first step to building winning coalitions[7] of robust technology and climate policy. But many negative emissions technologies lack sufficient technological development for actor preferences to be clear and concrete. Using roadmap goals to prioritise technologies or sectors which can potentially provide material benefits and connecting key technologies with industry or consumer actors can bridge the gap between innovation supply and innovation adoption.

There are a number of options to create a wide but sufficiently specialised innovation landscape. Technological roadmaps can articulate visions and priorities, which then shape directions of innovation. Emphasising the potential of a new suite of material benefits (for instance, mineral carbonation providing a competitive alternative to cement) introduced by negative emissions would also incentivise broad but material benefit oriented innovation. In addition, funding for demonstration projects or public procurement in smaller, early applications can demonstrate material benefits for private sector actors, without private sector actors having to take on initial experimentation risks. Building negative emissions innovator networks and promoting knowledge sharing, similar to initiatives like the Canberra Innovation Network or ARENA's A-Lab, can greatly accelerate learning processes.

**Early stage technologies: carbon-based polymers**

One recommended early stage carbon capture and utilisation technology that warrants investment is carbon-based polymer manufacture. These materials can be made by natural sunlight and water, and reliable, affordable catalysts that convert atmospheric $CO_2$ to value-added reusable materials. Manufacture has the dual benefits of capturing a waste product ($CO_2$) and storing it in simple reusable solid materials (carbon-based polymers) with uses as varied as packaging, surface coatings, adhesives, and different functional devices. The global polymers market is estimated to reach around $ 546 billion in 2020 and is projected to reach $ 693 billion by 2025[8].

Both materials and manufacturing are targeted with up-scalability, price-affordability and environmental-sustainability, with practical applications. The $CO_2$-to-reusable solids strategy will enable net $CO_2$ reduction from our air and great economic benefit.

Investment is required to advance materials science, catalysis, polymerization, carbonization and scalable manufacturing technologies to make large scale manufacture a reality. To enable Australia to be globally competitive and take a leading role in this important field, it will be critical to develop a national technology incubation programme supporting technology development from level 1 to 5 of The Technology Readiness Level (TRL) in laboratories, prior to commercialization.

[5] ANU Energy Change Institute response
[6] https://www-sciencedirect-com.virtual.anu.edu.au/science/article/pii/S0959378011000185
[7] https://science-sciencemag-org.virtual.anu.edu.au/content/349/6253/1170.full
[8] (https://www.businesswire.com/news/home/20200424005177/en/Global-Polymers-Market-2020-2025---Type)

**Agriculture, Ecosystems & land use: Storing carbon in soil, storing carbon in vegetation**

Protecting existing carbon rich ecosystems and sustaining productive farmland by reducing emissions are key opportunities that cannot be neglected. While these practices remove $CO_2$ from the atmosphere, they are not (strictly speaking) negative emission technologies but complementary solutions.

Regenerative Agriculture, including enhanced pasture diversity/**silvopasture**, managed rotational grazing (livestock productivity), pasture cropping, soil microbial amendments, perennial crops, alley farming and **agroforestry** are all emerging genetic and precision management farm technologies that can draw large amounts of carbon from the atmosphere into vegetation and soils, while improving farm yields of food, fodder, fibre and soil fertility. Additional carbon use and storage technologies include **landscape rehydration** to capture, spread and hold water, **re-mineralization** to boost soil alkalinity and nutrition via enhanced weathering of crushed basalt rock dust, and **biochar** to permanently store residual biomass below ground. These technologies have all been proven individually at pilot scale and development is necessary to integrate them and establish economic commercial feasibility. [

Furthermore, when not economically viable to regenerate farmland, including low productivity areas within existing farms, **ecosystem/catchment restoration** can be an attractive approach to build resilience and store carbon. This includes soil erosion repair/rehydration, farmer managed natural regeneration, feral animal control, and cool season burning, which together can also reduce losses and improve gains of carbon capture, use and storage. >300M hectares are available where these methods can be applied, with synergistic, multi layered capacity to draw up to $1GtCO_2$/y from the atmosphere in good years. 100,000s of Rangers and regenerative farmer builders/farmers can be employed working to improve land value, natural capital, carbon and water services as well as farm products and biodiversity improvements.

In industry and energy, large opportunities exist for using carbon negative hydrogen[9] and ammonia production as fertilizer.

**Industry-feedstocks/ industrial processes: Storing carbon in mineral forms, including alternative cements**

Australia has vast mineral reserves that provide a range of possibilities for carbon mineralization schemes. Mineral carbonation describes a suite of chemical and geochemical reactions wherein various metal substrates (typically calcium or magnesium-based) react with gaseous carbon dioxide ($CO_2$) to produce solid carbonates. Local access to mineral reserves also means Australia is well placed to become a global leader in these technologies, particularly those utilizing unique mineral feedstocks or process pipelines (e.g. use of solar-thermal for raw mineral activation).

Mineral carbonation processes provide a dual benefit of reducing carbon dioxide build-up in the atmosphere, from both “disposal” and “utilization” perspectives. Depending on the source of the $CO_2$ and the particular process, mineral carbonation products range from low- or zero-emissions (which may be used to replace carbon-intensive products, e.g. Portland cement) to negative emissions. A recent global market analysis[10] indicates that $CO_2$-based concretes and aggregates alone have potential to store 5 $GTCO_2$ per year with a potential annual revenue of

[9] https://www.nature.com/articles/s41558-018-0203-0
[10] https://deepblue.lib.umich.edu/handle/20

USD$650B by 2030. This forecast will improve as more varied building materials and carbon mineralization products are developed.

Carbonation reactions occur passively (and slowly) during natural geologic weathering; but new research focuses on leveraging carbonation reactions in engineered systems to promote rapid reactions, produce enhanced $CO_2$ uptake, and to create materials with favourable structural characteristics for building materials. Mineral carbonation can be implemented synergistically with other industrial processes, e.g. waste magnesium from brine desalination can be reacted with $CO_2$ to create negative-emissions building materials.

## Concluding thoughts

With many negative emissions technologies at a very early stage of development, they will require significant support to become commercially viable. Pre-emptively picking winners given the significant uncertainties is impossible. However, providing appropriate levels of support now and creating a consistent and predictable environment for innovation and technological development is essential if we are to meet our climate goals. This approach will pay dividends for Australia in the long-term, concurrently providing new economic opportunities and helping reduce atmospheric GHGs.