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Rebalancing Regional and Remote Australia: a vision for a global carbon sink while creating sustainable communities

Alberto Troccoli[1,*], **Roger Stone**[2], **Ugo Bardi**[3,4], **Christian Breyer**[5] and **Chris Henggeler**[6]

[1] World Energy and Meteorology Council, Norwich, United Kingdom and Brisbane, Australia & Inside Climate Service srl, Padova, Italy
[2] Speedbird Climate P/L, Brisbane and Toowoomba, Australia
[3] The Club of Rome, Lagerhausstrasse 9, 8400 Winterthur, Switzerland
[4] Università di Firenze, Florence, Italy
[5] LUT University, Yliopistonkatu 34, Lappeenranta, Finland
[6] Kachana Pastoral Company PL, Kimberley, WA, Australia
[*] Author to whom any correspondence should be addressed.

E-mail: alberto.troccoli@wemcouncil.org

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Abstract

This paper introduces a visionary strategy, **Rebalancing Regional and Remote Australia**. It aims at transforming Australia into a significant global carbon sink by sequestering 4 gigatonne (Gt) of CO_2 equivalent annually, leveraging about 25% of the nation's land area. Addressing the unique challenges of Australia's arid climate, the plan employs innovative, proven solutions in energy, water, and agriculture, including agrivoltaics, to enhance sustainability across diverse environmental and socioeconomic contexts. A central pillar of the plan is the creation of sustainable regional and remote communities. Designed for scalability, it begins with a pilot community of 100 000 residents, showcasing the initiative's feasibility and potential for significant return on investment. Beyond its environmental objectives, the plan presents substantial business opportunities, positioning Australia as a leader in global sustainability efforts. Through collaborative innovation, it offers a model for national and international action, highlighting the imperative for comprehensive strategies that promote economic, environmental, and social advancement.

1. Introduction

Global efforts to reduce greenhouse gas (GHG) emissions fall short of the ambitious targets set by international climate agreements, with emissions still rising (Sognnaes *et al* 2021, Friedlingstein *et al* 2023). Despite contributing approximately 1% of global anthropogenic emissions (Villalobos *et al* 2023), Australia's role in climate mitigation efforts could be disproportionately significant. The country has vast opportunities for impactful actions, such as restoring ecosystems to their former balance (Bradshaw 2012), through which environmental and industrial strategies could yield substantial global benefits. While recent policies have shown improvement (Australian Government 2022), they stand in stark contrast to the escalating devastation from bushfires and flooding, intensified by global climate change (Robinson *et al* 2021). The increasing frequency and severity of natural disasters open up a critical opportunity for Australia to spearhead technological innovation (Garnaut 2022) and the implementation of natural climate (or nature-based) solutions, such as reforestation or ecosystem restoration (Smith *et al* 2023). Australia's vast landscapes and abundant resources endow it with a unique capacity to lead global climate action, enhancing not only its economy but also its environmental, air, and water quality. The strategies presented here offer avenues for business growth through investment in sustainable practices.

Modifying Australia's landscape could exert a considerable influence on regional, national, and

potentially larger-scale climates, while acting as a major global carbon sink. This potential is supported by research illustrating the climatic benefits of landscape modifications. For instance, the climatic impacts of hypothetical, unrealistically sized structures across Australia provide insights into potential changes in rainfall, temperature, and solar irradiance, depending on the structures' dimensions, orientation and albedo (Nguyen *et al* 2017). Moreover, converting marginal agricultural lands to savanna woodlands could initiate a positive feedback loop, enhancing cloud formation and precipitation through increased evapotranspiration from deep-rooted vegetation, thereby improving soil moisture and mitigating warming trends (Syktus and McAlpine 2016). Research by Yosef *et al* (2018) indicates that afforestation in semi-arid regions of Australia (and Africa) could significantly enhance precipitation and carbon sequestration, thereby altering regional climate patterns. These changes are facilitated through modifications in low-level jets, which improve moisture penetration and result in an increase in local precipitation—a process potentially activating a *biotic pump* mechanism (Makarieva and Gorshkov 2007). Such modifications are estimated to offset bio-geophysical warming effects within about six years. Ornstein *et al* (2009) previously demonstrated that bio-geophysical feedback mechanisms could notably increase rainfall over irrigated forests in arid areas like Australia and the Sahara, supporting the strategies proposed herein (Pausata *et al* 2020).

2. Strategic approach to climate change in Australia

Australia stands to gain significantly from an integrated strategy aimed at addressing its climate change challenges. This necessitates moving beyond the prevalent trend of adopting popular, fragmented, and sector-specific technologies, lacking a cohesive, overarching framework. Such an approach should include comprehensive solutions that consider the interconnectivity of environmental, economic, and social factors, ensuring a sustainable and unified response to climate change. Current solutions mainly focus on either renewable energy developments (Garnaut 2022) or nature-based methods (Campbell *et al* 2017).

Rebalancing Regional and Remote Australia proposes a transformative strategy to harness Australia's extensive landscapes and resources, positioning it as a pivotal player in global climate mitigation and ecosystem restoration. Inspired by global large-scale ambitious projects such as China's Three Northern Shelter Forest Program, which covers 42% of the nation's land (Zhai *et al* 2023), Libya's Great Man Made River water supply project (Kumar 2022), and the futuristic city of Neom in Saudi Arabia (Farag 2019), this initiative embraces a holistic approach. It envisages the regeneration of approximately 2 million km^2, or 25% of Australia's land area, primarily targeting semi-arid and arid regions, which constitute 55% and 15% of the country, respectively (cf figure S1). Such a grand scale land restoration effort aims not only to transform Australia into a significant global carbon sink but also to address the urgent need for sustainable community development and environmental resilience.

The strategy integrates advanced technologies in renewable energy and agriculture with natural climate solutions to promote a balanced ecosystem and improve economic, environmental, and social well-being. It focuses on creating sustainable communities that harmonise with their surroundings, leveraging state-of-the-art technologies for energy, water, and food security, and resilience against floods, fires, and droughts. This scalable and adaptable framework is designed to evolve with technological advancements and accommodate Australia's growing population (ABS 2023), preserving biodiversity and indigenous cultural values. It represents a decisive step towards reimagining Australia's climate strategy, aiming for a more prosperous, secure, and sustainable future. Given the plan's complexity, this blueprint serves as a foundation for a feasibility assessment, outlining the initiative's key components and potential impacts. To substantiate the plan's viability, a preliminary quantitative evaluation is included (see next section).

Figure 1 illustrates a streamlined overview of our comprehensive strategy, delineated into eight critical phases. The strategy begins with foundational policy development and financing, setting the groundwork for integrated advancements in energy, water, food supply through agriculture, and natural climate solutions. Central to this approach is the commitment to active and inclusive stakeholder engagement, ensuring meaningful participation by indigenous Australian communities in both planning and implementation phases. The diagram highlights the initial focus on establishing robust policy frameworks and securing the necessary funding, essential precursors to the sustainable management of resources. Developments in energy, water, and agriculture are interlinked, aiming to fulfil the overarching goal of sustainable development. While community creation appears as the final phase, it epitomizes the culmination of preceding efforts, contingent upon the successful establishment of the requisite infrastructure for a thriving new community.

The strategy prioritises a stable, reliable, and cost-effective supply of water, energy, and food, vital in a country like Australia where water scarcity is a major concern (average annual rainfall of 450 mm).

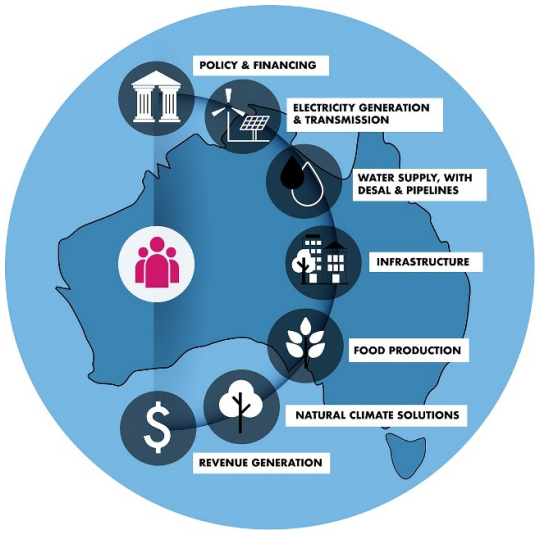

Figure 1. Representation of the integrated strategy for a rebalanced Australian inland. The ultimate objective is the creation of thriving communities in a well-balanced environment.

It advocates for the utilization of renewable resources, particularly solar and wind energy, to address these needs sustainably. The approach to energy encompasses not only the exploitation of renewable sources but also addresses the variability and storage challenges through state-of-the-art solutions (Breyer *et al* 2022). Proven technologies, such as batteries, biomass, small/medium-scale hydro power pumping (Blakers *et al* 2021) and geothermal, and potentially hydrogen fuel (pending its further development) are integral to this transition. In the interim, gas-fired peaking plants may be utilised to ensure energy reliability and manage peak demands (AEMO 2022).

Water provision is another critical component. The plan envisions a mix of strategies including renewable-powered desalination plants, dams, pumps, and possibly river water diversions. Underground water reservoirs (e.g. the Great Artesian Basin, with its 65 million GL) is considered, with careful usage to avoid depletion. This multifaceted approach is intended to initiate the regeneration of vast land areas. Emphasizing recycling and reuse, particularly in managing desalination by-products is crucial to prevent (marine) pollution and ecosystem destruction (Pistocchi *et al* 2020).

Direct climate improvement initiatives form a cornerstone of the plan. Beyond reducing GHG emissions by increasing renewable energy sources and promoting low-emission agricultural practices, the strategy also emphasizes removing GHGs from the atmosphere. This is achieved through nature-based measures such as reforestation, afforestation, land restoration, and regenerative farming, all of which are vital for creating a more sustainable ecological balance (Di Sacco *et al* 2021, FAO and ITPS 2021). Additionally, the prospects for effective afforestation projects, to be irrigated partially or entirely with renewable energy-based desalination, are considered a feasible reality (Caldera and Breyer 2023).

Agriculture plays an important role in the plan, with a focus on ensuring food security for future communities. The adoption of sustainable and regenerative farming practices, such as agrivoltaics—the synergistic integration of solar farms with farming—is crucial. This method not only optimizes land use but also improves energy efficiency, serving as a model for sustainable agricultural development (Schindele *et al* 2020).

A commitment to minimizing waste and adhering to circular economy principles is paramount, addressing the environmental impacts of renewable energy infrastructure like solar PV panels and batteries. Innovations in waste management and resource utilization are envisioned to significantly reduce the ecological footprint of these critical technologies (Ali *et al* 2017).

Biodiversity enhancement is a key objective, aimed at improving soil quality, climate resilience, and overall ecosystem health. This initiative is vital for ensuring cleaner air and water, contributing to a healthier environment for all Australians (White 1997).

The strategy advocates for the deployment of advanced IT systems powered by artificial intelligence, to streamline and optimize water, energy, and food supply chains. This includes implementing demand-side management approaches to allocate resources efficiently, minimize waste, and boost sustainability (Ullah *et al* 2024).

Additionally, the plan underscores the importance of expanding the observing network to more effectively monitor GHG fluxes and atmospheric concentrations. This enhanced system is essential not only as a verification tool for assessing the impact of implemented measures but also for establishing a solid evidence base to substantiate the outcomes of emissions reduction efforts. Data derived from this network are instrumental in securing further investment in climate mitigation initiatives (Ziehn *et al* 2016).

3. Pilot plan for a 100 000 people community

Scalability is a critical aspect of the **Rebalancing Regional and Remote Australia** strategy. It advocates for starting with manageable pilot projects, each adhering to the comprehensive approach outlined in the blueprint. This focus on scalability aims to enhance the plan's appeal to diverse stakeholders, including private investors, by demonstrating the practical viability of the proposed solutions. As exemplified in figure 2, this holistic approach integrates energy, water, natural climate solutions as well as

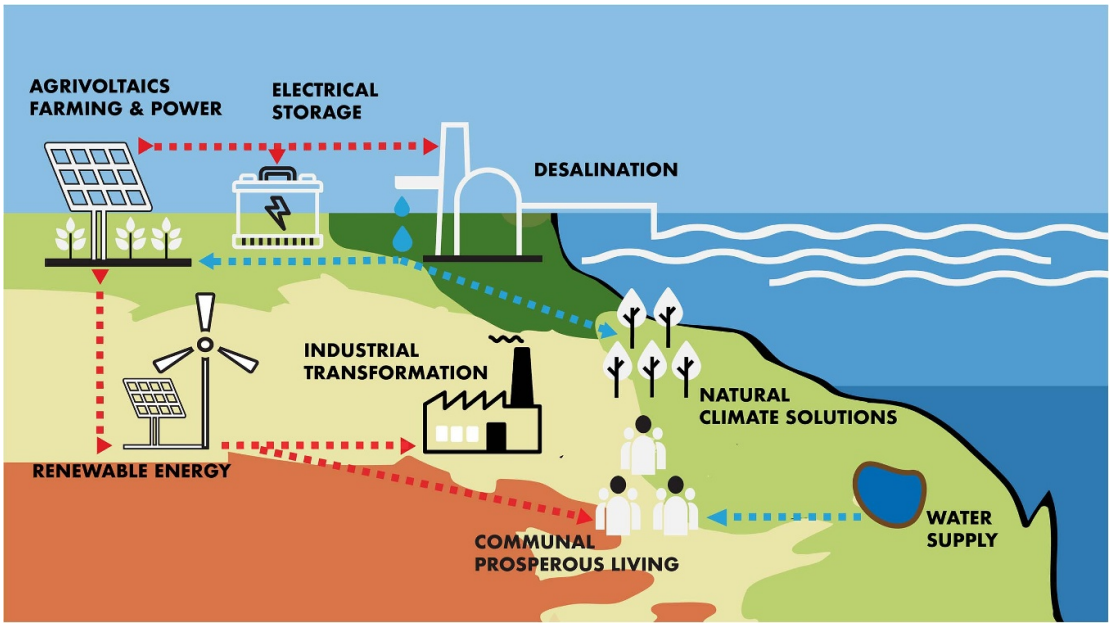

Figure 2. Simplified representation of the **Rebalancing Regional and Remote Australia** plan components.

Table 1. Main budget indicators for the plan. Capital Expenditures (CAPEX) and Operational Expenditures (OPEX) are outlined for the 100 000-person pilot project, detailing key investments. Note that most of the water budget is allocated to natural solutions (ca. 95%) with food production receiving about 2%. This budget projection does not include potential additional opportunities, such as those identified in the Superpower industrial transformation strategy of Garnaut (2022).

	CAPEX (in million A$)	OPEX (in million A$/year)	Area requirements (in km^2)	GHG emission saving (in Mt CO_2eq/yr)
Water	500	80	10	
Energy	4100	210	30	1.6
Food	100	60	110	
Infrastructure	10 400	620	400	
Natural Solutions	1500	120	10 000	18.1
Total	**16 600**	**1090**	**10 550**	**19.7**

innovative industrial processes to foster the development of sustainable communities. Wherever possible, it leverages existing communities rather than starting anew.

A pilot project designed to establish a community of 100 000 people serves as a practical demonstration of this strategy, which envisions around 200 such initiatives supporting a total of 20 million people. This ambition involves a mix of local residents and immigrants, also in line with projections of Australia's median population reaching 40 million by 2070 (ABS 2023), from the current nearly 27 million—equating to roughly 300 thousand people, or three pilot projects, annually. The strategy is also in line with the increasing interest in developing Australia's regional areas to boost population and economic growth (Gurran *et al* 2021). Criteria for selecting pilot locations include the availability of partially fertile land within a reasonable distance to the coast and communities with a vested interest in growth, with initial sites identified in Central West Queensland and Northern Western Australia.

The pre-feasibility assessment outlines a summary budget covering essential requirements—including water, energy, food production, infrastructure, and natural climate solutions—divided into Capital Expenditures and Operational Expenditures, alongside spatial requirements. This budget is broadly based on 2035 costing, reflecting a realistic start of the project. Two main indicators, overall cost and emission reduction/offset, are considered, with indicative figures presented in table 1 and the main assumptions detailed in supplementary material, particularly in table S1.

Conservative estimates, which do not factor in potential innovations over the next decades, anticipate a combined government and business income of A$2890 million annually, supplemented by A$390 million from sequestered or avoided GHG emissions. This results in a projected net annual cash

flow of A$2190 million, indicating a return on investment in under 10 years. Infrastructure emerges as the most significant expenditure but also the principal source of cash flow through population-driven income.

4. Concluding remarks

This paper presents **Rebalancing Regional and Remote Australia**, an integrated strategy to mitigate climate change in Australia and to create sustainable regional and remote communities. The envisaged plan hinges on highly innovative water, energy, and agricultural systems, leading to an ecological and industrial productive continent. Implementing this solution promises not only a substantial reduction in emissions, contributing significantly to the global net zero target, but also favourable climate feedback on a very large scale. This ambitious blueprint aims to cover approximately 2 million km^2 of land, targeting an emission reduction or offset of 4 Gt of CO_2 equivalent annually. This carbon dioxide amount equals about 10% of the total global annual volume needed to remain within the safe and just planetary climate boundary (Rockström *et al* 2023).

Critical to the plan's success is the active engagement of a wide array of stakeholders, encompassing indigenous communities, industry leaders, academic institutions, civil society, and governmental bodies from both Australia and the international community. Social acceptability will be a key focus, ensuring that the initiative is welcomed by remote and regional communities through continuous engagement and feedback. Education is also integral to the plan, ensuring the sustainability and social acceptance of this initiative. The plan demonstrates how nations with smaller total emissions but with vast natural resources can make substantial contributions to global climate mitigation efforts, particularly through the development of sustainable communities that serve as a model for environmental conservation and innovative development.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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ORCID iD

Alberto Troccoli https://orcid.org/0000-0001-5870-4367

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