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Future (bio)made in Australia?

An industrial biomanufacturing plan to enhance economic security

Dirk van der Kley, Dan Santos and Daniel Pavlich

Key points

- Biomanufacturing represents Australia's best opportunity to develop a resilient, green and profitable manufacturing industry by building on natural advantages, yet is underrepresented in Australia's critical technology and industry policy, including the *Future Made in Australia* agenda.
- Biomanufacturing could help solve three of Australia's pressing economic security problems by:
  1. enabling more resilient manufacturing, with the same inputs and infrastructure quickly adapted to produce a wide range of products.
  2. offering solutions to difficult environmental challenges such as aviation, agricultural emissions, and plastic pollution.
  3. providing alternative export revenue once coal, gas and iron ore exports decline.
- There are three key bottlenecks for all countries developing industrial biomanufacturing: scale-up infrastructure; feedstocks; and talent.

Policy recommendations

- The Australian government should establish a billion-dollar *Strategic Plan for Industrial Biomanufacturing* that develops a broad, robust and diverse industry. The plan should include government funding for scale-up and commercial-size facilities co-located with feedstock sources; a biomass research and development fund to enhance Australia's natural strengths in the collection and transportation of feedstocks, and research to develop alternative feedstocks; and a coordinated talent development plan to meet the workforce's future needs, from vocational technicians up to postdoctoral specialists.
- A joint industry-government body should be established to identify and fund facilities co-located with feedstocks. This would ensure efficient coordination across relevant government portfolios and with industry.
- A National Biomanufacturing Board should be established to coordinate functions across a wide range of government stakeholders.

Biomanufacturing: a solution to environmental and economic security challenges

Biomanufacturing is the production of a good using biological processes or inputs. There are many ways to do this, including:

- genetically engineering microbes, such as bacteria or fungi, so that they consume feedstocks such as sugar, agricultural by-products or even carbon dioxide and convert the feedstock into the desired product. Production at scale requires large bioreactors to grow enough of the microbe. A diverse range of outputs can be created using this method, such as industrial chemicals, enzymes that recycle plastic, and animal proteins for food, with waste gases converted to renewable natural gases such as biomethane or liquid fuels.
- genetically engineering plants (called plant-based molecular farming) to generate a desired product.
- thermochemical technologies can convert agricultural and forestry residues (like sugarcane offcuts and cereal straws) into renewable liquid fuels.

The appeal of biomanufacturing is clear – using inputs such as biomass, sugar or carbon dioxide, it will be possible to produce almost any output without having to rely on petrochemicals or conventional agri-

culture. If sufficient investment to support scale-up is provided, biomanufacturing could represent a form of programmable manufacturing that provides a high level of adaptability during crises.

A strong biomanufacturing industry also provides the best chance of solving complex environmental challenges compared to other green technologies including reducing agricultural emissions through alternative food production; decreasing plastic pollution through the production of biodegradable alternatives; lowering building material emissions through the production of goods such as green concrete; producing sustainable fuels for shipping and commercial aviation; and facilitating the environmentally friendly production of industrial chemicals. Industrial biomanufacturing is still more expensive than traditional chemical production in most industries, with the exception of biopharmaceuticals. But there are few alternatives for replacing fossil fuels in these sectors.

Australia's dual looming crises: fossil fuel exports and sustainability

Australia's three largest exports are coal, iron ore, and gas. In 2022 alone, these exports were equivalent to 20 per cent of Australia's gross domestic product (GDP), and despite not being large employers, they are an important source of Australian government revenue.[1]

However, these exports will not last forever. Sustainability pressures will reduce revenues from coal and gas, and changes to China's economy will end the iron ore boom. Outside of lithium exports, there are no obvious replacements for this revenue. The decline of fossil fuels will usher in the next industrial revolution, which will lead to changes in the production of pharmaceuticals, pesticides, chemicals, and many other goods that currently rely on fossil fuels.

Leading economic powerhouses have made their intentions clear in this respect and have already taken the initiative to establish a competitive advantage. In 2023, the United States (US) published an Executive Order on biomanufacturing, diverting tens of billions of dollars to the growing industry. These investments are being mirrored by China in its *14th Five-year Plan for Bioeconomy Development*.

The global scale of the biomanufacturing economic transformation will be enormous. Boston Consulting Group estimates that by 2030, biologically engineered systems could be used extensively in manufacturing industries that account for more than a third of global output – a shade under USD $30 trillion in terms of value.[2] Even if these estimates are optimistic, it is clear this will be a massive disruption.

Australia's recently published *Future Made in Australia* national interest framework only mentions biomanufacturing in terms of low-carbon liquid fuels (LCLF), which are fuels created from biological sources such as agricultural offcuts.[3] LCLFs are one of the few alternatives for the hard-to-abate carbon emissions from the maritime and aviation sectors.

However, Australia's biomanufacturing ambitions should go well beyond LCLFs. To make biomanufacturing (including LCLFs) financially viable in the face of mature and highly subsidised fossil fuels, Australia needs a broad base of facilities producing a wide range of products.

Unlike almost any of the other critical and emerging sectors, Australia already has companies that are biomanufacturing world-leading products. In April, Lululemon launched the world's first jacket that uses polyester recycled by plastic-attacking enzymes. Those enzymes were developed by Canberra-based SamSara Eco. Also in April, Vow began selling its "cultured Japanese quail" in Singapore, a cultured meat grown in a bioreactor in Sydney.

Instead of thinking about biomanufacturing as a narrow path to solve aviation and maritime emission challenges, Australia should conceptualise the establishment of a broad biomanufacturing industry as a pathway to prosperity that will let the country redirect manufacturing capacity to critical products when necessary. So far, very little of Australia's industrial policy spend has gone to biomanufacturing.

A biomanufacturing plan to maximise Australian advantages

For most industries, Australia is too expensive and too isolated to play a leading role in manufacturing. Furthermore, other governments with larger budgets offer more in terms of subsidies to early-stage development. However, industrial biomanufacturing has three unique characteristics that nullify these competitive disadvantages.

Firstly, the range of products is so broad and the development stage is so early that Australia can find appropriate niches, such as high-value, low-volume products. For once, we are not behind the curve. Once the infrastructure is established, this range of products could then encompass higher volume commodities like LCLFs.

Secondly, efficiently collected biomass and feedstocks will be a key input and cost. Unlike petrochemicals, biomass is bulky and inexpensive and thus production will need to be close to source. Australia has well-established capacities to recycle agricultural byproducts, as well as the most efficient agricultural industry in the world, giving the country a significant advantage.

Thirdly, due to significant economic constraints on biomass transportation, some parts of the industry will regionalise rather than centralise globally.

The Australian federal and state governments provide biomanufacturing support through research infrastructure schemes such as the Australian Research Council (ARC), The National Collaborative Research Infrastructure Strategy (NCRIS) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), through the Advanced Engineering Biology Future Science Platform (FSP). The Queensland and Federal governments help fund the Mackay Renewable Biocommodities Pilot Plant. Some of the federally funded National Reconstruction Fund (NRF) could fund biomanufacturing, but no money has yet been distributed through the NRF.

Current funding is too small and disjointed to genuinely support the sustained development of an industry. Instead, Australia requires an integrated biomanufacturing

plan with increased government funding and industry coordination. This strategy should focus on the following three components.

Component 1: dedicated government funding for pilot-level facilities

A key barrier to Australian biomanufacturing is the lack of pilot facilities (those within the 1,000–10,000 litre capacity) for startups. These can bridge the gap between lab bioreactors (1–100 litre capacity) and commercial facilities (100,000 litres-plus). For companies to optimise their growth and extraction processes, these pilot facilities are crucial to determining how increasing the bioreactor size (and thus altering growth conditions for microbes, such as pressure and temperature) affects product quality and yield.

Australian start-ups struggle to find pilot-scale facilities due to a global shortage, and they cannot build them in-house due to the prohibitive cost and lengthy construction times. Currently, no specific government program is set up to fund pilot-scale facilities. NCRIS is too small and focused on research facilities, while the NRF requires that "all investment proposals must be able to demonstrate an ability to generate a return (for equity) or repay debt".[4] Pilot facilities will not generate a return soon because the industry is too immature. Crucially, the ongoing maintenance and updating of equipment also needs government support.

There are only a handful of operational pilot-scale facilities in Australia such as the Mackay Renewable Biocommodities Pilot Plant, run by the Queensland University of Technology (QUT), and the Australian Food Innovation Centre in Melbourne, to be run by La Trobe University and CSIRO.

These facilities are geared to a narrow set of applications and biomass types. To help push the development of more pilot-scale plants, the Federal Government should fund biomanufacturing pilot facilities (co-located with feedstocks) through its *Future Made in Australia* policy. This can be via loan guarantees for private firms or grants for public institutions. Each facility will need to be designed to suit local feedstocks and avoid duplication. Some will be geared toward food, others toward industrial chemicals and others toward LCLFs. The crucial element is having multiple facilities, which allows for economies of scale across the broader industry.

The pilot facilities could act as incubators for bio-hubs that would have developed land (powered and sewered) such that companies could set up commercial and R&D facilities near the pilot infrastructure. There would need to be coordinated planning across industry, government and academia to correctly locate the initial pilot facilities. In the long term, hubs and subsidised funding would be open to foreign investors. Companies would be able to take advantage of schemes like the NRF because the initial scale-up risk had been partially borne by government.

Pilot facilities generally cost in the range of $10 million–$100 million (a larger facility next to gas extraction may be in the $100 million range), which is a relatively small outlay for the benefit.

Component 2: becoming a feedstock leader

Biomass feedstocks are bulky and inexpensive, making them unattractive to transport large distances. When biomanufacturing at a commercial level, it is difficult to efficiently collect and transport the volume of necessary biomass.

In the short-term, sugarcane is the most obvious biomass crop in Australia – it generates large volumes of by-products and there is pre-existing transport infrastructure. We have multiple other crops that could potentially be used for biomanufacturing purposes.

In the long-term, improving the economics of biomanufacturing requires research into improving biomass yields and developing more easily harvested biomass that can grow on non-agricultural terrain (such as the sea or arid land), along with developing technology to refine potential biomass into usable inputs. Biomass research could be an immense source of competitive, economic strength for Australia. As part of an integrated biomanufacturing strategy, Australia should establish a biomass research and development fund that would have the dual purpose of researching new biomass crops and better utilising existing agricultural by-products.

Component 3: establishing a better talent pathway

One biomanufacturing start-up employee told the authors, "Our biggest blockage is talent". The most acute shortage is process engineers who manage scale-up processes, and vocationally trained technicians who monitor facilities. Individual institutions recognise the lack of talent for commercial biomanufacturing, with QUT recently creating a Bioprocessing Engineering major at the master's level to try to develop talent. However, this is only a start, and it does not solve the underlying technician issue, which requires vocational training or micro-credentialling.

A strategic biomanufacturing plan should conduct dedicated skills mapping and then help coordinate training among various educational institutions and industries to grow a diversified workforce, including vocational skills training, re-skilling from other industries, and postdoctoral researchers. Critically, this would involve directly allocating government funds to training providers.

Coordinating the components

The industry is currently highly collaborative and motivated, and there are existing initiatives at the state level to coordinate efforts, such as the Queensland government's Biofutures Industry Advisory Committee. At the national level, the CSIRO, ARC Centre of Excellence in Synthetic Biology (CoESB), Bioplatforms Australia, the Queensland government and associated companies, including Main Sequence Ventures, are already working together to become more coordinated. These well-established initiatives need to be better coordinated with federal departments that bring money for infrastructure and education, and to align the wide range of relevant government departments.

We suggest two strategies to boost coordination:

A National Biomanufacturing Board

While the Australian Government has improved coordination over the past 10 years, there is still no centralised coordination for biomanufacturing, which could be an enormous part of this country's economic future. A dedicated biomanufacturing board would bring together the departments of Education, Agriculture, Climate Change, Energy, the Environment and Water, Industry, Science and Resources (DISR), Home Affairs, Defence, Health and the various regulators to allocate responsibility for funding and planning. Numerous government bodies have established early efforts to understand how biomanufacturing could impact their area. Home Affairs is looking at resilience, DISR at industrial competitiveness and supply chains, while Defence is focused on biomanufacturing applications in conflict environments. There are multiple efforts, sometimes coordinated, sometimes not, to pull toward biomanufacturing capability. Having a coordinated government board to oversee this would streamline efforts to setting up an industry.

A joint government-industry biomanufacturing body

A joint government-industry body is crucial to coordinate the activities that will drive the industry. These responsibilities would include decisions about the type and location of pilot and commercial biomanufacturing facilities, and a coordinated approach to talent development across government, academia and industry.

A successful model for this would be BioMADE in the US, which is an industry body funded by the Department of Defense. In Australia, it makes less sense for Defence to be the lead because we do not have a large Defence manufacturing base here. Instead, joint funding from DISR and Education would ensure that workforce base and scale-up are covered. The industry is already well-organised and could plug into a joint government program quickly.

Conclusion

These three components of the strategic plan for industrial biomanufacturing in Australia, if delivered with coordination, can create a viable biomanufacturing industry in Australia with opportunities that few other emerging technologies can match. This will occur in an industry that will drastically rewire global supply chains over the next few decades. The change is coming regardless – will we take advantage of the opportunity to enhance our economic security, or passively adapt to other countries' visions of bioeconomic futures?

Notes

1. Australia's GDP in 2022 was US$1.724 trillion. The combined value of coal (A$127.4 billion), iron ore (A$124.1 billion) and gas (A$92.2 billion) was A$343.7 billion, see "Australia Key Economic Indicators," Australian Department of Foreign Affairs and Trade, last accessed 14 April 2024, https://www.dfat.gov.au/sites/default/files/aust-cef.pdf
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3. "Future Made in Australia National Interest Framework", The Australian Treasury, 14 May 2024, https://treasury.gov.au/sites/default/files/2024-05/p2024-526942-fmia-nif.pdf
4. "More about our minimum investment requirements," National Reconstruction Fund Corporation, last accessed 14 April 2024, https://www.nrf.gov.au/what-we-do/investment-guidance/more-about-our-minimum-investment-requirements

About the authors

Dr Dirk van der Kley is a Research Fellow at the ANU National Security College (NSC). *Dr Dan Santos* is a Postdoctoral Fellow at the ANU Australian National Centre for the Public Awareness of Science. *Daniel Pavlich* is a Researcher at the NSC. The authors thank the many colleagues consulted for this project, including a roundtable conducted in 2024, though any errors remain theirs alone.

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