



Australia's National
Science Agency

Reshaping Australian Food Systems

A Roadmap towards a more sustainable, productive and
resilient future for Australia's food, its environment and people

2023



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Acknowledgement

CSIRO acknowledges the Traditional Owners of the land, sea and waters, of the area that we live and work on across Australia. We acknowledge their continuing connection to their culture, and we pay our respects to their Elders past and present.

The project team is grateful to the many stakeholders who generously gave their time to provide advice and feedback on this report. We thank members of the project's Steering Committee, including representatives from the Australian Department of Agriculture, Fisheries and Forestry; Australian Department of Health and Aged Care; Queensland Department of Agriculture and Fisheries; Tasmanian Department of Natural Resource and Environment; VicHealth; Food Standards Australia New Zealand; FoodBank Australia; the Australian Institute of Packaging; and Austrade.

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Foreword

Australia's food systems feed an estimated 60–75 million people across the country and in export markets. When we talk about food systems, we are referring to the entire pipeline for food – from production through to consumption and disposal and the enabling social, cultural, environmental and governance systems. Australia is no small player when it comes to food systems, which means we are vulnerable to threats at different stages of the complex and interconnected journey our food takes before it reaches our shopping baskets and fridges. Building our understanding of these systems and the risks within them is essential, especially given current economic, social, environmental, governance and geopolitical challenges.

This is why I am so proud of the CSIRO Food Systems Roadmap. It will support our nation's journey towards more sustainable, nutritious, productive, and resilient food systems. CSIRO has been solving the greatest scientific challenges for over 100 years, and we have always known we can't do it alone. Our missions program assembles broad coalitions of partners to solve complex scientific challenges, like drought resilience for our farming systems, future protein sources to feed more people, and developing systems to protect our trusted agrifood exports. This roadmap sits alongside the work of those missions and is part of our effort to deliver a positive impact to the community and environment; the economy and job creation; and scientific excellence.

As Australia's national science agency, CSIRO has deep expertise across sustainable food systems and has brought together the best minds from a range of stakeholder groups including government, industry consumers and the community. The report reflects years-long collaboration and has been designed to support decision makers with the knowledge needed to improve the security and nutrition of Australia's food systems and position us to take a leadership role when it comes to sustainable food. Thank you to our partners and stakeholders who contributed to this important report.

The underlying message in this roadmap is that we have to change course. Climate change, growing demand and supply chain disruptions are all increasing in severity. With our food at risk, we too are at risk. But with risk comes opportunity, and Australia is a nation rich in natural assets. Through collective action and a science-driven approach, we can seize on the opportunities that are unique to us and transform our food systems so they are fit for the future. So that they help deliver better health, better equity and better sustainability. I am heartened by the cooperation and shared vision evidenced in this report, and I hope you will be too.

Kirsten Rose

Executive Director
Future Industries, CSIRO

Consulted stakeholders

CSIRO would like to thank all consulted organisations for their contributions to this project through interviews, written submissions in response to the Discussion Paper, and reviews. Listed below are those organisations that have consented to being named.

Agribusiness Australia	EAT Foundation	Noumi
AgriFutures Australia	Eat Well Tasmania Incorporated	Obesity Policy Coalition
Austrade	Food Innovation Australia Ltd	Opal Packaging
Australian Banana Growers Council	Food Connect Brisbane	Open Food Network
Australian Farm Institute	Food Frontier	Orijin Plus
Australian Food and Grocery Council	Food Standards Agency UK	OzHarvest
Australian Food Sovereignty Alliance	Food Waste CRC	PackEng
Australian Institute of Packaging	Foodswell	Protected Cropping Australia
Australian Meat Industry Council	Foundation for Indigenous Sustainable Health	Public Health Association Australia
Australian National University	Gateway Health	Queensland Consumers Association
Australian Packaging Covenant Organisation	George Weston Foods	Queensland Government
Australian Regional Tourism	Global Centre for Preventive Health and Nutrition	Regnan
AusVeg	GrainCorp	South Australian Department of Trade and Investment
Bega Cheese and Bega Circular Valley	Healthy Food Systems Australia	Sanitarium
Black Duck Foods	Heart Foundation	Simplot
Brisbane City Council	Hort Innovation Australia	Singapore Food Agency
Canberra Regional Food Collaborative, RDA ACT	Huon Valley Food Hub	Sprout
Certified Organic and Biodynamic WA	Indigenous Allied Health Australia	Sugar Research Australia
Certified Sustainable Ltd	Kagome	The George Institute
City of Greater Bendigo	Kellogg Company	The Good Ancestors Project
ClimateWorks	KPMG Australia	University of Melbourne
Dairy Australia	Landcare Australia	University of Queensland School of Public Health
Dassault Systems	Leah Galvin Consulting	VicHealth
Department of Agriculture, Fisheries and Forestry	Lion	Victorian Department of Jobs, Skills, Industry and Regions
Department of Climate Change, Energy, the Environment and Water	Main Sequence Ventures	WA Salt Group
Department of Health and Aged Care	Meat and Livestock Australia	Western Sydney University
Department of Natural Resources and Environment Tasmania	National Farmers' Federation	Wine Australia
Dietitians Association Australia	National Resilience Taskforce	Women's Health Goulburn North East
	New South Wales Government	Woolworths
	North East Local Food Strategy Action Group & Albury Wodonga Local Food Network	

Executive summary

Food systems encompass the production, processing, packaging, distribution, consumption and disposal of food and beverages, as well as related social, cultural and governance systems. Australia's food systems are of national and international importance, delivering food and nutritional security at home and abroad. However, food systems also face unprecedented economic, social, environmental, governance and geopolitical challenges. Confronted with these challenges, this report looks at the opportunities and research and development (R&D) priorities for Australia. It explores these through five focal areas which are informed by a national consultation process, including over 120 food system stakeholders from industry, government, research, and the community.

The drive towards more sustainable, productive and resilient food systems

Internationally, there is widespread recognition that food systems must change to meet a number of critical challenges, including a changing climate, increasing demand, supply chain and workforce disruptions, rising input costs, and nutrition-related public health concerns.

Participating in global efforts to create a more sustainable future, Australia endorsed the 2030 Agenda for Sustainable Development adopted by the UN General Assembly in 2015 and the associated Sustainable Development Goals (SDGs). As a signatory to the Paris Agreement on climate change, Australia has recently committed itself to reach net zero emissions by 2050 in its updated Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC). In recognising the centrality of food systems within the broader sustainable development agenda, Australia also participated in the 2021 United Nations Food Systems Summit (UNFSS), convening its own dialogues in the process; ultimately supporting the international ambition toward delivering more sustainable, productive and resilient agricultural and food systems.

Australia's role in shifting the trajectory of food systems

Acknowledging that Australia's food systems are embedded within an interconnected global system, this report seeks to articulate a range of options for how Australia can proactively address global aspirations and challenges as they present themselves within the national context. The report identifies and synthesises opportunities and R&D priorities based on research into work undertaken to-date internationally and locally, and into the perspectives of the cross-sectoral stakeholders consulted during the project.

Australia has the opportunity to take on a leadership role in building sustainable, productive and resilient food systems. By taking strong immediate action, Australia can be a driving force, maximising the collective social impact of the nation's food systems and becoming more competitive in global markets; with flow on benefits for the environment, health and livelihoods.

The task is large and complex, requiring collaboration and shared values

Reshaping food systems in Australia requires collaboration, connection and mutual understanding across the vast and varied range of stakeholders within and adjacent to food systems, including industry, governments, and civil and research sectors. The task is large, and the many diverse views, objectives and trade-offs must be navigated to ensure change processes are safe, equitable and just – benefitting society at large. By proactively and

collectively preparing our food systems for the future, there is a significant opportunity to build consensus around broad, shared values about what more sustainable, productive and resilient food systems mean for Australia.

To drive progress, five system-wide focal areas have been identified through consultations. They include 2030 targets and 2050 goals (below).

Recognising there is no single way forward, this report instead aims to expand future thinking, generate discussion, build awareness of potential synergies and trade-offs between different choices and guide planning activities.



1. Enabling equitable access to healthy and sustainable diets



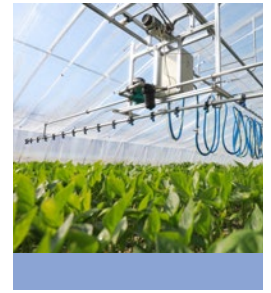
2. Minimising waste and improving circularity



3. Facilitating Australia's transition to net zero emissions



4. Aligning resilience with socioeconomic and environmental sustainability



5. Increasing value and productivity



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1 Introduction

Food systems encompass the people, places, policies, processes, and businesses involved in the production, processing, packaging, distribution, preparation and consumption of food and beverages and the waste produced throughout these steps. They are inextricably linked with other vital systems, including the health, economic, social, environmental, political and energy systems.¹

In the 20th century, food systems led to significant advances in global food and nutrition security. Stemming from the Green Revolution, technological advances have lifted crop yields, increased food availability and led to a 50% decline in the relative real price of food over a four-decade period from 1960-2000.² Without these advancements, millions more people would have suffered from hunger. Food systems have also led to more expansive and convenient product choices to meet consumer demands and have developed new revenue and employment opportunities. However, globally and in Australia, food systems also face unprecedented challenges, including a changing climate and expectations to reduce environmental footprints, increasing demand, disruptions to food supply chains and workforces, rising input costs, and nutrition-related public health issues.

It is now well recognized internationally that food systems require change to meet these challenges.³ Food systems are central to the 2030 Agenda for Sustainable Development adopted by the UN General Assembly in 2015, and the associated Sustainable Development Goals (SDGs).⁴ In particular, food systems are critical to delivering the goal of zero hunger (SDG 2), and for progress across the other 16 goals.⁵ The growing momentum for change has been strengthened by the 2021 UN Food Systems Summit, which brought together key players across the world;⁶ the UN Climate Change Conference (COP27), which placed food systems centre stage in addressing climate change and launched the World Health Organization Initiative on Climate Action and Nutrition (WHO I-CAN);⁷ and the UN Biodiversity Conference (COP15), that saw a historic deal to strengthen the protection of marine and terrestrial biodiversity through the 2022 Kunming-Montreal Global Biodiversity Framework.⁸

Australia participated in the UN Food Systems Summit. The Department of Agriculture, Water and the Environment (DAWE) – now the Department of Agriculture, Fisheries and Forestry (DAFF) – was the lead agency for Australian Government engagement. According to DAFF, “Australia supports the UN’s goal of delivering more sustainable, productive and resilient agricultural and food systems for producers and consumers alike.”⁹

CSIRO convened an Australian Dialogue with over 70 stakeholders from across food systems, as part of the

2021 UN Food Systems Summit. The Dialogue considered what science, innovation and actions are needed to achieve healthy diets from sustainable food systems by 2030.¹⁰ This Food Systems Roadmap builds on the Dialogue, consulting broadly with food system actors to define objectives for Australia’s food systems across various focus areas and identify actions and priorities.

1.1 Building food systems for our future: A global imperative

Our global food system faces profound challenges.¹¹ While in aggregate the world produces enough food to feed everyone, around 2.3 billion people were moderately or severely food insecure in 2021, and 3 billion people cannot afford a healthy diet.¹² At the same time, the number of people living with obesity, excess weight and associated human health problems is growing globally.¹³ Food demand is expected to increase by 50-60%¹⁴ between 2019 and 2050 with a global population expected to reach 9.7 billion people.¹⁵ These pressures on global food systems are expected to increase, further exacerbating inequalities and disproportionately affecting the world’s poorest and most disadvantaged populations.¹⁶

Food systems are vulnerable to environmental and climatic changes while also being a driver of these changes. Food systems contribute to greenhouse gas emissions, deforestation and other land-use changes, biodiversity loss, agrochemical use, environmental degradation, freshwater use, and pollution.¹⁷ Food systems must also contend with a warming world, changing environments, and shifts toward extreme climatic events and their consequences. The confluence of these environmental pressures and changes is reducing the ability of food systems to remain productive; threatening food security and livelihoods for current and future generations.¹⁸ These conditions are already contributing to significant humanitarian crises in some of the world’s most vulnerable nations, pushing millions towards famine.¹⁹

Addressing these challenges and redirecting our global food systems towards greater sustainability and resilience not only reduces risks and vulnerabilities to livelihoods and societies but is a necessity to ensure human welfare now and into the future.

1.2 Responding to challenges in Australia's food system

Australia's food systems feed an estimated 60-75 million people across the country and its export markets.²⁰ These food systems generally provide safe, high quality and nutritious food products for consumers, and jobs and revenue for Australians. Agriculture accounts for approximately 11.6% of Australia's goods and services exports, 2.4% of GDP and employs approximately 300,000 people.²¹ It also accounts for 55% of Australia's land use.²² Australia's food systems have demonstrated the capacity to navigate various risks and stressors. This includes managing disruptions during the COVID-19 pandemic and remaining a net food exporter even during severe drought years.²³ With that said, according to DAFF, "the world's food systems are facing many challenges, including here in Australia."²⁴ The following section summarises the key challenges in Australia:

Food and water security is not a given for every Australian. While Australia produces more food than it consumes, exporting approximately 70% of its agricultural production,²⁵ food insecurity is a challenge for many Australians. A 2022 study by Foodbank Australia found approximately 21% of Australians experienced multiple indications of disrupted eating patterns and reduced food intake in the previous 12 months (severe food insecurity), meanwhile a further 24% reported reduced quality, variety, or desirability of diets (moderate food insecurity).²⁶ Foodbank Australia suggests the primary causes of food insecurity in Australia include low incomes (42%) and high living expenses (64%).²⁷ Acknowledging the risks to the availability and accessibility of food in Australia, the House of Representatives Standing Committee on Agriculture has recently opened a Parliamentary Inquiry into food security in Australia.²⁸

Sufficient access to safe water is another critical aspect of food security. An estimated 630,000 people across over 400 regional and remote locations have poor-quality water that does not meet Australian Drinking Water Guidelines across safety, taste, and physical characteristics.²⁹ Access is especially a challenge in some rural towns, where during droughts, they run out of water and face high water transportation costs.³⁰

Beyond food and water insecurity, dietary risks contribute to disease burden among Australians. Many stakeholders consider the proliferation of low-cost, high-calorie and low-nutrient foods to be a system failure.³¹ Over 9 in 10 adults do not meet the recommendations for daily vegetable consumption, and 1 in 2 adults do not meet the daily recommendation for fruit.³² The proliferation of inexpensive high-calorie, low-nutrient foods hamper the ability of Australians to make healthy food choices and place growing burdens on the healthcare system through increased incidence of non-communicable diseases.³³ Dietary risks contribute to approximately 50% of coronary heart disease burden, and 26% for stroke, bowel cancer and type 2 diabetes respectively.³⁴ Vulnerable populations are disproportionately affected, where those who are food insecure are also more likely to live with obesity and excess weight, and are susceptible to micronutrient deficiency.³⁵ Supporting public health objectives to reduce weight related chronic disease is a Ministerial Priority under the joint Australia New Zealand food regulation system, and a review of the Australian Dietary Guidelines (ADGs) is currently underway.³⁶

Supply chain limitations and disruptions aggravate food and nutrition security, impeding the ability of food systems to provide equitable access and distribution of healthy foods. For example, the COVID-19 pandemic and the 2022 flooding in Queensland and New South Wales saw major supermarkets experience temporary food shortages, particularly of fresh produce, while Russia's invasion of Ukraine increased food prices.³⁷ Meanwhile, Australia's transportation system is limited across some regional and remote areas where communities are located significant distances from major freight corridors, creating additional logistical strain.³⁸

Domestic agricultural and horticultural production is concentrated across a few geographical areas, placing significant pressure to realise productivity gains in these regions. Production is primarily centred along Australia's southern and eastern coasts; determined in part by climatic conditions, water availability, biophysical conditions, and proximity to domestic and global markets.³⁹ Maintaining productivity in the face of growing resource, climate and land-use pressures such as urban expansion, is an ongoing challenge for Australia's food systems.⁴⁰ This geographical concentration also represents a key source of vulnerability, by creating an environment where the effects of localised crises (e.g., floods) may be amplified.

Maintaining food safety continues to be a priority for Australia's food systems. Australia's food safety and governance frameworks are generally successful in protecting public health and safety, educating the public, and monitoring and responding to food safety breaches. However, among industrialised countries, Australia has one of the highest infection rates of *Campylobacteriosis* – the most common foodborne zoonotic disease, followed by *Salmonella*.⁴¹ In 2019, there were an estimated 4.67 million cases of foodborne gastroenteritis, costing the country approximately \$2.1 billion.⁴² Rising temperatures, increased precipitation, and unpredictable weather patterns increase crop and livestock susceptibility to pests and diseases, potentially allowing new pathogens and their vectors to enter food environments.⁴³ Antimicrobial resistance is also rising, challenging the ability to respond to the growth of disease-causing microbes effectively. Innovations in novel food development and waste markets will also require new food safety processes. While Australia has a robust food regulatory landscape, it needs to continue to prepare for shifting and new risks.⁴⁴

Australia's food systems are facing skill and labour shortages. Australia's farming workforce is ageing – the average Australian farmer is 57 years old compared to the average Australian worker who is 40.⁴⁵ Even beyond the farm, the National Skills Commission has highlighted several sectors facing chronic labour and skills shortages with implications for the efficient functioning of food systems, including truck drivers, automotive and engineering tradespeople, meat processors, food technologists, food inspectors, and several health and medical professionals.⁴⁶ While the lingering effects of border closures and travel restrictions during COVID-19 have been largely resolved, workforce recruitment difficulties remain.⁴⁷ The causes of these difficulties include regional-to-urban migration patterns (often for education purposes), barriers to entry (e.g., farming profitability limiting the ability of enterprises to support multiple generations at once), and reports of poor conditions and pay.⁴⁸

Australia's food systems are wasteful. Australia produces 7.7 million tonnes of food loss and waste (FLW), which is linked to high volumes of food production and export and tends to be higher than the average FLW across other high-income countries.⁴⁹

Overproduction, overconsumption, poor temperature management during distribution and storage, and unsustainable food practices are core drivers of FLW.⁵⁰ This waste contributes to additional greenhouse gas (GHG) emissions from decomposing food and wasted inputs like water, land and energy used for food production.

Fragmented governance structures and data gaps impede decision-making processes. Food production, distribution and consumption in Australia are overseen by multiple layers of government. Ministerial responsibility covers many different parts of food systems, with no one minister overseeing food as a whole.⁵¹ According to stakeholders consulted, this means decision making is fragmented, creates competing priorities, and restricts the forming of cooperative strategies; particularly when a systems lens is not uniformly adopted. Stakeholders also noted that a lack of consistent and frequently collected datasets impedes informed strategic decisions around food systems.

Past experience is no longer a sufficient guide for the future. In the context of Australia's complex large geography and exposure to regional climate patterns, Australian agriculture's management of climate risk, has, to a large extent, been a success story. However, progressive global warming is altering average climatic conditions and exposure to extreme events. Australia's climate has warmed on average by 1.47°C since 1910, with most of the warming occurring post-1950.⁵² Australia is experiencing lower winter rainfall, increased frequency of extreme heat events and longer fire seasons.⁵³ Significant drying trends have been noted across south-east and south-west Australia, while heavy rainfall events are becoming more intense, increasing risks of flash flooding.⁵⁴ In addition, Australia's interconnected food systems are exposed to global environmental, socioeconomic and geopolitical changes, which may compound stressors or introduce new vulnerabilities.

As such, while the Australian food systems have always had to manage climate risk, the impact and interplay of risk and uncertainty across scales have become more complex. New approaches and solutions are needed.

1.3 Systems thinking and trade-offs

Food systems need to meet multiple objectives in an increasingly complex and interconnected world. This complexity results in overlapping and interacting activities that require careful and considered management. There are a number of reinforcing factors that maintain existing practices across the value chain that create lock-ins and incur environmental and social costs.

To enable change, managing contesting viewpoints will be an inevitable feature of the transition and will require broad and meaningful consultation with stakeholders within and beyond the agrifood sector. Agile and participatory approaches from research, policy and industry, and considerable coordination of planning, investment, action and governance will be required to orchestrate system wide changes.

Depending on the decisions made, actions in one area may create synergies or trade-offs for other elements or stakeholders within food systems, and these impacts and effects are not necessarily linear. Hence, monitoring progress to deliver on multiple food system outcomes and applying iterative adjustments, where necessary, may be critical. The role of this report is to advocate the importance of systems thinking and outline potential opportunities while acknowledging the existence of possible trade-offs that may need to be managed. Examples of key trade-offs raised during consultations include:

Conflicting productivity, profitability, environmental sustainability and public health goals. Australia operates a market economy that prioritises productivity and profitability and struggles to account for environmental and public health externalities. There are examples where the goals align, such as profitable businesses providing healthy and sustainable foods and environmental sustainability practices improving business profitability. However, there are also examples where the goals conflict, such as when environmental sustainability practices involve upfront costs for businesses and instances of business practices that mislead consumers about environmental sustainability credentials (greenwashing).

Reducing food prices and “the cheaper food paradigm”.

Efforts to reduce food prices through improved productivity help to deliver increased access to food (and therefore greater food security). Furthermore, research has shown that eating a healthy diet, as recommended by the Australian Dietary Guidelines, is not necessarily more expensive than some current (unhealthy) diets, although it remains unaffordable for the most vulnerable groups.⁵⁵ However, like the above tension around conflicting goals, producing cheaper food has typically relied on ‘externalising’ the environmental and public health costs of doing so.⁵⁶ For example, calories from staple crops have become increasingly cheaper and abundant, leading to an overconsumption of calories and underconsumption of nutrients.⁵⁷ Cheaper food is also valued less and is wasted more, producing GHG emissions in landfill and wasting resources expended over the food’s life cycle.⁵⁸ Nutrition Australia has called for systemic changes that allow for the “purchase [of] food at its real cost – rather than cheapening food to the detriment of human health and social and environmental systems.”⁵⁹

Consumers are demanding more functional and traceable foods at no additional cost.

Consulted stakeholders described changing consumer preferences towards value-added foods that offer health benefits beyond their nutritional value (functional foods), as well as foods that demonstrate sustainability and animal welfare attributes through traceability. However, stakeholders also described consumers’ limited willingness to pay for these more premium attributes. They also noted a lack of consistency and certainty around sustainability and other metrics, making it difficult for producers to meet these changing consumer preferences.⁶⁰

Competition over land use planning. Stakeholders noted that future policy decisions in the agriculture, forestry, energy and conservation sectors could increase competition for land and affect food production capacity. Land may be required for alternative energy production (e.g., crop production for biofuel), expansion of urban centres,⁶¹ conservation and regeneration, and the custodianship of lands and waters to Traditional Owners. Stakeholders also highlighted tensions around certain land uses not being well suited to local environmental conditions, driving biodiversity loss and increased use of natural resources.

2 Shaping Australian food systems for the future

This report is informed by work undertaken to-date internationally and locally, and by the perspectives of the cross-sectoral stakeholders consulted during the project. It seeks to synthesise the many opportunities and actions identified from this research and ultimately articulate how Australia can more proactively support the UN's ambition of "delivering more sustainable, productive and resilient agricultural and food systems for producers and consumers alike."⁶²

The task is large, and many diverse views, objectives and trade-offs must be navigated. However, there is also a significant opportunity to build consensus around a shared vision and the values of what more sustainable, productive and resilient food systems mean for Australia.

Based on the literature and the stakeholders consulted during this project, more sustainable, productive and resilient food systems in Australia have the capacity to:

- equitably and safely feed entire current and future populations, even during weather extremes and other supply disruptions
- advance global food and nutrition security
- support dignified livelihoods for workers and prosperity for regional economies
- avoid or minimise waste
- contribute towards local and global environmental sustainability and climate change mitigation and adaptation efforts
- sustain the environment and enable the protection and restoration of critical ecosystem functions
- embed Aboriginal and Torres Strait Islander knowledge systems and practices
- develop, adopt and integrate new innovation processes and technologies.



The capacity needed to deliver the change described in this roadmap extends beyond any organisation or group. Different stakeholders from across food systems will be responsible for driving or supporting the change.

Primary producers: Producers drive the adoption and piloting of technologies, infrastructure, methodologies and business models that uphold sustainability, equity, and healthy principles, particularly in land management. They also play a key role in meeting industry-led and government-mandated targets and advocating for these targets to remain ambitious and goal-orientated.

Manufacturers: Processors and manufacturing companies will be key drivers in piloting and implementing technologies, systems and organisational-level strategies that support change. Investing and partnering with technology development companies are also feasible for larger operators.

Retailers: The scale at which major Australian retailers operate ensures that they are well positioned to drive system-wide changes by issuing upstream mandates to their suppliers (e.g., sustainability goals, tackling waste, product health ratings), while engaging downstream (e.g., consumers through education campaigns) and with a range of supply chain participants through data sharing and collaboration efforts.

Federal government: The Federal government is well-positioned to facilitate knowledge exchange, address misinformation, build consensus on crucial system challenges, and provide clear direction through nationwide strategic planning and initiatives. The Federal government also plays a key role in reviewing and amending existing legislative mechanisms, market infrastructure, or related fiscal and industry policies. Catalysing investment into designated priority areas (e.g., infrastructure, capability building, transition processes, regional development, and business development) is also within the remit of the Federal government.

State and local government: State and local governments occupy a unique space, operating at regional and community levels while possessing the legislative mechanisms to tailor policies to these levels.⁶³ This supports governments in forming place-based strategies and solutions, informed by consultation with communities. The purview of state and local

government is broad but often includes food provision and procurement, food security/relief, land use planning, and support for local enterprises.⁶⁴ The monitoring and enforcement of food standards and regulations typically fall within the remit of state governments through food related legislation. However, local governments may also participate.⁶⁵ State and local governments also catalyse funding and resources for local actions, including infrastructure deployments, business incubation, technology adoption and educational campaigns.

Research community: Continued research, development, demonstration, and innovation activities are required to achieve food systems change. This requires transdisciplinary analysis skills that serve whole-of-system needs (i.e., co-creation of solutions drawing on diverse knowledge bases), behavioural study and mechanisms that support business incubation.⁶⁶ The research community is also responsible for promoting diversity of voices (including supporting the coalescence of Western and Indigenous science), and ensuring findings are understood and digestible to industry and the public. It is also within their remit to engage with industry and lead research efforts in alignment with industry challenges.

Representative groups: Representative groups, including industry and other non-governmental bodies, open communication channels between community, industry and government, strengthening vertical links across food systems. These groups can operate in an influencing and advisory capacity, maintaining pressure to ensure accountability and visibility on delivering shared values and influencing policy objectives and targets.⁶⁷

Community: Community support is critical for the success of local food systems, with community purchasing patterns influencing the direction of local and national food systems and markets. Communities also interact with food systems through marketing and advertising campaigns, educational resources, and the food waste they produce. Communities can also influence and participate in local or State food systems and local land planning decisions by participating in forums and other consultation activities.

Focal areas to drive change



3.1 Enabling equitable access to healthy and sustainable diets



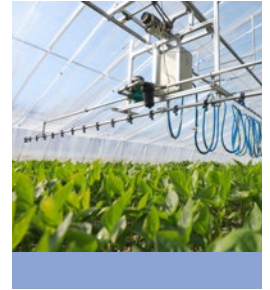
3.2 Minimising waste and improving circularity



3.3 Facilitating Australia's transition to net zero emissions



3.4 Aligning resilience with socioeconomic and environmental sustainability



3.5 Increasing value and productivity

SUSTAINABLE DEVELOPMENT GOALS



Figure 1: The 5 focal areas contribute towards the UN SDGs

To drive progress towards more sustainable, productive and resilient food systems in Australia, five system-wide focal areas have been identified through consultations (Figure 1).

2030 targets and 2050 goals are identified for each area. The timing of the 2050 goals aligns with important national and global aspirations, such as the Paris Agreement⁶⁸ and

Australia's net zero 2050 target.⁶⁹ They guide the realisation of aspirational, ambitious, yet achievable future visions. The 2030 targets are more specific, and their timing aligns with critical benchmark years, such as for the SDGs. The identified focal areas support many SDGs, helping Australia's food systems contribute to global goals.



3 Enabling change

The case for change across Australia's food systems is compelling, however, we must also consider how this change will be enabled. The system-wide nature of challenges and the vision for a new future state point to a very different type of change process than may have been thought of in the past. Many individual components of the current system have been identified as ineffective or inappropriate, and needing change, but tackling these alone will not be sufficient. An approach to change is needed that also addresses the path dependency of the current system that gives rise to these ineffective and inappropriate elements. That is, tackling an interconnected set of long-established practices, capabilities, mindsets, values and incentives that reproduce undesirable food systems outcomes. Unravelling these persistent and self-reinforcing factors, and reconfiguring these in ways that direct food systems toward new goals, present a new and complex intervention and policy solution space.

The practice of enabling this type of change process (or food system transformation) is at a formative stage. However, a number of principles are apparent, including the need to couple governance, institutional, policy and technological innovations across different scales of food systems; foster, coordinate and co-design actions across different policy and practice domains; be transparent about the values that are shaping policy and interventions, and their objectives; couple top-down and bottom-up change processes; invest in translational actions; use research as a catalyst for informing or facilitating collaborative action; and develop and share lessons on enabling actions. This last principle is particularly critical for navigating the unfolding processes of systems-wide change and the unpredictability of change pathways.

Opportunities, R&D priorities and action areas (see supplementary material) are identified across each focal area. These will need to be approached with the above principles in mind, recognising that their exploration and progression will be iterative. Action requires the capacity of our food systems to navigate, manage and direct transformational change processes aligned to priorities and ambitions and that embed coordinated action and collaborative mechanisms. Shared lessons and close monitoring will be critical to progress over time towards proposed targets and goals.



3.1 Enabling equitable access to healthy and sustainable diets

2030 Target

Australia's food systems enable equitable access to sufficient, safe, nutritious, and sustainably produced food with a strengthened focus on adapting to diverse cultural and community needs.

2050 Goal

All Australians can access safe, nutritious, acceptable, sufficient, sustainably produced, and affordable food, regardless of location, socio-economic status and cultural background. This equitable access contributes to improved population nutrition and reduced burden of disease. Consumers are empowered to source foods (whether they grow or purchase them) that support healthy dietary patterns while also preserving and celebrating diverse food cultures. They also have equitable access to information, services, equipment and facilities that support healthy food consumption.

The current state of play...

Prevalence of moderate and severe food insecurity (2022)

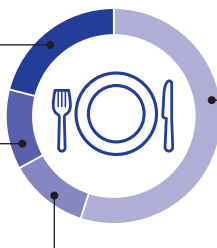


33%

of Australians experienced food insecurity in the past 12 months, or 3.3 million households

Severely food insecure 21%

Moderately food insecure 12%



Highly food secure 55%

Marginally food secure 12%



32%

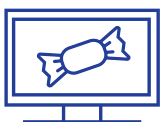
of households with children experienced **severe food insecurity** in the past 12 months



23%

of households perceive they **struggle financially** to access food more often in 2022 compared to the previous year

Number of TV ads for discretionary vs healthy foods (2016)



2.3/hr vs 1.0/hr in children's peak viewing times

1.7/hr vs 0.7/hr at all viewing times

Inadequate fruit and vegetable consumption (2017–18)



Less than 1 in 10 adults met the recommendations for **daily vegetable consumption**



Only **around half** met the recommendations for **daily fruit consumption**

Dietary risk and disease (2018)



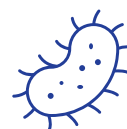
Dietary risks are responsible for **5.4% of burden of diseases**

↓ from 5.9% in 2015

The burden is **twice as high** for the most **disadvantaged Australians** compared to least.

A measure of the amount of burden that could have been avoided if all Australians ate a healthy diet.

Cost of foodborne illness



Over \$2.4 billion each year from lost productivity, premature mortality, health care, etc.



There were **4.7 million cases** of gastroenteritis in 2019, associated with 47,900 hospitalisations and 38 deaths

Proportion of packaged food and drinks that display the Health Star Rating (2019–20)



41% of all eligible products

↑ from 39% in 2018–19

Efforts to improve equitable access to healthy and sustainable diets are underway

While various levels of government have begun to undertake policies and measures to help Australians eat a nutritious and healthy diet, enhancing coordination and line-of-sight between them could significantly improve their impact.⁷⁰ The Australian Government has commenced the development of a National Nutrition Policy Framework, aiming to address this through a multi-sector, whole-of-government approach to guide policy action and improve eating patterns.

Australia's *National Preventive Health Strategy (2021-2030)*⁷¹ aims to improve the general health and wellbeing of Australians over the next 10 years, through a systems-based approach to prevention that addresses the wider determinants of health, reduces health inequities and decreases the overall burden of disease. Similarly, the *National Obesity Strategy (2022-32)*⁷² offers a framework for preventing, reducing and treating obesity in Australia. Dietary strategic guidance is also provided via the *Australian Dietary Guidelines (2013, currently under review)*, *Australian National Breastfeeding Strategy (2019)*, *the Australian Guide to Healthy Eating*, and *the Aboriginal and Torres Strait Islander Guide to Healthy Eating*, among other documents. Advisory bodies, such as Dietitians Australia⁷³ and the World Cancer Research Fund⁷⁴, have also contributed to literature in this space.

There are a series of legislative mechanisms that aim to protect public health and safety. This includes

the *Food Standards Australia New Zealand (FSANZ) Act 1991*, *Biosecurity Act 2015*, and *Imported Food Control Act 1992*. States and Territories also have tailored legislation relating to food safety.⁷⁵

The Federal Government has also called for and initiated research through survey mechanisms to determine the eating habits of Australians and their consequential impacts on health and wellbeing. These surveys have attempted to measure national dietary patterns (e.g., 2017-18 *National Health Survey*⁷⁶ and 2011-13 *Australian Health Survey*⁷⁷), or have looked at select groups such as children⁷⁸ or Aboriginal and Torres Strait Islander peoples.⁷⁹ Recently, a number of inquiries have sought to investigate food pricing and food security in remote areas, particularly within Indigenous communities.⁸⁰ A *National Strategy for Food Security in Remote First Nations Communities* is set to be released by 2025.⁸¹

There are also several state-level strategies to improve regional nutrition and access (see below).

Further action and coordination is needed to reshape food systems to ensure that all Australians can access a sustainable healthy diet, which is defined as 'dietary patterns that promote all dimensions of individuals' health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable.'⁸²

Table 2: Examples of state and territory-level nutrition and access strategies

STATE	ACTIVITIES AND STRATEGIES
NSW	NSW Healthy Eating and Active Living Strategy 2022-2032
QLD	Gather + Grow Queensland Remote Food Security Strategy 2023-2032 and Action Plan 2023-2026 (pending)
	Making Healthy Happen Strategy 2023-2032 and Action Plan 2023-2026 (pending)
	Remote Community Healthy Food Supply Chain Study
	Remote Food Security Roundtable Series, co-delivered in partnership between Health and Wellbeing Queensland, the Torres and Cape Indigenous Council Alliance and the Local Government Association of Queensland
TAS	Healthy Tasmania Five-Year Strategic Plan
	Food Relief to Food Resilience Tasmanian Food Security Strategy 2021-2024
VIC	Towards a Healthy, Regenerative, and Equitable Food System in Victoria: A Consensus Statement
ACT	Capital Food and Fibre Strategy Discussion Paper
WA	Healthy Options WA Food and Nutrition Policy
SA	South Australian Food Relief Charter and Nutrition Guidelines
	Healthy Eating Local Policies and Programs project (HELPP)
NT	The Aboriginal Medical Services Alliance NT has partnered with the Australian Commonwealth Government to develop a National Strategy for Food Security in Remote First Nations Communities

Opportunities across food systems

Consultation has informed the identification of various opportunities for food system stakeholders across industry, government, research and civil society. Some of these opportunities are specific, while others are more systemic initiatives that deliver multiple co-benefits. Trade-offs with potentially undesirable consequences will need careful management through well-planned transition pathways, implementation of evidence-based targets and cross-sectoral multi-level monitoring.⁸³

Opportunity 1: Integrate equity and sustainability principles into the Australian Dietary Guidelines

The ADGs provide evidence-based advice about the amount and kinds of foods to eat for health and wellbeing.⁸⁴ The current guidelines were released in 2013 and are now under review, with updated guidelines expected in 2025. There is growing evidence on how dietary advice can improve both public and environmental health and how healthier diets are driven by sustainable food systems.⁸⁵ There is also evidence that increasing the focus on equity in the ADGs could build awareness of the relationship between socioeconomic status, dietary intake, and health outcomes.⁸⁶

The updated guidelines could embed principles of equity and sustainability for improved human health and the environment across the relevant policy and practice domains for nutrition and diet.⁸⁷ This change could support more equitable and sustainable eating patterns among Australians, at both a population and individual level. Any changes to the ADGs would need to be paired with policy guidance, investment for implementation and deliberate monitoring and evaluation processes to measure their impact.

Opportunity 2: Secure access to healthy and safe food for Aboriginal and Torres Strait Islander communities

Aboriginal and Torres Strait Islander peoples across Australia require significant improvements in food security and Indigenous communities living in remote and regional areas are at particular risk of food supply disruptions.⁸⁸ Stakeholders consulted believe that Australia has an opportunity to strengthen access to nutritious land and ocean food sources in these areas, year-round. Optimised logistics and place-based solutions, such as community stores and local community gardens, can enable this. Strengthened governance and financial certainty can also ensure the durability and scaling of such initiatives.

For example, policy makers may consider how arrangements, such as land tenure agreements affect access to healthy foods and financing for initiatives, and how licensing and regulation can influence the development of Indigenous food ventures (see also Opportunity 29).

According to stakeholders consulted, past policies and interventions to improve food and nutrition access and consumption for Aboriginal and Torres Strait Island peoples have had mixed success. It is also documented that Indigenous voices are consistently under-represented in national nutrition policy development processes.⁸⁹ A *National Remote First Nations Food Security Strategy* is currently under development by the National Indigenous Australians Agency.⁹⁰ Indigenous advocacy organisations emphasise that for initiatives to be successful and meaningful, policy and solutions development and implementation requires a participatory approach and must be co-designed with Aboriginal and Torres Strait Islander peoples, including strategies to improve food and nutrition security.⁹¹ Stakeholders and evidence suggest that systemic change is also required to improve access to healthy food (including traditional foods), ensure adequate housing, and reduce the availability and marketing of junk food.⁹² Successful community-led initiatives that have improved access to healthy food and seen measured improvements in the health and wellbeing of communities can be used as models for best practice in self-determined initiatives (see Box 1).

Box 1. The Arnhem Land Progress Aboriginal Corporation

The Arnhem Land Progress Aboriginal Corporation (ALPA) began as a co-operative of community stores and is now the largest independent Aboriginal corporation in Australia. In the early 1980s, their Board of Directors and nutritionists developed and launched the *ALPA Health and Nutrition Strategy*⁹³ intending to decrease the risk of chronic disease and improve the health and wellbeing of their communities. The Strategy identified key target areas, including improving healthy food availability and affordability, supporting customers to make healthy food choices through healthy merchandising and promotions, and increasing awareness of health and nutrition. The Strategy initiated the 100% freight subsidising policy on fresh fruit and vegetables that remains in place today and also supported research collaborations that inform more health-conscious retail merchandising practices.

Opportunity 3: Support localised food systems and innovative business models

Localised food systems and social enterprises can proactively respond to the varying needs of communities, including vulnerable and marginalised groups.⁹⁴

These systems can also improve community-determined access to nutritious foods, including in under-served areas, and address community food insecurity. Localised food systems and social enterprises can also build resilience in the face of increasing climate threats, such as bushfires and floods, that disrupt supply chains. The VicHealth Future Health Food Hubs initiative is an example of such a program (see Box 2).

In addition to improving consumers' access to healthy and seasonal food, stakeholders noted that these systems can provide farmers with more consistent income sources and brand visibility while boosting local economies and promoting environmentally friendly production practices. Localised food systems businesses and social enterprises have also been found to influence sustainable urban food production, provide training and employment opportunities, initiate value-adding activities to food, and promote cross-sector and community collaborations.⁹⁵ Localised food systems are community led, often involve diverse community participation and vary depending on size and existing resources. Mid-scale systems may require new supply chain arrangements and regulatory support to optimise their operation and integration into larger food systems.

Box 2. Local Food Hubs – VicHealth Future Healthy Food Hubs initiative⁹⁶

VicHealth has invested over \$4 million across seven local organisations to establish Future Healthy Food Hubs. The initiative seeks to “increase access to locally produced and healthy foods in regional and urban fringe communities”, aiming to improve the health of all Victorians. Each Food Hub offers collaborative space and community-based programs that establish local food production, celebrate cultural diversity, provide education on regenerative farming practices, provide traineeships for young people and empower business owners and entrepreneurs. By localising the food system and encouraging community participation at all levels, the Food Hub model helps increase knowledge about, and access to, healthy food while improving local economic resilience, food security and environmental health.

Opportunity 4: Government and business collaboration to reshape commercial food environments

Current food environments often promote and encourage unhealthy eating.⁹⁷ Governments and businesses can work together to reshape commercial food environments (e.g., variety within food outlets or institutions, availability of consumer information) to provide food options that are healthier (e.g., low sugar/salt, more micronutrients/wholefoods), more sustainable (e.g., sustainably-reared livestock), and more diversified (e.g., a variety of nuts, fruits, vegetables, legumes).⁹⁸ Regulations, policy and business also shape demand through the use of nutritious ingredients, as well as improved product formulations, processing methods and distribution.

According to stakeholders consulted, creating positive healthy food environments that provide equitable access, dietary guidance, and controls on inexpensive high-calorie, low-nutrient foods are also important.⁹⁹ Some Australian jurisdictions are working towards improving industry and community food settings to influence consumer purchasing and dietary decisions, such as Health and Wellbeing Queensland's A Better Choice.¹⁰⁰

Box 3. Health and Wellbeing Queensland's A Better Choice¹⁰¹

A Better Choice is an initiative designed by Health and Wellbeing Queensland - a statutory agency apart from Queensland Health - to make it easier for Queenslanders to access healthy food and drink options in places outside the home, such as in healthcare settings, schools, and restaurants. The initiative promotes food and drinks in line with the Australian Guide to Healthy Eating and supports Queensland food venues to offer healthier menu options. It also uses a traffic light system to classify products according to their nutritional value. Green means 'Best nutritional value', amber means 'Some nutritional value' and red means 'Limited or no nutritional value.'

Opportunity 5: Leverage institutional procurement to prioritise healthy and sustainable diets

Institutional procurement practices can substantially influence the food available to a large proportion of the population, such as in schools, aged-care facilities, and prisons. These institutional procurement practices can prioritise positive food environments that enable healthy and sustainable diets with nutrient-dense foods and controls on inexpensive high-calorie, low-nutrient foods.¹⁰²

Governments can develop strategies for evidence-based social and ethical food procurement standards,¹⁰³ supported by comprehensive implementation assistance and evaluation mechanisms to monitor progress and enhance outcomes. The Victorian Government's Healthy Choices Framework¹⁰⁴ and the Healthy Food and Drink in NSW Health Facilities for Staff and Visitors Framework¹⁰⁵ are examples of such strategies.

Opportunity 6: Educate and empower consumers to eat healthier

Significant behaviour change can improve the healthiness and environmental sustainability of dietary habits in Australia.¹⁰⁶ This shift, already commenced by some consumers, focuses on increasing the consumption of fruit and vegetables and reducing the consumption of high-calorie and low-nutrient foods.

Greater investment in public health information, food systems and sustainability education, food literacy, technological advancements, and improved coordination across relevant government departments (e.g. health, environment, agriculture, education) have been shown to support behaviour change.¹⁰⁷ However, according to stakeholders consulted, public education campaigns need to be evidence-based and their reach needs to include vulnerable populations who are often most directly affected by food health policy.

R&D priorities

The research and development priorities outlined during stakeholder consultation to inform this report are presented below. Alongside these priorities for the research sector, there is a requirement for significant demonstration, extension and commercialisation activities.

Integrated data platforms to enable greater engagement and participation for all stakeholders across the value chain: Enabling end-to-end accountability and transparency of food systems can be achieved through more robust data collection platforms and methodologies. For example, technology-enabled end-to-end traceability can track comprehensive and consistent data across the supply chain or map the level of food and nutrition imports and exports. These end-to-end platforms can also inform cost-efficient food testing, authenticity, and monitoring solutions to improve food safety and mitigate fraud.

Improve population data and nutritional surveillance to inform policy responses towards food-related inequities and chronic illnesses: Qualitative and quantitative data are needed to support targeted co-designed actions, both to inform their implementation and monitor and

evaluate their impact. Comprehensive and consistent data collection is required to better understand food security, nutrition, and equity components across the country, and assess progress, especially for priority populations. Enabling culturally appropriate Indigenous methods and data to be embedded into a national data systems is also necessary. Modelling and risk assessment tools can help to maximise the impacts of this data collection, for example, by identifying and addressing accessibility and affordability gaps through geographic assessments of communities facing 'food deserts' and 'food swamps'.

Research into current best practice tools and approaches for fostering consumer behaviour change: Continued research into best practice tools and approaches can drive consumer behaviour towards making more informed decisions that support healthier diets. This may include social innovation research that can inform methods to maximise impact and encourage knowledge sharing. Mapping power dynamics and interactions among stakeholders in food systems, especially in disadvantaged parts of the country, could inform these tools.

Research of systems-based approaches that balance ecological, health, social, cultural and economic goals:¹⁰⁸ Continued research into systems-based approaches for healthy, sustainable and equitable diets can help ensure that systems-wide changes will benefit health and nutrition metrics. This research could consider broader whole-of-system impacts; including ecological, social, cultural and economic. Research priorities could focus on tackling malnutrition and obesity; improving nutrition for healthy ageing; reducing the environmental impacts of food production and consumption; and supporting nutritious diets that are environmentally sustainable. Conducting Life Cycle Assessments (LCAs) can evaluate their nutritional impact, affordability and environmental sustainability over the entire supply chain, and better understand trade-offs.

Expand research into microbes and viral agents that contribute to adverse health outcomes (and food loss): Biological hazards can cause acute foodborne diseases, also resulting in mass food loss as contaminated produce is dumped or recalled. Research priorities may include screening, detection and enumeration methods for quantifying pathogens, pathogen characterisation, and intervention strategies.¹⁰⁹

Additional R&D priorities relating to enabling equitable access to healthy and sustainable diets are discussed in other sections of this report. For innovations to extend the shelf-life of perishable foods, please refer to Section 3.2. For research into early-warning systems for climate and other events, please refer to Section 3.4.



3.2 Minimising waste and improving circularity

2030 Target

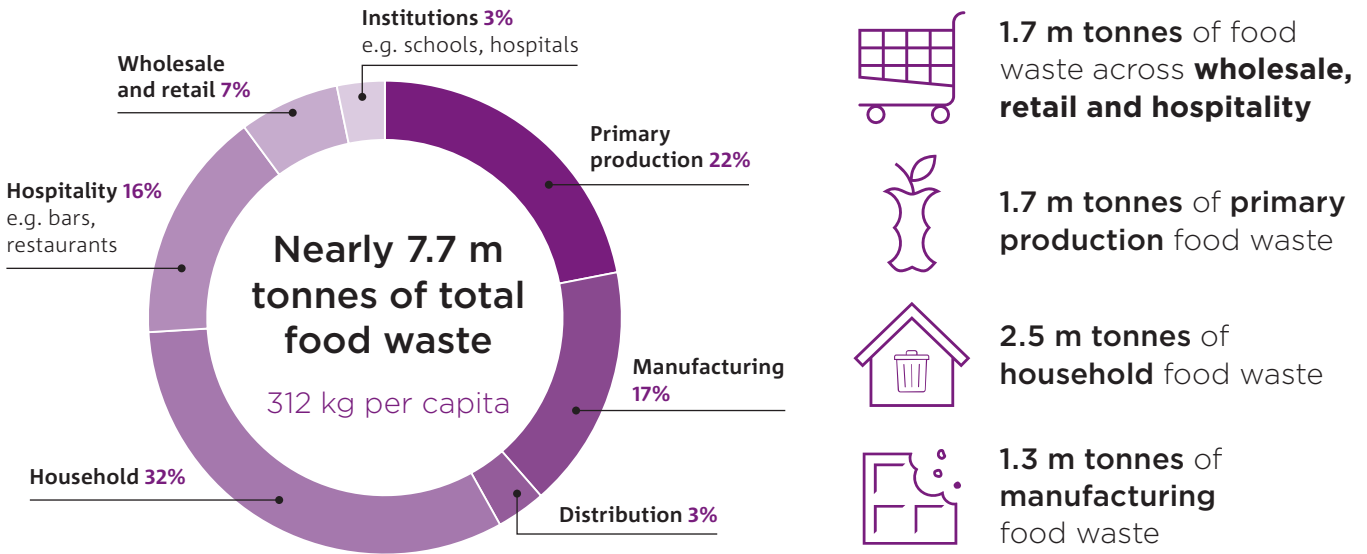
Australia, realising its 2030 National Food Waste Strategy¹¹⁰ goals and 2025 National Packaging Targets,¹¹¹ halves its food waste at the retail and consumer levels, and reduces food, packaging and other losses along production and supply chains.

2050 Goal

Australia has circular food systems with zero avoidable food waste. Unavoidable food and packaging waste along the value chain is minimised, redistributed or transformed into value-added products as part of an increasingly thriving circular bioeconomy.

The current state of play...

Australian food loss and waste (2018–19)



90% of food waste ended up in **three main destinations:**



Climate resilient water sources (2014–15)



1,950,000 ML/year production capacity

184% increase from 2001–02

Measures Australia's maximum production potential from its water recycling and desalination sites.

Recycling rate of organic material (2018–19)



49% of food, garden organics, timber and biosolids, etc. (7 Mt in total)

↑ from 37% in 2006–07 (5 Mt in total)

Packaging waste (2020–21)

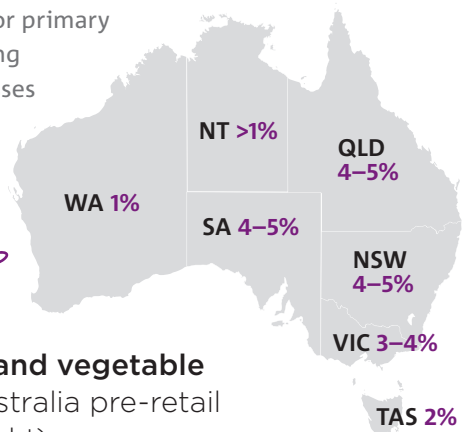


3 million tonnes of all post-consumer packaging were **disposed in landfills**

This is **44%** of total packaging placed on the Australian market (across food and other categories)

Food production losses pre-retail (2017–18)

Estimated range for primary production, packing and processing losses



18–22% fruit and vegetable losses for Australia pre-retail (1,174 to 1,455 kt)

Efforts to reduce waste and improve circularity are underway

In 2017, Australia published a *National Food Waste Strategy*¹¹² with the goal of halving Australia’s food waste by 2030, in alignment with global efforts (e.g., SDG 12.3). Specifically, the strategy seeks to halve both food loss and food waste and identify the core drivers of waste along supply and consumption chains. In support of this, the Australian government has enacted a range of initiatives to reduce and improve the circularity of organics waste management (see Table 3). A number of industry¹¹³ and not-for-profit organisations¹¹⁴ are also reducing FLW through food rescue and redirection activities.

Beyond food waste, the Australian Packaging Covenant Organisation (APCO) is leading actions to phase out problematic and unnecessary plastics by 2025, in line with National Packaging Targets. The National Packaging Targets apply to all packaging made, used and sold in Australia and sets out to reach 100% reusable, recyclable or compostable packaging; 70% of plastic packaging being recycled or composted; and an average of 50% of recycled content included in packaging by 2025.¹¹⁹ CSIRO is also supporting these efforts through its Ending Plastic Waste Mission, aiming for an 80% reduction in plastic waste entering the Australian environment by 2030.¹²⁰

Box 4. Defining food loss and waste (FLW)¹¹⁵

Food loss refers to the decrease in edible food mass at the production, post-harvest, and processing stages of the food chain. Food waste refers to the discarding of edible foods at retail and consumer levels.

Further action and coordination is needed to shift Australia’s food systems to be more circular, efficient, and sustainable and to improve the social and environmental wellbeing of Australian consumers and natural landscapes.

Table 3: Examples of government-led initiatives to reduce food waste

INITIATIVE	DESCRIPTION
Stop Food Waste Australia ¹¹⁶	An independent entity tasked with delivering the National Food Waste Strategy and its goals.
The Food Waste for Healthy Soils Fund ¹¹⁷	A \$67 million fund supporting the diversion and recycling of organic waste from landfill, comprised of \$57 million towards improved organic waste recycling infrastructure and \$10 million towards supportive government actions (e.g., education initiatives and the updating of compost standards and procurement guidelines).
The Australian Food Pact ¹¹⁸	A voluntary agreement bringing together organisations from across the food supply chain to reduce food waste, while aiming to build more sustainable, resilient, and profitable food systems. The Pact has 28 signatories (as of January 2023).

Opportunities across food systems

Opportunity 7: Implement sustainable and recyclable packaging with improved labelling

Increasing sustainable and recyclable materials in packaging can reduce FLW. More efficiently diverting materials to recycling plants has the potential to save over \$500 million per annum and reduce the 130,000 tonnes of plastic leaking into Australian marine ecosystems per annum.¹²¹ According to stakeholders consulted, however, voluntary industry efforts are insufficient to reduce packaging related waste and Australia's recycling systems need more investment in infrastructure.

The Australasian Recycling Label (ARL) Program¹²² is an on-pack labelling scheme that helps consumers recycle correctly and supports manufacturers to design recyclable packaging. It aims to improve consumer awareness and increase recycling rates. While the program includes many well-known brands in Australia and is supported by all levels of government, stakeholders believed it should be extended to more brands and products. The European Commission's Food 2030 Pathways for Action initiative¹²³ provides another model for the industry to transform packaging and distribution waste through efficient recycling, innovation in food packaging, and tackling whole-of-value-chain waste streams. Stakeholders noted that any changes to food packaging would require careful planning with industry, including an assessment of both the costs and benefits of packaging redesign options. They also suggest that retailers could play a role in prioritising the use of sustainable packaging options by their suppliers.

Opportunity 8: Educate and empower consumers to reduce food waste

Addressing the socioeconomic factors and motivations driving consumer purchasing and consumption choices through education, awareness and infrastructure can speed up the reduction of food waste.¹²⁴ Unfortunately, consumers generally have a poor understanding of the role that packaging plays in minimising food waste and many lack the knowledge to correctly store food.¹²⁵ However, 76% of Australian individuals have indicated a high to moderate level of motivation to reduce food waste,¹²⁶ and nationwide education campaigns can support consumer behaviour change.¹²⁷

In addition to improved packaging (discussed above), empowering consumers with practical information through an education campaign could also be effective in reducing food waste. Such a campaign would need to involve consumers in a co-design process and acknowledge the multi-dimensional nature of food waste and the range of consumer-led initiatives that can reduce personal wastage. It could also address gaps in consumer knowledge around the purpose and correct interpretation of packaging and labelling information (such as portions and expiry dates), show consumers how to correctly and safely reuse and recycle food packaging, and encourage the adoption of new packaging technologies.¹²⁸ The UK's "Love Food Hate Waste" initiative (see Box 5), for example, has successfully demonstrated the impact of evidence-based and consumer-focused national education on reducing food waste, and sustaining this.

Scaling the recycling capacity in communities, where, for example, only 32% have access to Food Organics Garden Organics (FOGO) kerbside collection service, can play a crucial role in facilitating behaviour change.¹²⁹ Policy and regulatory actions and ensuring equitable access to healthy and sustainable diets can also support nationwide campaigns.

Box 5. Love Food Hate Waste

Love Food Hate Waste, a UK-founded initiative, collaborates with partners to create innovative food-saving methods and technology, simplify how food is labelled, and work with producers and retailers to reconsider how food is packaged and sold.¹³⁰ They have since branched out to educate consumers on proper recycling methods for waste, plastics, and clothing. A dedicated recipe section on their website helps consumers repurpose their 'leftover' food items into meals and a portion calculator shows how much food to buy or cook per person. 1 in 3 UK citizens now recognise the campaign, and between its commencement in 2007 and 2018, the campaign contributed to a reduction of 9.5 million tonnes (15%) of food waste.¹³¹

Opportunity 9: Transform waste into Australian value-added products

Australian businesses may be able to transform by-products that are currently low value or valueless into higher value or value-added products. Novel by-product innovation has seen advances in utilising food by-products for human consumption, animal feeds, industrial uses (such as fuel conversion and energy recovery), fertilisation and composting products, clothing and other non-consumable products, as well as for alternative building and construction materials.¹³² The Mackay Renewable Biocommodities Pilot Plant, for example, has tested the commercial viability of a wide range of high value compounds using sugarcane as a feedstock (see Box 6). This innovation also extends to businesses within Australia's marine industry; with the potential to derive a wide range of high value compounds from the treatment of fish discards for use within medical, pharmaceutical, food and biofuel production fields.¹³³ According to stakeholders consulted, further investment is needed to establish the production and manufacturing capabilities for these value-adding processes, and coordination across the supply chain is required to identify and redistribute by-products effectively.

Box 6. Mackay Renewable Biocommodities Pilot Plant (MRBPP)

Established in 2010, Queensland University of Technology's (QUT) MRBPP is pioneering research and innovation in biorefining. Researchers partner with a range of local, national and international stakeholders to develop, demonstrate and test technologies at pilot scale to assess whether they are commercially viable products.¹³⁴ These projects take biomass feedstocks from sugarcane, cotton, grains and horticultural waste to create biofuels, green chemicals and other bioproducts, including feedstocks for precision fermentation and cultivated meat processes.¹³⁵

R&D priorities

Investigate methods to estimate the full cost of products and their disposal, and embed product life cycle assessment data into costing: Full (or true) costing refers to the market price of products, in addition to unpaid external costs incurred by their production, use and disposal. While efforts have been made in educating consumers on unit pricing in the food sector, there is a paucity of research into methods to accurately estimate the true cost of food products by considering life-cycle costs, waste disposal costs, sustainability elements and ethical labour costs. There is a need for further research into how to embed this data into food costing and then translate this into true-cost pricing of foods in retail settings.

Map the quantity and quality of both avoidable and unavoidable FLW: Understanding waste pathways and the structural impediments contributing to excess waste is key to more effective redistribution or waste utilisation along the food value chain. While setting-based approaches and technological advances may assist this, cross-sectoral data collection and sharing will be required to underpin logistics and supply chain models that, together with infrastructure and transport information, can enable better supply chain monitoring and management. Machine learning (ML) and artificial intelligence (AI) approaches can jump-start circular economy practices that fight FLW.¹³⁶

Develop and scale new production platforms to process by-product waste streams: Greater research into new processing and manufacturing technologies is needed that enable value-adding and repurposing of wastes into new products in line with the National Food Waste Strategy's waste hierarchy.¹³⁷ Innovation priorities could include technologies and platforms that upcycle landfill waste and perishable fresh produce by-products into a non-synthetic soil amendment, shelf-stable food products, animal feed, biomaterials and renewable energy. These novel production platforms currently require feasibility demonstration, scale-up, and market development.

Research into sustainable packaging to extend the shelf life of food: The Fight Food Waste CRC has highlighted that research and education are needed to improve smart, intelligent packaging design. This may reduce FLW and associated GHG emissions (see Section 3.3), optimise shelf-life and improve overall product storage. Innovative and sustainable packaging can help stakeholders control FLW by monitoring food quality, managing food to surpass its shelf life and administering the right physical environment for storage, especially concerning temperature and humidity.¹³⁸

Life-cycle assessments of plastic use across the value chain and its comparison to alternative bio-based packaging: Stakeholders highlighted the importance of understanding how and where plastic is used across the value chain to target specific interventions for reducing, reusing and recycling this plastic. Similar assessments are needed for emerging novel bio-based packaging solutions so that producers, processors, and manufacturers can make informed decisions around their packaging choices.

Research into on-farm plastic waste solutions: Agricultural products – particularly silage wrap, irrigation pipe, plastic mulch and drip tape – are rarely recycled after use, mainly due to the waste being contaminated with dirt and located in regional and remote areas.¹³⁹ Investment in research and infrastructure that aids this waste’s collection and reprocessing capabilities may assist with waste reduction in the sector.





3.3 Facilitating Australia's transition to net zero emissions

2030 Target

Industries across food value chains are aligning with Australian Government's pledge to achieve a 43% reduction in economy wide GHG emissions by 2030 from 2005 levels on the path towards net zero by mid-century.¹⁴⁰ This alignment is demonstrated through strategic plans, defined targets and indicators, and actions.

2050 Goal

Australian food systems are aligned with a net zero economy, value nature-based solutions and sequester carbon. Food producers and supply chain participants minimise emissions while remaining productive. Consumers are informed and can easily make purchasing decisions that support lower emissions.

The current state of play...

Greenhouse gas emissions of food consumption per capita



3.4 kg CO₂ equivalent per day per person
Or 1.2 tonnes CO₂ equivalent per year per person

Renewable energy usage in food and beverage manufacturing (2020–21)



52% of total energy consumption
↑ from 30% in 2002–03

Annual greenhouse gas emissions from Australia's food system activities (2020)

Emissions accounted for are those generated within farm gate, associated with land use change and emissions from pre- and post-production food processes.



Emissions on agricultural land, including land change
e.g. forest conversion, crop residues, fires



119,300 kt CO₂ equivalent

40% drop from 2010



Pre-production activities
e.g. fertiliser manufacturing, on-farm electricity use



1,800 kt CO₂ equivalent

9% drop from 2010



Post-production activities
e.g. processing, packaging, transport, waste disposal



53,800 kt CO₂ equivalent

10% drop from 2010



Total agri-food system emissions (sum of the above)



174,900 kt CO₂ equivalent

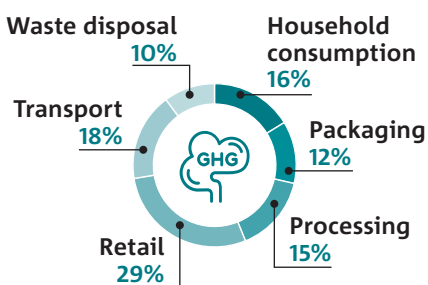
33% drop from 2010

Greenhouse gas emissions from Australia's food system per capita (2020)

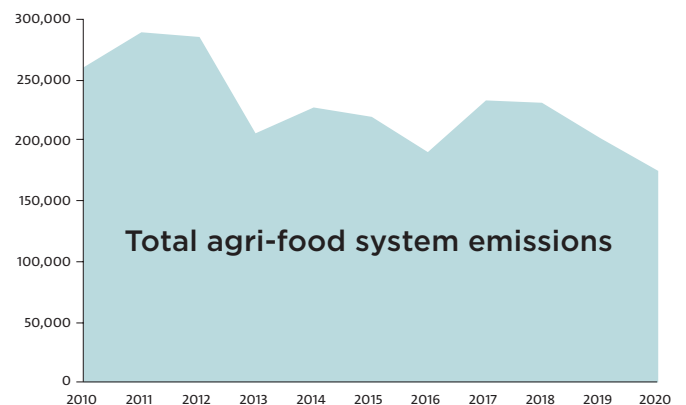


6.8 tonnes CO₂ equivalent per year per person

2020 share of emissions across post-production food system activities (2020)



Total agri-food CO₂ equivalent emissions (kt)



Efforts to reduce greenhouse gas emissions are underway

Many primary production industries are working towards sustainability initiatives, with some of these initiatives citing net zero ambitions. Primary industries increasingly recognise their role as environmental stewards, looking to protect and restore native habitats on properties and reduce their emissions (Table 4). The Australian Agricultural Sustainability Framework (developed by the National Farmers' Federation (NFF) and funded by the Australian Government, see Box 13) looks at sustainability from a whole-of-agriculture perspective and provides principles around GHG emissions,¹⁴¹ while the NFF's 2030 roadmap has aspirations to embrace carbon neutrality by 2030, and metrics around Australian farms sourcing 50% renewable energy within the same timeframe.¹⁴² Ambitions of the agricultural sector are also supported by the development of representative groups like Farmers for Climate Action.¹⁴³ Governments are also supporting agriculture's goals, for example, through the Federal Government's Emissions Reduction Fund and Carbon Farming Outreach Program,¹⁴⁴ the Queensland Government's Low Emissions Agriculture Roadmap,¹⁴⁵ Tasmania's Climate Change Action Plan that requires government to work with industry and business to develop sector-based Emissions Reduction and Resilience Plans,¹⁴⁶ and the Victorian Government's aspiration for the State's farmers to be leaders in low-emissions agriculture and, more broadly, to reach net-zero emissions state-wide by 2050.¹⁴⁷ CSIRO's Towards Net Zero Mission further aims to help agriculture (and other hard-to-abate sectors) halve emissions by 2035.¹⁴⁸

Many larger food manufacturers in Australia have begun investing in renewable energy sources for their factories and committing to cutting emissions. For example, Mars has committed to net zero by 2050 across its entire value chain, with several 100% renewable factories in Australia,¹⁴⁹ and Arnott's has committed to achieving net zero in their operations by 2040, and across the value chain by 2050.¹⁵⁰ Retailers, large and small, are also on the journey, with Coles and Woolworths both committing to deliver 'net-zero or better' GHG emissions by 2050.¹⁵¹

Consulted stakeholders noted that these industry commitments to emissions reduction need to be supported by evidence-based pathways and more consistently adopted across food systems.

Several tertiary education institutions are also undertaking efforts to improve awareness and understanding of climate change, including the carbon costs and impacts of everyday activities and actions to reduce emissions. This includes the University of Queensland's Carbon Literacy Program,¹⁵² an Australian-first micro-credential certification for climate mitigation, among others.¹⁵³

Box 7. Collaborative research efforts

Collaborative research efforts are also supporting food systems to minimise emissions and drive cross-sector R&D and innovation. This includes CSIRO's Towards Net Zero Mission aims to bring together research, industry, government, and communities to help Australia's hardest to abate sectors – including steel, sustainable aviation fuel, and agriculture – halve their emissions by 2035.¹⁵⁴ The proposed Zero Net Emissions from Agriculture Cooperative Research Centre (ZNE-Ag CRC) also aims to catalyse industry, community, and government action to achieve Zero Net Emissions from agriculture by 2040, and below zero net emissions by 2050.¹⁵⁵

Further action and coordination is needed to reduce GHG emissions further across food systems, including through primary production, processing, distribution, consumption, and waste streams.

Table 4: Australian primary production industry commitments towards emissions reduction

INDUSTRY	COMMITMENT	SOURCE
Dairy	Adoption of the NFF's climate change policy (net zero emissions by 2050) with conditions.	<i>Australian Dairy Sustainability Framework – 2021 Sustainability Report</i> (Dairy Australia Ltd, 2022)
Egg	Investigations into a carbon neutral egg and low carbon supply chains.	<i>Sustainability Framework Report 2022</i> (Australian Eggs, 2022)
Grain	Priority goal of reducing industry's net GHG emissions. 15% reduction in grains emissions intensity by 2030.	<i>State of the Australian Grains Industry 2021</i> (GrainGrowers 2021) <i>GrainGrowers' Climate Change Policy</i> (GrainGrowers, 2022)
Horticulture	Horticultural production systems minimise greenhouse gas emissions.	<i>2021 Australia-Grown Horticulture Sustainability Framework</i> (Hort Innovation, 2021)
Pig	Focus area around carbon cycling and nutrient accounting to ensure pork is a low emissions protein. Goal of reducing emissions to 1kg CO ₂ e/kg of pork (2020 estimates 3.3kg CO ₂ e/kg of pork).	<i>Australian Pork Limited Sustainability Framework 2021-2030</i> (Australian Pork, 2021)
Poultry	The chicken industry is committed to contributing to Australia's Long Term Emissions Reduction Plan, to deliver net zero emissions by 2050.	<i>Environment – Australian Chicken Meat Federation.</i> (Australian Chicken Meat Federation, 2022)
Red Meat	Carbon neutral by 2030 (CN30): an ambitious target for the Australian red meat and livestock industry to achieve net zero GHG emissions by 2030.	<i>The Australian Red Meat Industry's Carbon Neutral by 2030 Roadmap</i> (Meat and Livestock Australia, 2020)
Sheep	Industry priority to reduce net GHG emissions.	<i>Sheep Sustainability Framework, 2022</i> (Sheep Producers Australia and WoolProducers Australia 2022)

Opportunities across food systems

Opportunity 10: Reducing emissions through nature-based solutions

There is an opportunity to leverage nature-based solutions to farming, with significant carbon capture potential.¹⁵⁶ Nature-based solutions are actions that protect, sustainably manage, or restore ecosystems; addressing societal challenges (e.g., climate change, human ill-health) and benefitting people and nature.¹⁵⁷ Examples include reduced application of synthetic fertilisers, improving soil quality and sequestering carbon.¹⁵⁸ Carbon storage is fundamental to land productivity and maintaining climate stability. Depending on the use and management of land, carbon can be absorbed from the atmosphere (e.g., through soil regeneration) or released (e.g., through the removal of vegetation).¹⁵⁹ While reducing emissions, these solutions could offer co-benefits for other environmental concerns, for example, offering habitat and biodiversity benefits or flood protection.

The Australian Government is supporting a number of these solutions including protection and restoration projects, national strategies, research, and financing solutions such as market-based carbon and biodiversity pilots.¹⁶⁰

Incorporating Aboriginal and Torres Strait Islander knowledge systems into land management approaches through co-designed and Indigenous-led initiatives is also important for this opportunity, with the successful incorporation apparent in multiple jurisdictions. For example, cultural burning in the Northern Territory has led to the development of an Indigenous carbon industry that has abated 8.4 million tonnes of emissions since 2012.¹⁶¹

Stakeholders warned however that poorly planned nature-based solutions can exacerbate vulnerabilities to climate change and stressed the importance of undertaking accurate vulnerability assessments, management, and monitoring activities.

Opportunity 11: Strengthen markets for low carbon and nature-positive land use

Creating efficient, profitable and sustainable markets for carbon sequestration and biodiversity can provide farmers with sufficient incentives to shift towards more sustainable and lower emissions intense land use.¹⁶² For example, Australia's carbon market aims to give farmers new revenue streams via emissions reduction projects that offset hard-to-abate emissions from other

industries. The Australian Government is also developing several schemes to reward landholders for restoring and protecting nature, including market mechanisms¹⁶³, project funding for environmental restoration initiatives,¹⁶⁴ and community grants.¹⁶⁵ All landholders, including Aboriginal and Torres Strait Islander peoples, conservation groups, governments and farmers, can undertake projects to enhance or protect existing habitats or to establish and restore habitats. The Australian Government is also developing a new Nature Repair Market to reward landholders for restoring and protecting nature.¹⁶⁶ The market mechanism will operate in parallel with the carbon markets, so landholders can receive certificates from carbon projects that also create biodiversity co-benefits.

According to stakeholders consulted, participation in carbon markets can be significantly improved by providing greater clarity around the mechanisms, more opportunities for smaller participants, and on-the-ground outreach and assistance for primary producers. The current carbon market is complex with many primary producers hesitant to participate due to uncertainty around the program, scale requirements due to time and financial investment, and several anticipated risks associated with participation (e.g., complex verification, farmers may require their credits in the future for their own market access¹⁶⁷). An independent review noted in 2022 that reform was required to “clarify governance, improve transparency, facilitate positive project outcomes and co-benefits, and enhance confidence in the integrity and effectiveness of the scheme”.¹⁶⁸ The Government, in principle, accepted all 16 recommendations presented by the independent panel.

Opportunity 12: Expanding the availability of climate-neutral foods

Businesses seeking to reduce the footprint of their foods and find a competitive edge can explore ways to innovate and market climate-neutral products. Existing certification schemes such as the Climate Active program, NoCO2 Certification Standard and Certified Sustainable offer a starting point, verifying businesses that have reached a carbon-neutral status.

The average Australian diet has a climate footprint of approximately 3.4kg CO₂ equivalent per person per day, and there are limited climate-neutral foods available in Australian food systems.¹⁶⁹ Consumers require access to information to make informed decisions around both the health and nutrition, but also the sustainability and emissions profile of their diets. Alongside certification

schemes, stakeholders consulted believed that consideration should also be given towards the cost-benefit analysis of on-pack sustainability labelling and the incorporation of sustainability messaging into the nutritional guidelines that are under review and due to be completed in 2025.

Box 8. Climate-neutral foods

While there are still limited products in the Australian market that are certified as carbon-neutral, momentum is building with small businesses and large corporations alike launching new products.

Similarly, Queensland's Fenn Foods have leveraged research and innovation to develop carbon-neutral alternative meat products, including the world's first carbon-neutral, plant-based mince that is stocked in major supermarkets across Victoria, New South Wales and the ACT.¹⁷⁰

Opportunity 13: Reducing emissions through innovative technologies

Australian and global research endeavours are also producing novel technologies and methodologies that will help agricultural operations reduce emissions, sequester carbon and improve on-farm and ecosystem biodiversity. Precision agriculture and new livestock feed supplements are two examples.

Precision agriculture uses advanced technologies and methods to exert more control over a production system by recognising variations across different areas of land and managing these differently. These technologies have the potential to reduce emissions by optimising operations and the quantity, timing and location of farming input, thereby reducing fuel and grid electricity demand and improving on-farm energy productivity.¹⁷¹

Feed supplements help reduce emissions associated with the digestive process of livestock,¹⁷² which account for around 10% of Australia's total annual emissions.¹⁷³ Low emissions feed technologies such as Asparagopsis, 3-NOP (Bovaer), Desmanthus and Leucaena are emerging as potential solutions for reducing livestock emissions and are the subject of significant R&D and commercialisation efforts.¹⁷⁴

Box 9. Sea Forest – Tasmanian seaweed farming

Sea Forest is a Tasmanian company that is developing the culture, harvest and commercialisation of *Asparagopsis*, an Australian native seaweed that has the ability to reduce methane emissions in cattle by up to 98 per cent.¹⁷⁵ The project will seek to develop a commercial formulation for a seaweed-based feed supplement that can be fed to cattle and sheep to reduce their methane emissions and deliver productivity gains.

Sea Forest has received grants from the Tasmanian Government's Agricultural Development Fund, the Federal Government's Accelerating Commercialisation fund and Entrepreneurs' Programme, as well as over \$34 million in private equity funding.¹⁷⁶

Opportunity 14: Integrate renewable energy sources throughout the food supply chain

There is an opportunity to expand the uptake of renewables across food systems to help reduce energy consumption and lower related emissions. This aligns with the NFF's aim to reduce the agricultural value chain's reliance on fossil fuels in favour of renewable sources and see Australian farms sourcing 50% renewable energy by 2030.¹⁷⁷ While uptake to-date has been hampered by cost, installation delays, intermittency and unpredictability of supply, financial incentives exist,¹⁷⁸ Food Innovation Australia Ltd (FIAT) suggests that energy-smart food production and manufacturing could be worth \$6 billion in value-add by 2030.¹⁷⁹

In 2019, the NFF, Clean Energy Finance Corporation (CEFC) and the University of Southern Queensland (USQ) produced a practical guide to help farmers identify opportunities to reduce energy usage by improving energy efficiency and switching to renewables, helping to lower energy related emissions.¹⁸⁰

An emerging example of renewable energy integration is on-farm and on-demand generation of hydrogen using biowaste, which is being developed by Australian start-up HydGene Renewables.¹⁸¹ Agrivoltaics is another area of rapid research and pilot projects.¹⁸² It combines solar panels with farming activities,¹⁸³ where the shaded space under the panels is used to grow crops or have sheep grazing.¹⁸⁴

Opportunity 15: Creating diversified lower emission protein products and markets

Australia is well positioned to take on a leadership role in global protein through the growth and expansion of lower emission protein products and markets. These include sustainable livestock protein, complementary plant-based proteins and emerging novel protein production systems (e.g., edible insects, precision fermentation, and cultivated meats).¹⁸⁵ For example, the livestock industry emission reduction targets (see Table 4) have strong support from the R&D sector around improving feeds, breeding, and feeding practices. Additionally, there is research into the potential for locally grown plant-based protein ingredients, like concentrates and isolates, to be used to create finished food products with low emission profiles.¹⁸⁶

Insects have high levels of protein, high feed conversion efficiency, low emissions profile and low environmental footprint and require small amounts of land, water and energy.¹⁸⁷ Although there are challenges with systems scale up, regulatory pathways, and consumer acceptance, insects offer significant economic opportunities for Australia. Precision fermentation uses bacteria and yeast to produce specific functional ingredients and could supply large quantities of protein.¹⁸⁸ The emissions profile and environmental proposition of precision fermentation is still developing, however a lifecycle assessment of US company Perfect Day's precision fermented whey proteins found that its product has 91% to 97% lower greenhouse gas emissions compared to a conventional equivalent product.¹⁸⁹ Cultivated meat uses tissue engineering concepts to grow animal cell-based proteins in controlled environments. Although many technical and commercial challenges still exist, it is a longer-term opportunity with the potential for lower emission protein products.¹⁹⁰

Opportunity 16: Reduce emissions from food loss and waste

Given food waste accounts for approximately 3% of Australia's annual GHG emissions,¹⁹¹ reducing FLW across the value chain could significantly reduce GHG emissions. Approaches to reduce FLW and GHG emissions include upcycling FLW into fertilisers and minimising the volume of FLW in the first instance across the value chain.¹⁹² Another promising approach that can rescue FLW across the value chain is via biogas conversion to recover energy.

Conversion of agricultural waste to biogas alone can reduce manure-management-related GHG emissions by more than 50%,¹⁹³ and increased reliance on biogas can help to reduce Australia's overall emissions output. According to stakeholders consulted, investment in biogas infrastructure, and scaling this to meet demand is necessary to realise this potential. Robust collaboration and transportation networks are also needed to enable by-product sharing and reallocation for value-adding purposes.

R&D priorities

Collaborative research that develops a systems approach to emissions reduction in food systems:

Through consultation across the sector, further research is needed to model and redefine how Australia produces food within its unique growing conditions, with an emphasis on using a systems approach and promoting emissions reduction. In the agriculture and food context, a systems approach involves examining food systems in their totality, taking into account interrelations and interdependencies of various components and stakeholders within.¹⁹⁴ Modelling and mapping out an agriculture wide plan for emissions reduction (rather than industry specific) while considering the reduction potential of other parts of food systems will help ensure that different industries are not working against each other. In particular, research priorities may include developing and performing analysis through integrated assessment and E3 models (Energy-Environment-Economy), and potential pathways for sustainability transitions.

Research to improve the efficacy of carbon markets in reducing emissions:

Further research is required to develop rigorous methods for calculating carbon credits, including the tools and methodologies for measuring carbon sequestration at scale and modelling to better predict outcomes in the absence of incentive-based approaches; both of which can better enable researchers to distinguish between carbon abatement from human activity or natural variability.¹⁹⁵ Other research priorities include identifying opportunities to equitably share the benefits with local communities and investigating initiatives to minimise 'fraudulent' credits.

Develop negative emission technologies for agriculture and food production: Continued R&D is needed to ensure a pipeline of low and negative emissions technologies, techniques and innovations for food systems. These might include food processing technologies that are not reliant on gas, more efficient food manufacturing methods, and low emissions food and ingredient formulations. It could also include low emission fertilisers, crop breeding and pre-breeding with lower emission credentials (e.g., increased carbon deposition in the soil), innovation in composting, methane reducing livestock supplements and precision agriculture tools. For instance, to reduce the CO₂ emissions associated with ammonia production (which is the starting point for mineral nitrogen fertilisers), near-zero-emission ammonia production methods – such as electrolysis, methane pyrolysis and fossil fuel-based carbon capture and storage - could be developed.¹⁹⁶

Tools to improve GHG emissions data collection, measurement and modelling: Continued research will help improve the accuracy of measurement, transparency, connectivity and utilisation of collected data, and scientific consensus on appropriate methodologies. Other technology developments, such as supply chain digital twins, may help to identify data/calculation gaps and assist decisions makers in modelling the results of deliberate actions on GHG emissions. Additionally, differentiated FLW data could be captured as part of emissions reporting to create explicit links between Australia's food waste and climate change targets.

Develop accessible technology platforms to help primary producers reduce emissions: Continued research and investment in accessible farm management technologies that provide primary producers with precise data, such as hyperlocal weather forecasts applications and in-field sensors, will ensure they are well positioned to increase their yield efficiency while lowering emissions intensity and decreasing food waste (see Section 3.2).

Tools and best practices to disseminate the latest data and recommendations to farmers and businesses: Continued research, including social science research into best practice, is necessary to ensure farmers and businesses across the food value chain have access to the latest data and guidance on how to optimise their environmental stewardship and reduced their emissions. This could involve providing tailored guidance to different industry sectors on sustainable farming practices, with a focus on sharing knowledge on emerging technologies that can help reduce an operation's emissions. As with all data and information sharing, appropriate platforms that protect IP and sensitive information are required.

Research and pilot studies to investigate current best practice for sustainability labelling on foods: Research could support best practice food labelling activities to ensure that methodologies used are consistent, credible, and backed by science. Labels that are misleading, confusing or contain unsubstantiated environmental claims about foods should be replaced. Furthermore, consumer behaviour research is required to minimise potentially perverse effects from these labels, such as consumers purchasing for sustainability over nutrition, as well as pricing considerations.

Continued collaborative research into Indigenous land management techniques used by Aboriginal and Torres Strait Islanders: While progress has been made to embed Aboriginal and Torres Strait Islander land management approaches throughout Australia (particularly in northern Australia), continued investment with a broadened scope would help ensure that Indigenous knowledge systems underpin the design of Australia's natural capital systems. Combining western science with Indigenous land management techniques may lead to more robust sustainable solutions for long-term resilience (see also Section 4.4), and caring for Country.

Additional R&D priorities relating to reducing greenhouse gas emissions are discussed in other sections of this report. For new production platforms with lowered GHG emissions please refer to Section 3.5 and Section 3.4. For innovations to extend the shelf-life of perishable foods, please refer to Section 3.2.



3.4 Aligning resilience with socioeconomic and environmental sustainability

2030 Target

The resilience of Australia's food systems is strengthened through improved capacity to deal with diverse and evolving risks and stressors. Information is more freely shared between participants, and procedures for predicting and responding to threats (e.g., biosecurity, natural disasters, climate change, market and cybersecurity) are tested and become increasingly robust. Sustainable land management practices to improve and value biodiversity and ecological environments are widely adopted. Supply chains offer greater diversity, supported by improved domestic manufacturing capability.

2050 Goal

Australia's food systems are safe, resilient to system-wide disturbances, and are contributing to environmental, economic and social sustainability outcomes. They have the absorptive capacity to respond to volatilities without severe setbacks.

The current state of play...

Biodiversity Habitat Index (higher = better)



73.4 score (out of 100)
17th out of 180 countries
10-year change: **0.5 points** ↑

Biosecurity score (2021) (higher = better)



62.7 score (out of 100)
9th out of 195 countries
Global average: **18.7**

Measure focused on dangerous pathogens, toxins, and biological materials.

2018 Climate Risk Index (lower = more at risk)



49.5 CRI score (out of 100)
43rd most at risk out of 181 countries

Measures fatalities and economic losses from extreme weather events (e.g., storms, floods, heatwaves).

Average proportion of natural vegetation embedded in agricultural lands (2015)



12% for Australia
OECD average: **17%**

Agricultural water use as percentage of renewable water resources (2019)



1.8% for Australia
1.5% in 2009

Fertiliser consumption (2019)



84 kg per hectare of arable land
OECD average: **142 kg per hectare**
↑ from **77 kg per hectare in 2010**

Soil health



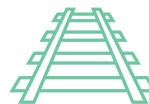
Assessed as “Poor” due to being deeply weathered, old and infertile with ongoing erosion issues

Native vegetation extent and condition



Assessed as “Poor” due to ongoing clearing and intensification of land in remnant areas

Supply chain resilience (higher = better)



75.3 supply chain infrastructure index score of (out of 100)
High-income country average: 73.1

Total ecological footprint per person (2018)



7.1 global hectares per capita
13th highest footprint out of 185 countries



Agricultural land change during the last ten years
5% decrease in land use from 2010 to 2020



Water footprint of the average Australian diet
362 litres per person per day

Measured by water used to produce food, weighted by the scarcity of water at source it was drawn from.



Pesticide consumption (2020)
63,416 tonnes in total
↑ **50% from 2010**

Efforts to build system-wide resilience are underway

A non-exhaustive list of activities is captured in Table 5, grouped by theme. While this selection focuses primarily on government funded initiatives, industry players are also supporting efforts through private investment, research and trialling, and participation in the below activities.

Table 5: Summary of resilience-building efforts to date

THEME	LEAD - DESCRIPTION
Landcare and restoration	<p>DAFF has established a \$214.9 million soil package to assist implementation of Australia’s National Soil Strategy.¹⁹⁷</p> <p>DCCEEW is currently consulting on legislation to develop a nature repair market that would incentivise investment in nature restoration by creating tradable certificates for projects that protect and restore biodiversity.¹⁹⁸</p> <p>The department also leads the Agriculture Biodiversity Stewardship Package, with key partners: Australian National University, NFF and 6 Natural Resource Management organisations.¹⁹⁹</p> <p>DAFF & DCCEEW jointly administer the National Landcare Program, Australia’s key commitment towards natural resource management. Phase 1 (2014-18) saw \$1 billion invested in regional communities, biosecurity and sustainable agricultural outcomes. Stage 2 (2018-23) will see \$1 billion invested towards projects addressing vegetation loss, soil degradation, weed and animal pests, changing water quality and flow, and changing fire regimes.²⁰⁰</p>
Climate adaptation	<p>DAFF has established a \$5 billion Future Drought Fund for drought resilience initiatives,²⁰¹ and a National Drought Agreement that sets out a joint approach to drought preparedness, responses and recovery.²⁰²</p>
Supply chains and traceability	<p>DAFF has spearheaded several initiatives as part of a \$68.4 million investment in agricultural traceability, encompassing a traceability hub for collaborative research developments, the formation of a national traceability alliance, and a National Agricultural Traceability Strategy, set to be released mid-2023.²⁰³</p> <p>The Department of Home Affairs has established a National Resilience Taskforce to explore reforms that can enhance Australia’s resilience while examining exposure and vulnerability to nationally significant crises.²⁰⁴</p> <p>The Office of Supply Chain Resilience monitors critical supply chain vulnerabilities and is leading the Australia-UK Joint Supply Chain Resilience Initiative which aims to (1) share best practice approaches in identifying supply chain vulnerabilities; (2) promote solutions; and (3) support collaborative efforts to ensure robust, sustainable global supply chains.²⁰⁵</p>
Research efforts	<p>Future of Food Systems CRC is a partnership between leading Australian universities, industry, and government bodies, delivering research across the areas of regional food-industry clusters and value creation; new tools, technologies and systems for food production; and food product innovation.²⁰⁶</p> <p>Food Agility CRC launched the \$10 million Mission for Life initiative to bolster supply chain resilience through data-driven tools and digitalisation,²⁰⁷ including mapping strategic digital R&D opportunities.²⁰⁸</p> <p>Rural Research and Development Corporations continue to drive innovations in agriculture, climate resilience, and biosecurity futureproofing, supported by stakeholder investment.²⁰⁹</p>
Area strategies	<p>Foodprint Melbourne (University of Melbourne) is a research project investigating opportunities to strengthen Victoria’s food systems through a series of reports.²¹⁰</p> <p>There are also a number of State and Territory resilience strategies. See Queensland,²¹¹ Victoria,²¹² New South Wales,²¹³ Northern Territory,²¹⁴ Western Australia,²¹⁵ South Australia,²¹⁶ and Tasmania.²¹⁷</p>

Further action and coordination is needed to strengthen the resilience of Australia’s food systems and align this resilience with socioeconomic and environmental sustainability considerations.

Box 10. Resilience in food systems²¹⁸

A resilient food system has the dynamic capacity to **absorb, adapt, and transform** in response to a disruption; towards the goal of **reliably** providing nutritious, safe, accessible and sustainable food despite disturbances.

Preserving the long-term functioning of the system further requires that resilience be aligned with sustainability thinking, across social, economic and environmental dimensions.

Opportunities across food systems

Opportunity 17: Improve environmental health, biodiversity and sustainability outcomes of agricultural practices

There is a suite of sustainable agricultural practices that can help to address the interlinked challenges of food security, accelerating climate change and environmental health, and sustainably managing Australia's renewable marine and terrestrial natural resources. These practices may be *adaptive* (e.g., precision agriculture), *protective* (e.g., controlled cropping) and/or *ecologically beneficial* (e.g., agroecology, regenerative farming and Indigenous land management). Benefits may include improved biodiversity; reduced pests and disease incidence; reduced dependency on agrochemicals; reduced GHG emissions;²¹⁹ improved crop performance; enhanced soil and crop quality, and improved human health and nutrition.²²⁰ They also offer avenues to conserve finite resources, notably water, improved irrigation efficiencies, optimised drainage and improved soil water retention. In particular, Indigenous knowledge of Australia's unique ecosystems is well-regarded in sustainability and land-care discourse. Integrating cultural wisdom and insight into infrastructure planning and resource management through co-designed and Indigenous-led processes could support these objectives.

According to the Food and Land Use Coalition,²²¹ the transformation of the global food system has the potential to deliver an additional \$5.7 trillion (USD) in annual societal benefit by 2030, compared to a scenario that models current trends. In Australia, FIAL has estimated the economic gains realisable from transitioning towards sustainable agricultural practices by 2030, including through soil, water and land management (\$17 billion), protected cropping (\$2 billion), technology in smallholder farms (\$1 billion), and the development and application of sustainable inputs for primary production (\$1 billion).²²² Sustainable fisheries are estimated to have an additional \$3 billion in value-add potential.

In a local context, the adoption of sustainable agricultural practices is highly influenced by government activities; further embedding these practices into broader agricultural policies and actions that support decarbonisation and environmental objectives may support their uptake.²²³

Box 11. Examples of approaches and their definitions contributing to sustainable agricultural practices

Climate-smart agriculture: An integrated approach to managing landscapes that aim to simultaneously achieve outcomes of increased productivity, enhanced resilience, and reduced emissions.²²⁴

Agroecology: An integrated approach that applies ecological and social concepts to the design and management of sustainable agriculture and food systems.²²⁵

Regenerative farming: A holistic conservation and rehabilitation approach to food production, guided by principles that aim to rejuvenate soil health, improve water cycles, restore landscape function, maintain biological balances, and minimise the use of materials and practices that disturb desired biological relationships.²²⁶

Controlled environment agriculture: A technology-based approach toward food production through which resources (e.g., water, energy, space, capital and labour) are optimised. Indoor production systems are utilised for their ability to protect crops from external conditions.²²⁷

Opportunity 18: Diversify food supply chains to improve system flexibility

Diversifying Australia's food supply chains can build their absorptive and adaptive capacity and ensure that they are flexible and able to withstand and respond to external and internal shocks. This diversification could take several forms.

Differing in their roles and serviceability, supply chains of varying lengths can act as buffers against different shocks and stresses. Bolstering and ensuring access to both local supply chains and larger regional- or national-scale systems is required. With fewer intermediaries and shorter distribution timeframes, a decentralised system comprised of local supply chains and actors can build a broader level of environmental and economic resilience into the system as a default position.²²⁸ Meanwhile, larger systems and those comprised of larger corporations can serve wider geographical areas and more efficiently respond to local disruptions.²²⁹ Larger corporations also benefit from greater access to resources and financial strengths allowing them to buffer against shocks for longer periods.

Diversity may also be expanded through food chain participants, drawing on large and small-scale operations of food production, processing and manufacturing (both commercial and community-based, including SMEs and Aboriginal and Torres Strait Islander enterprises).²³⁰ In doing so, there is an opportunity to further develop an enabling environment that allows small-scale businesses to overcome scale-related constraints and diversify into new markets. In a global context, scoping new product markets that align with growth in Australia's domestic manufacturing capabilities could allow Australia to expand market access.²³¹

Opportunity 19: Strengthen Australia's sovereign manufacturing capabilities and workforce

This opportunity entails the ability to locally generate necessary inputs for food production and manufacturing, such as agricultural chemicals and renewable energy, and also includes expanding food production capabilities in Australia. Shoring up domestic manufacturing capabilities can reduce Australia's reliance on international food imports and imports of critical inputs for food production and manufacturing (e.g., fuel, energy, agrochemicals, equipment). This could also ensure that Australian producers and manufacturers can continue accessing critical inputs at reasonable prices while capturing more of the value of the products they export.²³² Where onshore manufacturing is not feasible or practical, Australia can achieve greater resilience by exploring potential risks and bottlenecks in supply chains.

Strengthening Australia's domestic capabilities can attract and retain skilled workers to the sector to keep pace with the growing adoption of sophisticated technologies (such as automation, robotics and AgTech) and the future strategic direction of the sector (including advanced manufacturing and food sciences).²³³ Strong domestic advantages, such as access to high-quality local inputs and expertise, positions Australia well to create a modern manufacturing sector that allows Australia's primary producers to realise greater value for their outputs while building industrial capability and capacity.²³⁴ Digital training tools and credential systems can support the building and retention of workers within local talent pools and support seasonal onboarding during peak seasons.²³⁵ Multiple stakeholders discussed how additional job security, technical training, and career development offerings might address the sector's workforce retention and sustainability challenges.

The Australian Government and some states have developed strategies to support the growth and modernisation of Australia's manufacturing capabilities.²³⁶

However, stakeholders noted that there should be greater alignment between these strategies and initiatives. Stakeholders also noted that ageing and outdated infrastructure is currently limiting operational productivity and needs to be upgraded and replaced to enable manufacturing at scale.²³⁷ Policy levers and technology solutions may also be considered to improve the economic viability of manufacturing for onshore industry leaders.²³⁸

Opportunity 20: Bolster transparency and trust of food supply chains

Traceability and digital systems can be bolstered to enable Australia to better predict, identify and respond to vulnerabilities, manage risks, and optimise processes. For example, data collection tools can provide real-time measurements for process optimisation and can also mitigate and minimise impacts of food safety crises and biosecurity incursions through greater supply chain traceability and digital auditing. Notable benefits include preventing incidents in the first instance, improving response rates, limiting financial and reputational impact, and minimising disease transmission. Provenance and verification of product attributes (e.g., origin, sustainability and ethical credentials) can also improve brand reputation and sustainable sourcing of products.

CSIRO's Trusted Agrifood Export Mission is currently developing verification and provenance technologies to enable expanded market access and increased economic returns for Australian producers.²³⁹ The Australian Government has also recently established the Australian Agricultural Traceability Alliance and is developing a National Agricultural Strategy and 5-year implementation plan.²⁴⁰

Opportunity 21: Promote integrated regional planning for industry development

Integrated planning for regional food industries can support the growth and improved productivity of the food sector (see Section 3.5); build broader regional resilience and adaptive capacity; and create new secure employment opportunities that can draw and retain workers in these areas.²⁴¹

Agrifood clusters or hubs – comprised of geographically concentrated and interconnected food and agriculture businesses – are one way to accelerate regional industry development by providing a collaborative environment that fosters trust and knowledge-sharing and limits liabilities associated with calculated risks.²⁴²

While sector-specific challenges exist, many challenges are experienced across sectors (e.g., climate variability, labour/skills shortages, changing consumer preferences, and global competition). These clusters allow for regional challenges to be jointly understood and solutions do-developed for existing geographical and regional strengths to be leveraged and built upon.

Stakeholders noted that infrastructure investments in adjacent sectors can also support regional development efforts, citing the connection between the performance of agricultural-related industries and regional economies. Potential synergies and co-benefits may include establishing education infrastructure that could increase the capability, capacity and socioeconomic wellbeing of regional communities, and strategic investment in infrastructure assets and social services to assist priority residents (e.g., labourers, and vulnerable and ageing populations).

Box 12. Driving innovation and development through Agrifood clusters

Agrifood clusters are well established in international contexts. The Netherlands, for example, has an international reputation for successfully implementing large-scale agrifood clusters such as Agriport A7²⁴³ and FoodValley.²⁴⁴ The latter of which seeks to enable innovation and accelerate a transition towards sustainable food systems, operating across three domains of circular agriculture, the protein shift, and nutrition and health.

Within Australia, agrifood clusters are also gaining traction, driving collaboration between businesses in common geographic areas and often with a unified focus on a food type or sector. FIAL's Cluster Grant Program has assisted in the establishment of eight regional agrifood clusters since 2018, including the Central Coast Food Alliance, Fermentasmania, Food and Agribusiness Network (Sunshine Coast), and Food and Fibre Gippsland.²⁴⁵ Planning is underway for further developments, including the Western Sydney Airport Agriculture and Agribusiness Precinct,²⁴⁶ the Parkes Special Activation Precinct,²⁴⁷ and the Transform Peel project.²⁴⁸

Opportunity 22: Advance industry-wide adoption of risk management and sustainability strategies

Ensuring comprehensive risk management strategies are in place can enable businesses to better anticipate, withstand and respond to disturbances. It also helps businesses meet environmental, social and governance (ESG) and corporate objectives even in the face of an increasingly volatile business landscape. Several risk management strategies have been identified to bolster business resilience, including increasing flexibility of operations during sourcing, production and distribution stages (e.g., diversified cropping); building in operation-specific redundancies (e.g., alternative transportation routes, backup infrastructure, spare inventory); implementing early warning detection systems (e.g., intelligence generation through big data/IoT, staff training and procedures); and developing a risk aware workplace culture (e.g., security procedures).²⁴⁹ Sustainability strategies could be incorporated in-line with existing frameworks (See Box 13).

Businesses may also benefit from income diversification through alternative revenue streams. These pathways include renewable energy generation, biofuel production, agritourism ventures,²⁵⁰ development of new product ranges, and participation in emerging market mechanisms (e.g., carbon and biodiversity markets). The selection and implementation of a particular path requires careful consideration to ensure it is feasible and tailored to individual enterprises.ⁱ

Box 13. Australian Agricultural Sustainability Framework (AASF)²⁵¹

The AASF has been designed as a central source of information on Australian agricultural sustainability. At a high level, the AASF has outlined three themes: environmental stewardship; people, animals and community; and economic resilience. Under these themes are nested 13 non-hierarchical categories, 17 principles and 43 criteria describing the agricultural industry's sustainability status and goals.

The AASF seeks to create alignment across existing and emerging national-level programs and reduce the duplication of industry specific schemes, providing a translation layer between farm practices, markets, and the community. Development has been coordinated by the NFF with support from the Australian Farm Institute, as part of the Australian Government's Agricultural Stewardship Package.

ⁱ Selection may depend on several factors including land availability and topography, infrastructure requirements (e.g., grid connection), labour intensity, permit and legal requirements, and the time and effort preferences of the land holder.

R&D priorities

Research into resilient and climate-tolerant cultivars:

Continued R&D is required to improve the resilience and climate-tolerance of crop varieties.

According to stakeholders, continued research is needed into examples of crop varieties (both from Western agriculture and native Aboriginal and Torres Strait Islander agriculture) that boast a natural resistance to drought, heat, pests and diseases and adaptability to Australia's unique climate and soil conditions. The research involves identifying and selecting these species, better understanding management and growth practices, and assessing their ability to integrate into Australian farming practices to meet Australia's energy and nutrition needs.

Other research priorities include extending conventional breeding techniques and gene-editing technologies (e.g., CRISPR/Cas 9, TALEN), reducing development timeframes and developing new traits and trait stacks. Related research priorities include further developing biological agricultural treatments (e.g., microbial N-fixing biofertilisers, RNAi pesticides) and remediation solutions that offer alternatives to conventional agrochemicals and that pose fewer environmental and human safety risks.

Selective breeding for climate-tolerant livestock:

Continued R&D is required to determine breeding and genetics-based approaches to improve climate resilience among livestock. Heat tolerance is of particular importance in the Australian context with the negative impacts of heat stress on livestock being well-documented, including impacts on productivity, fertility, and disease.²⁵² Research is required to identify DNA markers that can allow for robust and heat-resilient animals, and move beyond identification through selective genomic breeding. Recent research has focused on heat tolerance in dairy cows. However, new adaptations and production traits and species, such as pigs, could be investigated.²⁵³

Process engineering for greater flexibility within production, manufacturing and transportation operations:

Continued R&D is required to optimise food system processes and improve their flexibility and resilience to shocks. Priority areas include increasing resource efficiency and the flexibility of feedstocks and inputs to ensure operations can continue to operate if access to critical materials is restricted. Further R&D for on-site renewable energy systems is also needed to support longer-term environmental resilience through reduced GHG emissions.

According to stakeholders, the scaling up of food production will also be critical for bolstering food system resilience; namely by allowing less affected production methods to pick up output deficits created by operations more affected in times of crises. Research and piloting are required to determine the scaling capacity of current and emerging production systems, including assessing existing process limitations and improving construction lead times for enabling infrastructure.

Improved and efficient water management and infrastructure:

Amid growing concerns about the increasing frequency and severity of climate change-induced drought and flooding, stakeholders have suggested that further research is required to ensure water management strategies and infrastructure is optimised and efficient. This research priority captures the need for technologies that facilitate the upgrading and scale-up of existing water infrastructure; research on the impacts of land use change on water availability; further research on crop water consumption; and mapping Australia's hydrology networks.

Developing and enhancing digital systems that can collect and aggregate data for multi-use purposes that support resilience outcomes:

There is a growing need to establish expansive databases that collect and aggregate information for multi-purpose uses. These include predictive analysis and system modelling to inform decision making, development of digital twins, and real-time surveillance to detect food safety hazards and biosecurity incursions, among others. Doing so will require the continued development of digital tools to capture data (e.g., Internet of Things (IoT), cloud computing, blockchain, Big Data, AI and ML). Specific research priorities are context-specific and heavily dependent on the application in which the data will be used. For example, further research on food safety and spoilage risks and tools that can rapidly identify and characterise foodborne hazards will be required to optimise responses to food safety hazards and aid in food recalls.

Development and deployment of automation, drones and robotics technologies to address labour shortages:

Continued R&D of sophisticated remote and automated technologies that can support labour-intensive processes is required to enhance operational consistency and efficiency and tackle workforce challenges in the industry. These systems can also remove human involvement in unsafe or repetitive tasks.

Improved pasture management and on-farm resilience can be achieved by developing AgTech technologies such as autonomous tractors, robotic seeders and harvesters, remote monitoring, and automatic irrigation. The processing and manufacturing industries could leverage advancements in ML and AI to automate processes automate inventory management and enhance product flows. Further R&D is required to develop these technologies, translate them into new sectors and facilitate their adoption (e.g., cost reductions and useability).

Research and piloting of new market mechanisms and business financing models to improve business

resilience: Business resilience can be enhanced by researching and testing novel market mechanisms, financing models and business models. This can support the adoption of sustainable agricultural practices by de-risking/catalysing investments, offering alternative revenue streams (e.g., carbon/biodiversity markets), and facilitating risk management (e.g., index-based insurance). For example, the incorporation of natural capital into lending and insurance decisions could improve our understanding of the interconnections between land governance, economic structures and food production, and has been investigated by financial²⁵⁴ and research²⁵⁵ institutions and governments.²⁵⁶ However, further research and piloting are needed to explore the feasibility, efficiency, interconnections and trade-offs of these new mechanisms and models, as well as any potential social, economic and environmental implications.²⁵⁷

Research of agroecological and environmentally sustainable farming practices, including Aboriginal and Torres Strait Islander techniques:

It is well-established that the implementation of sustainable land and water management practices, including those rooted in Indigenous and local knowledge, is an effective means to achieve climate adaptation and build the resilience of agricultural systems; in part by enhancing environmental outcomes such as soil health and biodiversity, and reducing GHG emissions (see Section 3.3).²⁵⁸ However, continued research is required to investigate potential knowledge and technologies that support these outcomes, alongside efforts to determine their effectiveness, trade-offs, benefits, scalability, and the environments and operations that they are suited and amenable to. There is a need for continued research to better understand how to harness this knowledge to detect environmental changes and where these practices themselves are vulnerable due to climate change.

Further research to investigate links between marine and terrestrial food production systems to reduce land-use pressures:

Continued modelling and systems research are required to examine interactions between blue and green food production systems; for example, complementary relationships between land-based aquaculture and the use of wild fisheries or seaweed production for food, feed and fuel. This research can investigate ways to enhance synergies and optimise production while reducing pressures on land and GHG emissions. It can also support future land-use planning and community or industry decision making. Future research priorities may include utilising smart technologies (e.g., AI and ML) to estimate parameters, accelerate calibration and identify new relationships that were not previously recognised. Continual and updated mapping of natural resources across marine²⁵⁹ and terrestrial²⁶⁰ systems will be critical in informing this analysis.

Additional R&D priorities relating to aligning resilience with socioeconomic and environmental sustainability considerations are discussed in other sections of this report.

For developing and scaling new production platforms with reduced environmental impacts please see Section 3.5 and Section 3.3. For innovations to extend the shelf-life of perishable foods, please refer to Section 3.2.



3.5 Increasing value and productivity

2030 Target

Australia realises its target to exceed \$100 billion in farm gate output by 2030.²⁶¹ Additional value is generated from highly differentiated and value-added food products as Australia begins to significantly ramp up domestic processing and manufacturing capabilities, leveraging its national advantages in particular food areas while supporting resilience and sustainability.

2050 Goal

Domestically grown and manufactured food products are healthy, environmentally sustainable, and underpinned by efficient technologies and innovation-driven production changes. They are unique in their differentiation and provenance, enabling Australian farmers and processors to capture greater value in domestic and offshore markets. Australian businesses export high value food products seen as novel or newly established.

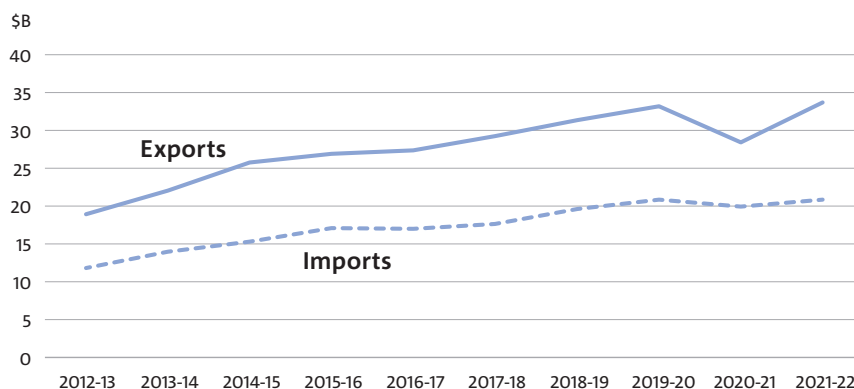
Export and import of food and beverage manufacturing products (2021–22)

\$34 B in exports

↑ from 78% in 2012–13

\$21 B in imports

↑ from 77% in 2012–13

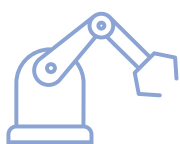


Food exports as a percentage of goods exports (2021–22)



12% food exports

14% in 2012–13



Food and beverage manufacturing value added per worker (2020–21)

\$112,600

Food and beverage manufacturing employment (2021–22)

242,000 employed persons

1.8% of total

28% of manufacturing

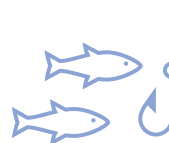


Food and beverage manufacturing's contribution to total manufacturing employment (2020–21)



26% of total manufacturing value added

Australia's largest manufacturing industry by industry value added



Agriculture, forestry, and fishing value added per worker (2020–21)

\$71,600

Agriculture, forestry, and fishing employment (2021–22)

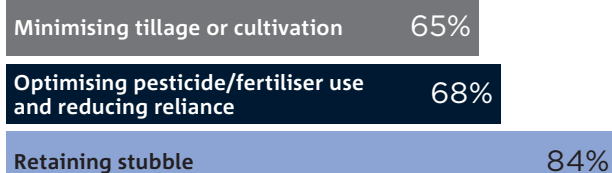
313,000 employed persons

2.3% of total



The current state of play...

Proportion of farms with sustainable land management practices for long-term productivity (2021)



Agriculture infrastructure level (higher = more developed)

53.2 infrastructure index score (out of 100)

High-income country average: 59.3

Data sources listed in Supplementary material

Business R&D expenditure in the food production (2019–20)



\$329 m in agriculture, forestry, and fishing and \$485 m in food and beverage manufacturing

4% of total business R&D

Crop yields



2011		2021	
2,098 kg/ha	Grain	2,548 kg/ha	↑ 21%
22,570 kg/ha	Vegetable	24,290 kg/ha	↑ 8%
12,154 kg/ha	Fruit	14,540 kg/ha	↑ 20%

Efforts to increase value and productivity are underway

A number of ambitious, though achievable, targets have been declared across Australia's food systems, by industry representatives and research leaders alike. These have been captured in Table 6 below.

Stakeholders across the system are actively pursuing these goals. For example, the Australian Government has undertaken efforts to modernise agricultural trade by streamlining export regulation and information access, improving services, and investing in digital upgrades.²⁶² Value-added agriculture, forestry and fisheries outputs are a key investment sector under the Federal Government's National Reconstruction Fund to drive economic growth, and 'food and beverage' is a key investment sector under the Modern Manufacturing Strategy to integrate Australian businesses into new markets.²⁶³ Australia has also seen industry activities

in new high value food manufacturing areas, such as a March 2022 announcement of major investments and partnerships to grow Australia's plant protein ingredient manufacturing capabilities in South Australia.²⁶⁴ Likewise, there has been the promising emergence of innovative domestic start-ups in the precision fermentation space in recent years, such as Nourish Ingredients which seeks to use an advanced food manufacturing platform to derive plant-based fats,²⁶⁵ and Eden Brew, which seeks to create proteins for milk alternatives.²⁶⁶

Further action and coordination is needed to support Australian producers and exporters to improve the differentiation and value of their offerings, and ensure they are well positioned to continue providing healthy and sustainable food to Australian and export markets.

Table 6: Output and export value targets

INDUSTRY	AMBITIONS BY 2030	SOURCE
Agriculture	Australia's agricultural sector exceeds \$100 billion in farm gate output.	2030 Roadmap: Australian Agriculture's Plan for a \$100 Billion Industry (National Farmers Federation, 2019)
Dairy	The Australian dairy industry's share of the global dairy trade increases to 10% by volume.	Australian Dairy Sustainability Report 2020 (Dairy Australia Ltd, 2021)
Protein	CSIRO's Future Protein Mission has the goal of creating new Australian protein products and ingredients that earn an additional \$10 billion in revenue.	Future Protein Mission (CSIRO)
Red Meat	The sale of red meat doubles as it is recognised as a trusted, high-quality protein source.	Red Meat 2030: A shared vision and direction for Australia's red meat and livestock business (Red Meat Advisory Council, 2019)
Seafood	The export value of seafood products increases by 2.5%.	National Fisheries Plan 2022-2030 (DAFF, 2022)
Cross-sector	CSIRO's Trusted Agrifood Export Mission has set the goal of boosting Australian agrifood exports by \$10 billion through integrated data solutions across the value chain. FIAL has outlined the potential to generate over \$200 billion in value-add in the agriculture, fishing and food-related manufacturing value chain.	Trusted Agrifood Exports Mission (CSIRO) Capturing the Prize: The A\$200 billion opportunity for the Australian food and agribusiness sector (FIAL, 2020)

Opportunities across food systems

Opportunity 23: Diversify exports for long-term economic prosperity

Export diversification serves to reduce economic risks and volatilities, such as geopolitical tensions, as well as external shocks from a single consumer market; allowing an economy to build more sustainable, longer-term prosperity via expanded trade relationships.²⁶⁷ The Export Council of Australia, described the current state of Australia's exports as "too small and too concentrated",²⁶⁸ echoing the sentiments of other government and industry stakeholders during consultation.

Diversification also necessitates novel products and production processes. A range of technologies, R&D and emerging consumer preferences can offer a source of diversification for Australian exporters and contribute to overall export growth. Examples include the development of new aquaculture products (e.g. Australian-grown white flesh fish) for Asian markets, red meat co-products for overseas health and wellness markets and beef, veal and sheepmeat products with verifiable premium qualities.²⁶⁹ There are additional market avenues from capitalising on the pre-breeding and crop breeding of high protein crops such as faba beans, field peas, and lupins,²⁷⁰ as well as a host of horticultural crops (e.g., fruits, vegetables, mushrooms) that could be cultivated to create products with desirable nutritional, textural, and taste-related traits for global consumers.²⁷¹ Likewise, global demand in high growth markets such as fortified and functional foods can spur Australian diversification in value-added food ingredient exports.²⁷²

Stakeholders have highlighted several enablers of this diversification. These include export market sizing and growth data to inform business strategy, more processing and manufacturing infrastructure within Australia, and digitalisation across the sector. Likewise, streamlining the regulatory and compliance landscape domestically, along with overseas regulatory and compliance requirements may support exporters to access foreign markets. As mentioned above, CSIRO's Trusted Agrifood Export Mission is focusing on some of these solutions,²⁷³ as is the Australian Government's draft National Agricultural Traceability Strategy.²⁷⁴

Opportunity 24: Create additional value-add opportunities for Australia in global value chains

Australian exporters can increase their share in global markets and improve productivity growth by closely integrating high value, often niche, food items into complex global supply chains.²⁷⁵ Global collaboration and partnering can help Australian food exporters grow their international exposure. For instance, it may be more efficient to transport Australian plant protein ingredients as a dry powder for rehydration and assembly into finished goods at an export destination than as a finished product or hydrated ingredient.²⁷⁶ Domestic plant protein producers could partner with overseas protein companies as trusted suppliers of high-quality inputs in these supply chains. This would save on transportation costs (and associated emissions). However, it would require Australian food manufacturers to develop and master spray drying and powder processing technology, among other manufacturing infrastructure. According to stakeholders consulted, innovation precincts and clusters are also important (see Box 12), allowing food manufacturing companies to better explore developing new, innovative, highly technical products (e.g., specialised ingredients such as biomanufactured animal-free proteins and fats), and vegetable-based extruded snack products.

Further, technology solutions can enable global value chain integration with, for example, ML, AI, and automation improving productivity and reducing costs for manufacturers by optimising domestic operations, streamlining logistics, and improving scale, agility, and efficiency.²⁷⁷ Technologies such as data analytics, E-commerce infrastructure, and transportation and logistics computer-modelling systems can also facilitate greater linkage between Australian businesses and global value chains.

Opportunity 25: Regional leadership through the sharing of technology solutions and expertise

As Australian food systems continue to respond to challenges and opportunities, system stakeholders can share their expertise and technologies with other nations to help make their own food systems healthier, more secure and more sustainable. Australia has long played a role in building capacity in the Asia Pacific region, providing social, economic and security support.²⁷⁸ Stakeholders consulted believed that Australia is well-positioned to step up its regional leadership and help to reshape the trajectory of food systems internationally.

This regional leadership could encompass licensing or selling IP and innovations, particularly to countries with comparable climatic and environmental conditions. For example, CSIRO holds over 200 pieces of agri-food technology IP ready for licensing arrangements, including enhancements to improve food product functionality, sensory perception, health attributes, and sustainability attributes.²⁷⁹ Leadership could also include export of knowledge through consultancy activities, such as the utilisation of new and globally differentiated food sources, sustainable land management, workforce upskilling, and overseas product development. Finally, Australia's food systems leadership could also be reflected through participation in international dialogues and summits by industry, research and government, as well as joint pilot schemes. Critical to the success of this leadership position is the coordination and streamlining of representative organisations, engagement with players across the value chain, and fostering greater connection and alignment between the objectives of industry and government.

Opportunity 26: Promote healthy landscapes to protect current and future productive capacity

Government is well positioned to work with business to promote environmental stewardship and support sustainable agricultural approaches that protect the long-term productive capacity of food systems (See Opportunity 19). This involves developing national- and state-level strategies and mechanisms that enable bottom-up implementation, alongside new incentivisation approaches. Financial mechanisms, such as those that link natural capital to on-farm accounting or employ environmental profit and loss accounting, are possible avenues for accurately measuring and valuing natural capital.²⁸⁰ There is also room to overcome critical barriers that are limiting the adoption of these practices, including improving land tenure security, access to resources and advisory services, access to funding and incentives, and training to increase knowledge and practical experience.²⁸¹

Promotion of environmental stewardship and support of sustainable agricultural approaches may also leverage place-based community and cultural knowledges that, in turn, provide greater community and environmental benefit.²⁸² Aboriginal and Torres Strait Islander land managers can be empowered through leadership positions in land management and decision making roles, enabling the continuation of cultural practices that improve ecological and cultural heritage outcomes, and further enabling the coalescence of western and Indigenous science.²⁸³ Cross-cultural knowledge sharing through

partnerships between senior knowledge custodians and western scientists can contribute to overcoming the combined challenges of climate change, land degradation, and food security through enhanced productive capacity.²⁸⁴ In Australia, Indigenous knowledge continues to be integrated into biodiversity and land management programs, and Indigenous land and sea management (ILSM) is the fastest-growing sector for Indigenous employment.²⁸⁵

Box 14. The essential contribution of trees and forests to healthy landscapes

More than half of all human-consumed fruits and all nuts grow on trees, a large proportion of food crops are pollinated by insects and animals that depend on forests for nesting and foraging, and trees are critical to protect soil quality, regulate pests and increase water availability.

According to CGIAR (formerly the Consultative Group for International Agricultural Research), these benefits can be enhanced to promote healthy landscapes and protect productive capacity. In particular, they recommend repurposing producer and consumer incentives towards nutrient-dense foods, more sustainable production practices and explicitly integrating food and nutrition objectives into forest restoration and conservation practice and policy.²⁸⁶

Opportunity 27: Expand Australia's self-determined Aboriginal and Torres Strait Islander food industry

Box 15. The right to self determination

According to the Australian Human Rights Commission, the right to self-determination concerns the right of all people to (1) have choice in determining how lives are governed, (2) participate in decisions that affect their lives, and (3) have control over their lives and future, including economic, social, and cultural development.²⁸⁷

It has a particular application to Aboriginal and Torres Strait Islander peoples as Australia's first peoples, where it is recognised as an 'ongoing process of choice' to ensure communities can meet their social, cultural and economic needs.

The development of Australia's Aboriginal and Torres Strait Islander food industry can diversify food systems, increase economic prosperity for Indigenous communities, and preserve and recognise culture. Many native foods have noted health benefits, including their richness in select minerals, vitamins, and potent antioxidant capacity, which could present a comparative advantage in domestic and overseas markets.²⁸⁸ Although further exploration of enabling actions is required, stakeholders have suggested that developing the industry requires identification and removal of current barriers to entry; solutions that are co-designed and led by Aboriginal and Torres Strait Islander peoples; and checks to ensure benefits are returned to Indigenous participants.

Hurdles identified from consultation include supermarket contractual hurdles (e.g., certification processes, trademark considerations), access to finance where shared tenure arrangements are in place, and resource-intensive food safety testing requirements. There is also room for communication activities that could help instil the value of cultural meanings behind native foods by, for example, implementing social and cultural food metrics for the industry, co-designed by Indigenous communities themselves. Qualitative and quantitative metrics could support the financial sustainability of Indigenous-led ventures, guide culturally respectful relationships and monitor the protection of Aboriginal and Torres Strait Islander knowledge, norms, stories, foods and practices. Traceability technologies could support sustainability, health and other claims around these products. Notably, the ARC Training Centre for Uniquely Australian Foods was established in response to consumer interest in the provenance and characteristics of native foods,²⁸⁹ working to identify domestic and export market opportunities and build ethical social and business models.²⁹⁰

Beyond retail, agritourism presents a related and promising avenue to boost revenue, with 61% of tourism experiences associated with remote Aboriginal and Torres Strait Islander enterprises being food-related, and 77% cultural tours.²⁹¹ Agritourism ventures could create employment pathways, provide financial benefits and reorientate tourism and food industry practices to support the native food regions.

Protecting Indigenous Cultural and Intellectual Property (ICIP) and confidential information regarding foods, customs, knowledge, and stories is critical to this opportunity. Protection measures have been

successfully implemented in certain areas²⁹² – but could be expanded into food as well. Limitations on traditional hunting and gathering of food (e.g., conservation protection laws, land access and management policies, specie catch limits, weapon restrictions) can also impact Aboriginal and Torres Strait Islanders' ability to maintain cultural hunting traditions, pass down knowledge and prevent the production and selling of food in a culturally appropriate way.

R&D priorities

Digital technologies to verify food credentials and enable traceability across domestic and international supply chains:

Digital traceability can reduce food fraud, verify certification and product attributes, maintain Australia's strong reputation in competitive export markets and enable compliance with international partner trading standards and regulations. Furthermore, there is growing consumer interest and awareness of provenance and traceability for characteristics such as nutritional value, sustainability and environmental credentials. Digital traceability tools, such as cloud-based supply chain tracking and RFID-based inventory management, could also help to reduce regulatory costs to producers and de-risk export activities.²⁹³ Critical aspects to improving traceability include ensuring that the design of any new system incorporates all stakeholders across a particular supply chain and that the system provides timely interoperable and user-friendly access to encourage broad-based adoption. Priority areas are identified in the draft National Agricultural Traceability Strategy,²⁹⁴ however they focus on policy and infrastructure actions, and stakeholders noted that R&D priority areas also need to be identified.

Digital and automated export compliance procedures:

The food supply chain involves multiple industries, government agencies, and countries, with numerous layers of regulations and protocols to ensure the quality and safety of food products. However, the current paper-based system of handling registrations, approvals, and sign-offs is costly, complex and not easily scalable.²⁹⁵ As such, there are significant financial gains in digitising and improving efficiency in export compliance by using computerised, automated technologies to streamline compliance and coordination across the supply chain. R&D can focus on developing systems that map the compliance network, identify the most impactful areas for compliance cost reduction, and implement suitable technologies.

New product development of functional foods, alternative healthy foods, and value-added products:

Research is needed to develop novel products that contain added nutrients and healthy ingredients, meat, dairy and milk alternative and premium value-added food products (e.g., ready-to-eat meals, soups and sauces, snacks and spreads), especially for the health and wellness market.²⁹⁶ These products with enhanced nutritional functionality will also promote access to healthy and sustainable diets. Research is also needed to deliver these products with better food quality and safety, superior taste and freshness, and a more substantial evidence base and metrics to demonstrate health and sustainability attributes. Product development activities also need to be supported by improved risk assessment and regulatory procedures for new product approvals, ensuring that uncommon foods with an established history of safety can be commercialised faster and with little regulatory burden.

Develop and scale new production platforms: Novel production platforms, such as precision fermentation, biomanufacturing, and cell-based agriculture, require feasibility demonstration, scale-up, and market development. For precision fermentation, specific R&D areas include research to support microorganism engineering and strain development and optimisation, along with feedstock selection and process improvement.²⁹⁷ For biomanufacturing in general, R&D should focus on developing pilot and demonstration-scale facilities certified to work with GMOs, collaboration with adjacent sectors and sharing infrastructure for efficiency gains, and national facilities to build scale and capability.²⁹⁸ For cell-based agriculture, R&D includes optimising cell culture media and identifying appropriate and sustainable cell sources.²⁹⁹ Research is also needed into understanding the nutritional profile and food safety of novel products. See Section 3.3 and 3.4.

Research into best practice tools and frameworks to inform business decisions: Businesses often face various technology options, each with a different balance of economic, environmental, and societal outcomes. Research is needed to explore tools and frameworks that can inform business decision-making by clearly outlining the trade-offs of technology adoption choices. For instance, potential best practice approaches such as techno-economic modelling and comprehensive evaluation metrics that consider both financial and non-financial goals can help businesses choose process pathways.

Tools and data to improve resource management:

Australian researchers are developing a suite of tools and data sources to improve the management of natural resources for sustainable, long-term productivity. This includes water resource assessments,³⁰⁰ soil testing and mapping,³⁰¹ forestry monitoring and carbon accounting,³⁰² along with the integration of Indigenous land and water management techniques.³⁰³ Technologies that map out and enable the valorisation of waste/lower value streams are also an important component of resource management, particularly in a circular economy context (see Section 3.2 for further discussion). These tools are particularly effective at improving resource management when they are integrated into strategic frameworks co-designed by affected stakeholders. These strategic frameworks can provide the “big picture” view of Australia’s various regions in terms of their natural resources and the tangible actions that are needed to reduce risks, manage resource scarcity, and ensure they maintain their current and future productive capacity.

Co-production of robust social and cultural Aboriginal and Torres Strait Islander food metrics: Opportunities for Aboriginal and Torres Strait Islander peoples may be strengthened by the development of social and cultural metrics to monitor and guide the direction of growth of self-determined Indigenous food ventures. According to stakeholders consulted, social metrics that encompass engagement metrics such as financial performance (e.g., economic sustainability and Aboriginal and Torres Strait Islander employment), equity metrics (e.g., availability and affordability), as well as qualitative and quantitative metrics could more accurately capture the value of these businesses and support the building of a respectful relationship between these food ventures and their external supporters. They may also contribute to efforts to empower and enable the participation of Aboriginal and Torres Strait Islander communities in food ventures, natural resource and land management, and traditional foodways. Cultural metrics could monitor safeguarding traditional knowledge and ICIP, cultural norms, stories, foods and practices supporting communities.

4 Concluding remarks

This report first outlined the global and national challenges confronting Australia's food systems. Meeting these challenges will require transitioning towards productive and resilient food systems, which deliver food and nutritional security for Australia's population, and are economically viable, socially just and environmentally sustainable.

By acting now, Australia has an opportunity to determine the trajectory of its food systems and provide leadership in the region.

Given the system-wide nature of challenges, bridging the gap between the current form of Australia's food systems and vision for a future state necessitates new change processes that diverge from existing practices and ways of thinking.

This report described a series of opportunities for catalysing change, organised under five focal areas. These are further complemented by specific action areas emerging from the consultative process and documented in the supplementary materials. Seizing these opportunities effectively will require deep engagement with different stakeholder groups and industries and strengthening capacities for cross-disciplinary cooperation. In this context, science can inform solutions through knowledge sharing efforts, combining systems thinking and analysis with deep disciplinary knowledge. This integrated approach will be important for identifying and managing possible trade-offs in pursuing multiple economic, social and environmental objectives. It involves harnessing diverse knowledge and research capabilities to enable innovations in technology, practice, and processes, including governance and finance. Research is also needed to better understand the value systems that underpin decisions and are reflected in policy, regulation, organisation practice, mindsets, and consumer behaviours.

Ways to enable food system transformations are still emerging and will continue to evolve over time. However, a set of guiding principles are becoming apparent that can underpin these processes and help shape transition pathways. These relate to the need for governance systems to couple with science and technological innovation at

varying scales; coordinated and co-designed actions across different policy and practice domains; transparency around the values and objectives that are shaping targeted policy interventions; coordinated processes driven from the top-down and bottom-up; and research to catalyse, inform and assess collaborative action. For navigating and keeping pace with unfolding change processes, convening spaces that allow for exchange of perspectives on enabling actions and sharing lessons learned will be critical.

Preparing food systems for the future means strengthening the interfaces and feedback loops between science, policy and practice. As a complex system operating across multiple scales in a dynamic and uncertain world, progress across the various food systems domains will need to be monitored and iterative adjustments applied, where necessary. This requires understanding which suites of investments and actions are successful in accelerating just, sustainable, productive and resilient food system outcomes in different contexts. As one example of a cross-disciplinary approach forward, CSIRO is partnering with the University of Queensland to establish the Food System Horizons initiative.³⁰⁴ Food System Horizons will bring together a range of stakeholders with diverse experiences and perspectives to inform systems level science and drive evidence-based dialogues. In doing so, it seeks to advance the national conversation around opportunities and challenges to prepare Australia's food systems for the future, building capacity in Australia to navigate, manage and direct change processes.

Ultimately, this report is an invitation to anticipate changes, to engage in preparing food systems proactively and collectively for the future, and to position Australia as having a leadership role internationally.

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