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# Navigating the rapids of agrifood systems transformation: reflections on Aotearoa New Zealand's emerging mission-oriented agrifood innovation system

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## ABSTRACT

In this paper, we discuss how agrifood systems transformation is addressed by the Aotearoa New Zealand agrifood innovation system, and to what extent it can be mission-oriented in view of emerging Agriculture 4.0 technologies. There are several initiatives that work on different transition pathways towards agrifood systems transformation, and hence there seems to be an emerging NZ mission-oriented AIS. New networks of actors are formed, also consisting of non-traditional players (e.g. AgTech) and incorporating Māori visions of transformed agrifood systems. Nonetheless, initiatives are sometimes still concerned with optimisation, whereas engaging with phase-out or exnovation of unsustainable food systems would also be needed. Hence, it seems that challenges such as fragmentation, lock-in of current systems and legacy policies, and limited attention to exnovation, are still standing in the way of enacting a truly mission-oriented NZ AIS. Enhancing coordination amongst these initiatives and clarifying how they envision and enact agrifood system transformation missions seem key to move forward.

## ARTICLE HISTORY

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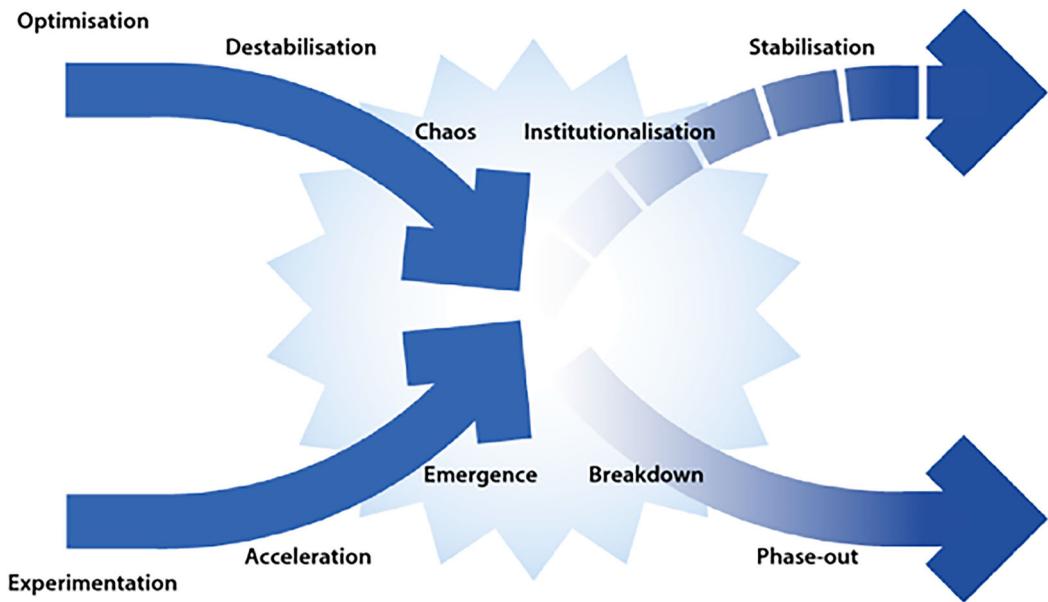
## KEYWORDS

Mission-oriented innovation; agricultural innovation systems; agrifood sector; exnovation; sustainability transitions; Agriculture 4.0

## Introduction

As in other parts of the world, in Aotearoa New Zealand (henceforth NZ) there is currently debate on agrifood systems transformation (Wreford, Bayne, Edwards, & Renwick, 2019; Ma, Vatsa, & Bicknell, 2022). Agrifood systems transformation is needed to address the negative effects of current systems of food production, processing, distribution, consumption, and waste, with impacts including climate change, biodiversity loss, social inequity, and unhealthy diets (Eastwood, Ayre, Nettle, & Dela Rue, 2019). Connected to these debates, there are proposals, strategies, programmes, and actions by a range of players (including government, companies, NGOs, and science) to take agrifood systems transformation forward. Many visions exist on what a transformed agrifood system should look like (Zurek, Hebinck, & Selomane, 2021), and accordingly there is a plethora of possible transition pathways (e.g. Brooks, 2021; Daum, 2021; Lajoie-O'Malley, Bronson, van der Burg, & Klerkx, 2020). For some, transformed agrifood systems are driven by agri-tech and food-tech (e.g. robotics and AI-supported production, cultured meat) which some reject as too techno-optimist (Eastwood, Edwards, & Turner, 2021). Conversely, other groups propose agroecological, nature-based and regenerative

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**Figure 1.** The X-curve showing the phases of simultaneous build up and breakdown that characterise system transformation. Source: Hebinck *et al.* (2022).

food systems (Gliessman, 2016). The latter in turn are sometimes seen as techno-pessimist and unrealistic in view of the need to feed a growing population (Giller, Hijbeek, Andersson, & Sumberg, 2021). Within these debates, there are strong opposing values, but also shades of grey (Mockshell & Kamanda, 2018; Sumberg & Giller, 2022; Wojtynia, van Dijk, Derks, Groot Koerkamp, & Hekkert, 2021) and hybrid systems such as digital agroecology (Bellon-Maurel *et al.*, 2022; Ditzler & Driessen, 2022; Willett *et al.*, 2019).

Given the current exploration, contestation, experimentation, and negotiation on what future agrifood systems should look like, one could say we are in a turbulent phase of the transition towards transformed agrifood systems. These transition dynamics can be understood through the lens of the so-called X-curve (Figure 1), which has been constructed by transition scholars (Hebinck *et al.*, 2022), to grasp how new agrifood systems build up to replace current unsustainable systems.

We argue that agrifood systems transformation is moving towards the phase of emergence and chaos. In this phase, there is recognition that existing systems are no longer fit for purpose in all aspects. In the case of agrifood systems, whilst these still produce sufficient food and have shown resilience in the COVID pandemic (Stephens *et al.*, 2022), climate change may severely disrupt these, access to food is unequal and the system produces negative externalities on the environment and human health (Einarsson, McCrory, & Persson, 2019). Since this has been recognised for some time (Willett *et al.*, 2019), there has been experimentation and acceleration of alternative food production systems (e.g. alternative protein, agroecology, vertical farming – see Herrero *et al.*, 2020; Pigford, Hickey, & Klerkx, 2018, and below). Emerging and tentative systems and more established alternatives, however have not yet replaced dominant incumbent agrifood systems. Some alternatives go through a phase of hype (e.g. plant-based protein), but then decline in terms of development and interest (Helliwell & Burton, 2021) and have not yet progressed to emergence. Also, agrifood systems transformation requires undoing current agrifood systems, either through phase-out or conversion to alternative food systems, but this is far from easy and from finished (Conti, Zanello, & Hall, 2021).

Current agrifood systems are becoming destabilised due to increasing environmental and societal pressures but are not yet in breakdown and phase-out.

In terms of supporting these diverse pathways towards agrifood systems transformation, it has been argued that *agrifood innovation systems* (AIS)<sup>1</sup> need to develop a stronger orientation towards transformative innovation as opposed to incremental innovation focused on optimising current food production and consumption systems. In this light, increasingly AIS are seen through the lens of ‘mission-oriented innovation’ (Hekkert, Janssen, Wesseling, & Negro, 2020; Klerkx & Begemann, 2020; Mazzucato, 2016), in which there is a strong emphasis on complementary technological, institutional, and social innovation for agrifood systems transformation. In summary, mission-oriented innovation has the following characteristics (Mazzucato, 2016):

- (1) Clear direction-setting from the start.
- (2) A portfolio of innovation projects to embrace risks, failures, and uncertainties.
- (3) Investments across different sectors by different types of actors (public, private and third sector actors along the innovation process).
- (4) Joined up policymaking (transformative policy mixes) and reflexivity to avoid lock-in scenarios (that a mission becomes a fixation whilst it turns out to be no longer the most viable, just, and equitable option).

In addition, there needs to be more attention to what has been called ‘exnovation’ which is about proactively achieving the breakdown and phase-out of current unsustainable systems (David, 2017). This inevitably means shifts in influence, power, and resources in agrifood systems leading to some groups being negatively affected. Therefore, making this process of transformative innovation and exnovation as fair as possible also requires attention to elements of justice and equity (Broad, 2019; Tribaldos & Kortetmäki, 2022).

The idea of mission-oriented innovation goes beyond mission-oriented science and calls for ‘mission-oriented agrifood innovation systems’ (mission-oriented AIS), which incorporate all innovation activities (including activities beyond public science such as corporate innovation, start-up driven innovation, grassroots, and citizen-driven innovation).<sup>2</sup> Whilst the concept of mission-oriented AIS has the potential to orchestrate innovation and exnovation for agri-food systems transformation, it is not easy to realise. This is partly due to the diversity of future agrifood system visions (or ‘directionalities’) making prioritisation and cohesiveness difficult (Wojtynia *et al.*, 2021), partly due to the influence of lobbies of incumbents with vested interests and sunk investments and powerful positions and dependencies in global trade networks<sup>3</sup> (Clapp, Newell, & Brent, 2018; Conti *et al.*, 2021), and partly due to the need for agrifood innovation systems and policies to break with previous paradigms of innovation for economic growth (Hall & Dijkman, 2019). Nonetheless in many countries mission-oriented AIS are emerging, with more targeted investment and collective efforts to transform agrifood systems (for example, in Sweden and The Netherlands<sup>4</sup>), often building on ‘legacy policies’ which did not have a clear mission-orientation (Grillitsch, Hansen, Coenen, Mörner, & Moodysson, 2019; Diercks, 2019).

While elements of transformative innovation can be found in NZ, in response to agrifood system challenges and the plethora of emerging technologies (as well as social innovations), it is unclear how this is reflected in the NZ AIS. Though Davenport (2019) and de Jong, Daellenbach, Davenport, Haar, and Leitch (2019) have already reported about mission-orientation in relation to the National Science Challenges, it has not been explored to what extent the NZ AIS has traits of a *mission-oriented AIS*. Therefore, in the remainder of this brief paper, we review where NZ stands in terms of having an emerging mission-oriented AIS to support agrifood systems transformation, and some of the challenges it faces in navigating the rapids of agrifood systems transformation in this phase of - in the words of the X-curve- ‘chaos and turbulence’.

## NZ's response to emerging technologies and agrifood systems transformation: where is NZ on the X-curve?

Herrero *et al.* (2020) identify nearly 80 future technologies with potential to transform agrifood system production, processing, distribution, consumption, and waste. We have adapted their classification of technologies into cellular agriculture (e.g. artificial meat, molecular printing), digital agriculture (e.g. artificial intelligence, traceability technologies), food processing and safety (e.g. biodegradable coatings, microrganisms coating), gene technology (e.g. synthetic biology, genome-wide selection), health (e.g. personalised food), intensification (e.g. vertical agriculture, nanofertilisers), nature-based (e.g. regenerative agriculture, agroecology, botanicals, biostimulants, ecological biocontrol), replacement food (e.g. microalgae, seaweed, insects, plant-based protein), and resource use efficiency (e.g. circular economy). It is important to note that change is never only technological, many of these technologies will require social innovations, such as behavioural changes around food consumption and diets, different sorts of business and revenue models, and some of these technologies are still in the stage of hype and may never reach maturity (Klerkx & Rose, 2020).

Many of these future technologies are being explored in NZ-based initiatives. We used the X-curve to interpret and reflect on the stages of build-up and breakdown that some of these initiatives are potentially operating at (see Table 1). The list of initiatives is not exhaustive and is based on the authors' knowledge of NZ-based activities.

Table 1 illustrates that our three examples of future technologies are at different phases in agrifood system transformation, with cellular agriculture at the experimentation phase and digital agriculture at the emergence phase. At the acceleration and emergence phases in nature-based and digital agriculture there is evidence of increasing interaction and initiatives by Government and industry to attempt to coordinate the myriad of innovation activities, e.g. AgriTechITP and AgriTechNZ. There appears to be limited but growing interaction between farmer-led and science-led innovation in nature-based and digital agriculture as these technologies move into the emergence phase, raising the question of whether cellular agriculture will experience something similar. Table 1 does not show initiatives aligned with existing food production and consumption systems, e.g. He Waka Eke Noa for pastoral livestock GHG emission reductions.<sup>5</sup> These aligned initiatives appear to remain the dominant activities and are focused on optimisation of existing systems. Finally, there appear to be only a few initiatives that address the directionality of innovation. For example recently, the Aotearoa Food System Dialogues provided an example of setting direction within the NZ AIS.<sup>6</sup> This is needed to critically reflect on the potential futures emerging from the technologies, and the synergies and tensions between the technologies and with existing systems of food production and consumption. For example, what do digital technologies within nature-based agriculture look like, and do supporting institutions differ from digital technologies in conventional agriculture? Providing direction and critically reflecting on this direction is an opportunity to increase the mission-orientation of the NZ AIS as we will argue in the next section.

## How does mission-orientation come in: is there an NZ mission-oriented AIS?

In view of the diversity of potential future food systems we now review how mission orientation has come in to drive transformative innovation and to what extent the NZ AIS can be seen as having traits of a mission-oriented AIS.

In 2010 the CRI Taskforce Review (Crown Research Institute Taskforce, 2010) recommended changes to the science system to encourage realising impact from science. Recommendations included, improving partnerships between research organisations and industry; increasing internal funding managed by each CRI to align with sector needs, and increasing each CRI's accountability for impact (Turner, Klerkx, Rijswijk, Williams, & Barnard, 2016).

The Ministry of Business, Innovation and Employment (MBIE) established National Science Challenges in 2014. These are 11 cross research organisation collaborations established to deliver science to

**Table 1.** Interpretation of some current New Zealand agrifood system transition dynamics based on the authors' desk-based research.

Class of future technologies	New Zealand-based initiatives	X-curve stage initiative is operating at	Sources
Cellular agriculture (e.g. artificial meat, molecular printing)	<p>Crown Research Institutes (CRIs) and universities researching cellular agriculture to develop capability, commercial opportunities and understanding of functionality and nutritional repercussions. Includes largest global publicly funded grant for cellular-agriculture research (University of Auckland).</p> <p>BioTechNZ and AgriTechNZ led discussion of cellular agriculture.</p> <p>Major food producers (e.g. Fonterra) investing in overseas cellular agriculture start-ups (e.g. Motif FoodWorks).</p> <p>No cellular agriculture start-ups, and NZ perceived as lagging in commercial cellular agriculture.</p> <p>Food Standards Australia New Zealand (FSANZ) require premarket approval.</p> <p>No cellular agriculture products available in NZ supermarkets at time of writing.</p>	<p>Early experimentation phase, with focus on academic research, investing in overseas start-ups and governance via existing food standards.</p> <p>Connections with gene technology.</p> <p>Described as a green alternative to co-exist alongside pasture-based farming to ensure future global population is fed without damaging the environment.</p>	<p><a href="https://matu.co.nz/2021/03/hot-topic-cellular-agriculture/">https://matu.co.nz/2021/03/hot-topic-cellular-agriculture/</a></p> <p><a href="https://www.pmcsa.ac.nz/topics/cellular-agriculture/">https://www.pmcsa.ac.nz/topics/cellular-agriculture/</a></p> <p><a href="https://thefeed.co.nz/2022/08/01/new-zealand-lab-grown-food-research-boosted-by-new-alliance/">https://thefeed.co.nz/2022/08/01/new-zealand-lab-grown-food-research-boosted-by-new-alliance/</a></p> <p><a href="https://agritechnz.org.nz/event/agritechnz-biotechnz-connect-event/">https://agritechnz.org.nz/event/agritechnz-biotechnz-connect-event/</a></p>
Digital agriculture (e.g. artificial intelligence, traceability technologies)	<p>CRIs, universities, industry bodies (e.g. DairyNZ), farmer cooperatives (e.g. Livestock Improvement Corporation, Ballance AgriNutrients) and private research institutes (e.g. PlantTech Research Institute) researching, developing and commercialising digital technologies, agriculture practices, and barriers to adoption.</p> <p>Digital innovation led by individual and groups of farmers.</p> <p>Existing (e.g. Gallagher), growing (e.g. Rezare Systems) and startup (e.g. Halter NZ) commercial companies developing digital technologies.</p> <p>AgriTech New Zealand – an association of organisations and individuals growing. New Zealand's capability to maximise opportunities from agritech. Projects on baselining adoption, agricultural data interoperability and sharing examples.</p> <p>AgriTech Industry Transformation Plan (ITP) provides a Government vision for the agritech sector, along with Government actions to realise this vision in partnership with industry.</p>	<p>Moving from experimentation to acceleration as digital technologies becoming established on more farms and more agritech companies establish.</p> <p>Emergence of an ecosystem of agritech providers, Government, industry and research is occurring through facilitation by cross organisation groups such as AgriTech NZ, AgriTechITP and KPMG.</p> <p>Very early phase of institutionalisation with questions regarding data governance, Māori data sovereignty beginning to be raised but not yet addressed in policy.</p> <p>Many actors in the ecosystem and now emerging attempts at coordination of activities (e.g. MPI and KPMG).</p>	<p><a href="https://www.agresearch.co.nz/nzbida/">https://www.agresearch.co.nz/nzbida/</a></p> <p><a href="https://www.planttechresearch.com/">https://www.planttechresearch.com/</a></p> <p><a href="https://am.gallagher.com/en-NZ">https://am.gallagher.com/en-NZ</a></p> <p><a href="https://halterhq.com/">https://halterhq.com/</a></p> <p><a href="https://agritechnz.org.nz/">https://agritechnz.org.nz/</a></p> <p><a href="https://home.kpmg/au/en/home/media/press-releases/2021/09/new-data-exchange-revolutionise-australian-agrifood-sector-14-september-2021.html">https://home.kpmg/au/en/home/media/press-releases/2021/09/new-data-exchange-revolutionise-australian-agrifood-sector-14-september-2021.html</a></p> <p><a href="https://www.mbie.govt.nz/dmsdocument/11572-growing-innovative-industries-in-new-zealand-agritech-industry-transformation-plan-july-2020-pdf">https://www.mbie.govt.nz/dmsdocument/11572-growing-innovative-industries-in-new-zealand-agritech-industry-transformation-plan-july-2020-pdf</a></p> <p><a href="https://home.kpmg/au/en/home/media/press-releases/2021/09/new-data-exchange-revolutionise-australian-agrifood-sector-14-september-2021.html">https://home.kpmg/au/en/home/media/press-releases/2021/09/new-data-exchange-revolutionise-australian-agrifood-sector-14-september-2021.html</a></p> <p><a href="https://www.temanararaunga.maori.nz/">https://www.temanararaunga.maori.nz/</a></p>

(continued).

Table 1. Continued.

Class of future technologies	New Zealand-based initiatives	X-curve stage initiative is operating at	Sources
	KPMG facilitated NZ Agrifood Data Exchange to develop examples of ecosystem-level sharing of data.	Limited initiatives debating the direction of development and desired outcomes from digital agriculture. Currently described as ways to increase efficiency and productivity and meet environmental and animal welfare requirements of regulations and consumers.	
	Ministry for Primary Industry (MPI) initiatives on model and data interoperability.		
	Māori Data Sovereignty in context of genomic data broadening to include all data.		
Nature-based (e.g. regenerative agriculture)	CRI, university and National Science Challenge research to build a scientific evidence-based of the benefits of regenerative agriculture.	Established experimentation phase with existing network of regenerative farmers and building evidence of regenerative agriculture practices by food system actors.	<a href="https://www.greenpeace.org/aot-earoa/campaign/regenerative-farming-revolution/">https://www.greenpeace.org/aot-earoa/campaign/regenerative-farming-revolution/</a>
	Food retailers (e.g. MacDonalds, Countdown), agribusiness (AgriSea) and producers (e.g. Ngāi Tahu Farming, Synlait) are trialling regenerative agriculture principles and practices.	Early acceleration phase with networks of producers, retailers, scientists and policy makers emerging.	<a href="https://ourlandandwater.nz/incentives-for-change/regenerative-agriculture-regen-ag/">https://ourlandandwater.nz/incentives-for-change/regenerative-agriculture-regen-ag/</a>
	Industry bodies (e.g. Beef + Lamb NZ) exploring market potential and comparisons of NZ and overseas practices.	Early emergence phase with farmer networks providing a structure for sharing of farmer knowledge and support.	<a href="https://ourlandandwater.nz/news/countdown-is-testing-regenerative-principles/">https://ourlandandwater.nz/news/countdown-is-testing-regenerative-principles/</a>
	Greenpeace promotion of regenerative agriculture to clean up NZ rivers and reduce net-GHG emissions.	Some evidence of chaos phase with conflict between opposing interests within academia and within agribusiness.	<a href="https://beeflambnz.com/news-views/beef-lamb-new-zealand-research-regenerative-agriculture-market">https://beeflambnz.com/news-views/beef-lamb-new-zealand-research-regenerative-agriculture-market</a>
	Building networks of farmers (Quorum Sense) and cross sector leaders with government support.		<a href="https://thedig.nz/apocaloptimism/insight-into-regenerative-agriculture-in-new-zealand-the-good-the-bad-and-the-opportunity/">https://thedig.nz/apocaloptimism/insight-into-regenerative-agriculture-in-new-zealand-the-good-the-bad-and-the-opportunity/</a>
	No defined standards or regulations for regenerative agriculture, with activities by government and science to develop these.		<a href="https://pureadvantage.org/social-cohesion-in-rural-communities-with-sam-lang/">https://pureadvantage.org/social-cohesion-in-rural-communities-with-sam-lang/</a>
			<a href="https://www.ravensdown.co.nz/expertise/regenerative-agriculture-insight-or-soundbite">https://www.ravensdown.co.nz/expertise/regenerative-agriculture-insight-or-soundbite</a>

address strategically significant national problems identified by the NZ public, mostly hosted within a CRI or University.<sup>7</sup> These Challenges align existing public-funded research and provide strategic direction for future public-funded research to stimulate coordination of innovation agendas and activities (de Jong *et al.*, 2019; Penman & Goldson, 2015), and are conceived as being mission-led (Davenport, 2019).

A once-in-a-generation redesign of the NZ innovation system is currently underway with Te Ara Paerangi<sup>8</sup> – the Ministry of Business, Innovation and Employment (MBIE) CRI Review. This review includes six main areas, of which one is a national ‘science priority-setting’ process, to focus research activities and resources on achieving national goals. Two of the other six areas contribute to this ‘science-priority-setting’ by referring to how funding and public research institutions can give effect to national priorities. MBIE’s Te Ara Paerangi Future Pathways Green Paper (2021) points to a future innovation system of greater collaboration to address societal challenges:

Meeting the challenges and opportunities of the future will require harnessing the collective capability of our RSI system across all fields and disciplines, including social research. Collaborative, multifaceted and interdisciplinary approaches will be essential to tackle the complex and interdependent challenges that are central to New Zealand’s future.<sup>9</sup>

A reflection on NZ AIS activities to support mission-oriented innovation (Table 2) highlights strengths and weaknesses in the NZ AIS that may need addressing to strengthen mission-orientation based on the characteristics outlined. While there is evidence of increased alignment of Government, research and industry visions and initiatives for the future of the NZ agrifood system (cf. Turner *et al.*, 2016) these visions and initiatives are predominantly focused on optimisation of the current system. Proposed processes for science priority-setting need to have truly transformative ambitions. This can be guided by critical reflection on the phases of the X-curve. Science-priority setting must also include equity and justice as explicit outcomes, as consideration of these appear to currently be limited to the energy sector and are a source of current contention in the pricing of agricultural emissions. Science-priority setting also needs to include ongoing reflexivity to respond to lessons from on-the-ground experimentation with alternatives and the rapidly changing innovation landscape. Furthermore, beyond science priority setting, broader food systems change priority setting is required. To realise transformative priorities will also require innovation projects that embrace risks and failures by shifting the balance of innovation investment away from the current emphasis on innovations that optimise the existing system to investing in innovations that are experimenting and accelerating alternatives. In addition, explicitly investing in exnovation and addressing legacy policies that maintain lock-in to existing systems must occur.

### Conclusion: challenges and opportunities to strengthen the NZ mission-oriented AIS

While the NZ AIS is in the turbulent phase of transition with many new developments emerging, a new system has not yet consolidated. It is timely to therefore take stock of what initiatives are happening to support this transition and in what direction this is taking the NZ agrifood system. This paper was not intended to cover all the current initiatives in detail, rather to present a snapshot of the current point in time, to illustrate the phases of this transition in relation to a larger picture of agrifood transformation in NZ. A more in-depth study would encompass all the initiatives as well as the attitudes and behaviours of the actors and organisations involved within them.

From the brief analysis above it becomes clear that there are several initiatives in NZ that work on different transition pathways towards agrifood systems transformation, and hence there seems to be an emerging NZ mission-oriented AIS. Mostly these are in experimentation, early acceleration, and early emergence phases in the transition X-curve. New networks of actors are formed, also consisting of non-traditional players (e.g. AgTech), and Māori visions of transformed food systems are increasingly coming to the forefront (e.g. Knook, Wreford, Gow, & Hemi, 2022). Nonetheless, initiatives are sometimes still concerned with optimisation, whereas engaging with what the transition X-curve denotes as destabilisation (i.e. phase-out and exnovation) would also be needed. Hence, it seems that challenges such as fragmentation (Turner *et al.*, 2016), lock-in of current systems and legacy policies (a key risk as Diercks, 2019, has also noted for other OECD countries), and limited attention to exnovation, are still standing in the way of enacting a truly mission-oriented NZ AIS.

A more consolidated NZ mission-oriented AIS calls for better integration of initiatives including cross-sectoral collaboration; being more explicit about – and perhaps also making stronger choices – in terms of directionality; more coherent policy mixes to support desired transition pathways, and where appropriate phasing out, or partly phasing out and helping to convert, incumbent systems and players.<sup>10</sup> A few concrete entry points to build on to achieve a more coherent NZ mission-oriented AIS are:

- (1) Through MBIE's Te Ara Paerangi process
- (2) Through building capacity and capability within the science system to engage in mission-orientated research approaches (for example National Science Challenges; AgResearch's T-Platform project; tertiary education training of science students in transdisciplinarity)
- (3) Māori-led transformation strategies (at hapū and iwi-level as well as within and between collectives of Māori land owning entities and agribusiness)

**Table 2.** New Zealand agrifood innovation system support for mission-oriented innovation.

Characteristics of mission-oriented innovation (Mazzucato, 2016)	NZ AIS support for mission-oriented innovation (strengths and weaknesses)	Strengths and weaknesses of support for mission-oriented innovation	Sources
Clear direction setting from the start	<p>Eleven National Science Challenges (NSCs) identification of visions through societal, government, industry and research input. For example Our Land and Water NSC’s objective is ‘To enhance the production and productivity of New Zealand’s primary sector, while maintaining and improving the quality of the country’s land and water for future generations.’ High Value Nutrition NSC vision is ‘To grow New Zealand food and beverage export revenue through international leadership in the science of food and health relationships.’</p> <p>Eight Government Industry Transformation Plans (ITP) (e.g. AgriTech, Fisheries, Food and Beverage, Forestry and Wood Processing) created in partnership with industry, Māori, and Government, to set ambitious long-term visions for sectors and identify actions for investment. For example, Food and Beverage ITP will support the growth of sustainable, innovative, and high-value food and beverage exports from existing and emerging industries. The ITP is not seeking to transform the food and beverage sector in its entirety.</p> <p>Fit for a Better World presents a vision for New Zealand’s primary sector of ‘rapidly moving to a low carbon emissions society, restoring the health of our water, reversing the decline in biodiversity and, at the same time, feeding our people’. Fit for a Better World identifies three targets where the primary sectors can contribute to New Zealand’s economic recovery, e.g. reduce biogenic methane to 24–47% below 2017 levels by 2050.</p> <p>The Climate Change Commission has set GHG emission reduction targets and 33 recommendations for how to achieve these. Pricing of agricultural emissions in response to Climate Change Commission and He Waka Eke Noa is currently under consultation, and is contentious amongst the rural sector right now so this is where the energy of the sector is focused. Pricing has equity implications for farmers with clear winners and losers (sheep and beef of which many are Māori land blocks).</p>	<p>Several Government, industry and research-led initiatives have set visions and targets for parts of the New Zealand agri-food sector, e.g. Our Land and Water NSC has set a vision for food production and improving land and water quality; the Food and Beverage ITP vision is to grow export revenue. There is no evidence of deliberate alignment of visions, however, many appear to align.</p> <p>The visions appear to be an optimisation of the current agri-food system, e.g. increasing economic and export growth while also improving environmental and social improvements.</p> <p>Current visions may align as they focus on optimisation rather than exploring radical alternatives to current systems of agrifood production and consumption.</p> <p>Attempts at cross-sector visions appear to breakdown when mechanisms for implementation are proposed, e.g. pricing agricultural emissions.</p>	<p>National Science Challenge Strategic Plans 2019–2024</p> <p>Industry Transformation Plans</p> <p><a href="https://fitforabetterworld.org.nz/">https://fitforabetterworld.org.nz/</a></p> <p><a href="https://environment.govt.nz/assets/publications/Pricing-agricultural-emissions-consultation-document.pdf">https://environment.govt.nz/assets/publications/Pricing-agricultural-emissions-consultation-document.pdf</a></p>

(continued).

**Table 2.** Continued.

Characteristics of mission-oriented innovation (Mazzucato, 2016)	NZ AIS support for mission-oriented innovation (strengths and weaknesses)	Strengths and weaknesses of support for mission-oriented innovation	Sources
A portfolio of innovation projects to embrace risks, failures, and uncertainties	<p>The 11 National Science Challenges have research plans with the based science identified to achieving the Challenge objective, including a credible impact pathway of research and related activities. Each Challenge involves public outreach and exhibits strong engagement between researchers and intended end users of the research activity.</p> <p>ITPs have action plans that include immediate high impact projects and longer-term workstreams of innovation, market development, and regulatory activity including lead agencies across Government.</p> <p>Fit for a Better World includes an ‘Acceleration Roadmap’ with transformational and other opportunities across industry, regulation, and research to achieve productivity, sustainability, and inclusiveness targets. For example, He Waka Eke Noa has been a key action to develop a system for farmers to generate and record their emissions footprint.</p> <p>Desk-based analyses of New Zealand’s food sector opportunities (e.g. Well NZ: Reframing New Zealand’s Food Sector Opportunities) related to alternative protein technologies (plant-based, cell-based and precision fermentation), personalised nutrition and food-as-software, have also been develop over the past two years.</p>	<p>There is evidence of portfolios of regulatory, technological and market innovation to realise missions, however, there appears to be limited diversity and risk-taking to explore and learn from the implementation of alternative pathways.</p> <p>There appears to be a dominance of innovations focused on optimisation of the current agri-food system, with limited exploration of radically alternative pathways as part of the mainstream discourse.</p> <p>For example, He Waka Eke Noa proposed a systems for farmers to generate and record their emissions footprint which has been proving contentious when linked to the pricing of emissions.</p>	<p><a href="https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/national-science-challenges/">https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/national-science-challenges/</a></p> <p><a href="https://www.mbie.govt.nz/dmsdocument/11572-growing-innovative-industries-in-new-zealand-agritech-industry-transformation-plan-july-2020-pdf">https://www.mbie.govt.nz/dmsdocument/11572-growing-innovative-industries-in-new-zealand-agritech-industry-transformation-plan-july-2020-pdf</a></p> <p><a href="https://www.mpi.govt.nz/dmsdocument/41031-Fit-for-a-Better-World-Accelerating-our-economic-potential">https://www.mpi.govt.nz/dmsdocument/41031-Fit-for-a-Better-World-Accelerating-our-economic-potential</a></p> <p><a href="https://fitforabetterworld.org.nz/assets/Te-Puna-Whakaaronui-publications/WELL-NZ-summary.pdf">https://fitforabetterworld.org.nz/assets/Te-Puna-Whakaaronui-publications/WELL-NZ-summary.pdf</a></p>
Investments across different sectors by different types of actors (public, private and third sector actors along the innovation chain)	<p>The 11 National Science Challenges include investment from end users in the Challenge’s research.</p> <p>ITPs and Fit for a Better World include identification of public and private sector-led activities, e.g. Government is leading modernisation of export legislation and industry is leading natural fibre product development and delivery of new products to market.</p>	<p>The Industry Transformation Plans, Fit for a Better World and He Waka Eke Noa are examples of increased partnering between Māori, Government and industry to achieve increased coordination of and investment in initiatives. This is helping to address an historical weakness in the NZ AIS of duplication, competition and lack of coordination (Turner <i>et al.</i>, 2016).</p>	

(continued).

Table 2. Continued.

Characteristics of mission-oriented innovation (Mazzucato, 2016)	NZ AIS support for mission-oriented innovation (strengths and weaknesses)	Strengths and weaknesses of support for mission-oriented innovation	Sources
Joined up policymaking (transformative policy mixes)	<p>Recognition in ITPs of the need to link to other industry strategies and reforms where possible, e.g. the Food and Beverage ITP recognises links to Te Puna Whakaaronui (Food and Fibre Sector Think Tank), Te Ara Paerangi (reform of science system) and Reform of Vocational Education.</p> <p>Fit for a Better World recognises need to align regulatory and research settings to the primary sector's strategic direction.</p> <p>Climate Change Commission includes policy recommendations across sectors to realise GHG reductions from construction, transport and agriculture.</p>	There is recognition of the need to align policies as part of the ITPs and Fit for a Better World. There is, however, limited evidence of explicit design of cross-sector policies to deliver to visions.	
Reflexivity to avoid lock-in scenarios (that a mission becomes a fixation whilst it turns out to be no longer the most viable, just and equitable option)	<p>NSCs had a strategic refresh after 5-years to update strategies and research plans to respond to changes in the research landscape, progress and Government and industry initiatives. The overall objectives, however, remained.</p> <p>ITPs, Fit for a Better World and NSCs include outcomes, indicators and monitoring of these to demonstrate progress toward objectives.</p>	Limited evidence of reflexivity, with monitoring focused on accountability for realising action plan targets. Less evidence of critical reflection on the direction of visions and limited examples of consideration of equitable outcomes (Climate Change Commission is an example).	
'exnovation' which is about proactively achieving the breakdown and phase-out of current unsustainable systems	Climate Change Commission has set targets for phasing out industry activities, e.g. phase out of fossil fuels used in boilers.	There is no evidence of activities explicitly focused on breakdown and phase-out in the agri-food sector.	<a href="https://ccc-production-media.s3.ap-southeast-2.amazonaws.com/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Recommendations-from-Inaia-tonu-nei-Advice-Report.pdf">https://ccc-production-media.s3.ap-southeast-2.amazonaws.com/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Recommendations-from-Inaia-tonu-nei-Advice-Report.pdf</a>

(continued).

**Table 2.** Continued.

Characteristics of mission-oriented innovation (Mazzucato, 2016)	NZ AIS support for mission-oriented innovation (strengths and weaknesses)	Strengths and weaknesses of support for mission-oriented innovation	Sources
Attention to elements of justice and equity	<p>One of the three pillars of Fit for a Better World is Inclusive with the target of employing 10% more New Zealanders from all walks of life in the primary sectors by 2030. Other activities include supporting rural communities through development of community hubs and supporting vulnerable communities with healthy food options.</p> <p>Climate Change Commission recommendations (27 and 28) include recognition a Māori-led approach to an equitable transition for Iwi/Māori and a fair, inclusive, and equitable transition.</p> <p>Just Transition Workplan development, investment and partnership by Government with region's exiting from significant economic activities, e.g. aluminium smelter in Southland and oil and gas in Taranaki.</p>	Limited evidence of activities addressing justice and equity from transformation of the agri-food sector. Just Transitions are focused on supporting regions with significant infrastructure investments in industries that are being phased-out, e.g. oil and gas in Taranaki.	<p><a href="https://www.mpi.govt.nz/dmsdocument/41031-Fit-for-a-Better-World-Accelerating-our-economic-potential">https://www.mpi.govt.nz/dmsdocument/41031-Fit-for-a-Better-World-Accelerating-our-economic-potential</a></p> <p><a href="https://www.mbie.govt.nz/business-and-employment/economic-development/just-transition/">https://www.mbie.govt.nz/business-and-employment/economic-development/just-transition/</a></p> <p><a href="https://southlandjusttransition.nz/">https://southlandjusttransition.nz/</a></p>

- (4) Funding support and direction from central and local government, for example Ministry for Primary Industries
- (5) Build on Aotearoa NZ Food Systems Dialogues
- (6) Other integrative initiatives, such as Industry Transformation Plans and Fit for a Better World

Enhancing coordination amongst these initiatives and clarifying how they envision and enact agri-food systems transformation missions seem key to move forward, to support clear direction setting and innovation and exnovation portfolio shaping. Once missions are defined it will also become more explicit which parts of the agri-food value chain in NZ should be prioritised in terms of innovation and exnovation. Enactment of innovation and exnovation portfolios can be supported by so-called 'transformative innovation policy mixes' (Kivimaa & Kern, 2016) along the transition X-curve, which include instruments to support both experimentation and scaling of novel technologies and food systems (e.g. high-risk research funding, venture capital, cross-sector alliance building support, tax breaks for alternative products) as well as directing destabilisation and phase-out of undesirable systems (e.g. banning certain practices through legislation, true cost pricing of unsustainable products).

Mission-oriented innovation (e.g. alternative protein, digital agriculture, agroecology) is typically a cross-country collaboration, given that it is driven by global science, business, policy and investments systems (Klerkx & Begemann, 2020). Nonetheless, countries may have geared their AIS to a mission-oriented approach in different ways, in view of their specific institutional and policy settings. In consolidating mission-oriented approaches to navigate the rapids of food systems transformation, the NZ AIS may learn from and join forces with global initiatives that are aimed at documenting lessons and strengthening policies for mission-oriented AIS to support agrifood systems transformation. These include, for example, FAO's recently launched Agrifood Systems Technologies and Innovations Outlook, OECD's recent Declaration on Transformative OECD Legal Instruments Solutions for Sustainable Agriculture and Food Systems, and the work of the International Panel of Experts on Sustainable Food Systems (IPES-Food) and the European Environment Agency.<sup>11</sup> On the application side of doing transformative research and innovation, exchange with earlier mentioned mission-oriented programmes in The Netherlands and Sweden, and closer to NZ the Australian Future Foods CRC, may provide relevant comparison of experiences.<sup>12</sup>

In terms of researching further development of the NZ mission-oriented AIS, first getting a more complete overview of current implicit and explicit missions would be needed (mission mapping) and what stage they are in as regards the X-curve, using frameworks for systemic analysis of mission-oriented innovation systems (Klerkx & Begemann, 2020; Wanzenböck, Wesseling, Frenken, Hekkert, & Weber, 2020), perhaps adapted for an NZ context. Additional case studies and evaluations highlighting the challenges and opportunities of working within mission-oriented programmes in Aotearoa New Zealand, for example those being provided through the National Science Challenges, are also useful to help to make explicit what is required for success. Furthermore, updating AIS structural-functional analysis as done by Turner *et al.* (2016) could inform policy making by getting more detailed insights on how a mission-oriented approach is enabled or hindered by current NZ AIS structures.

## Notes

1. An innovation system is composed of multiple individuals and organisations interacting, accessing, exchanging, and using knowledge, and realising other activities for innovation such as vision creation, resource mobilisation, and creating legitimacy for change. This emphasises the need to consider and create interactions throughout the entire supply chain, as well as with policy and financial services. The innovation system includes people, linkages, infrastructure, and institutions (defined as 'the rules by which individuals and organisations interact').
2. See Klerkx and Begemann (2020) for more details on mission-oriented agrifood innovation systems.

3. Conversely, global trade may also induce transformative innovation, e.g. through sustainability standards from key players in global value chains (Vilas-Boas, Klerkx, & Lie, 2022; Grabs & Carodenuto, 2021). However, in view of concepts such as ‘degrowth’ the position of global trade may also need revisiting.
4. See e.g. <https://www.vinnova.se/en/m/sustainable-food-systems/>, <https://topsectoragrifood.nl/wp-content/uploads/2020/03/TOAF1910-Kennisagenda-A5-landscape-English-1.pdf>.
5. <https://hewakaekenoa.nz/>.
6. [https://foodsystemsdialogues.org/wp-content/uploads/2020/08/IND\\_FSDs\\_200618\\_Aotearoa\\_Summary-Report\\_UPLOADED.pdf](https://foodsystemsdialogues.org/wp-content/uploads/2020/08/IND_FSDs_200618_Aotearoa_Summary-Report_UPLOADED.pdf).
7. <https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/national-science-challenges/>.
8. <https://www.mbie.govt.nz/have-your-say/future-pathways/>.
9. Ministry of Business, Innovation and Employment (2021, p. 2).
10. This may include asking difficult questions about long-term viability of for example large scale animal-based sectors, but it is needed to ask such questions and set priorities in view of societal concerns, climatological and ecological pressures, and emerging technologies. See for example Burton (2019) and Helliwell and Burton (2021).
11. <https://www.ipes-food.org/>, <https://www.oecd.org/newsroom/homepage/en/OECD%20Agriculture%20Ministerial%20DECLARATION%20EN.pdf>, <https://www.fao.org/documents/card/en/c/cc2506en>, <https://www.eea.europa.eu/publications/food-in-a-green-light>.
12. <https://www.vinnova.se/en/m/sustainable-food-systems/>, <https://topsectoragrifood.nl/wp-content/uploads/2020/03/TOAF1910-Kennisagenda-A5-landscape-English-1.pdf>, <https://www.futurefoodsystems.com.au/>. See also Klerkx and Begemann (2020) for other international initiatives.

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