

Future Forces

A ten-year horizon for
Australian agriculture



About



AgriFutures Australia is a new beginning for the Rural Industries Research and Development Corporation (RIRDC). Our vision is to grow the long-term prosperity of Australian rural industries as we invest in research and development that is adopted by and assists rural industries to be productive, profitable, and sustainable.

In practice, this means delivering research and development for established industries that do not have their own Research & Development Corporation (RDC), research and investment to address issues of national importance to Australian agriculture, research and development to accelerate the development of emerging rural industries, and initiatives to build the capability of our future rural leaders.

agrifutures.com.au



Agthentic Advisory is a global strategy and advisory firm working at the intersection of technology and agriculture to help innovators build the food system of the future. We work with agribusiness and industry to evaluate emerging technologies, engage with the food and agricultural innovation ecosystem, and scale business model innovations that lead to adoption and impact. We provide unique insights and deep expertise to help organisations understand and harness the processes that unlock the potential of innovative agriculture for global impact. agthentic.com



Institute for the Future (IFF) is the world's leading futures organisation. For over 50 years, businesses, governments, and social impact organisations have depended upon IFTF global forecasts, custom research, and foresight training to navigate complex change and develop world-ready strategies. IFTF methodologies and toolsets yield coherent views of transformative possibilities across all sectors that together support a more sustainable future. Institute for the Future is a registered 501(c)(3) nonprofit based in Palo Alto, California. iff.org

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Foreword

Being able to look over the horizon and prepare for the future is challenging. In times of rapid and diverse change, horizon scanning can be the difference between success and failure for farmers, fishers, foresters, their supply chain partners, research agencies, and governments.

In 2015, the Rural Industries Research and Development Corporation (now AgriFutures Australia) and CSIRO produced the '[Rural Industry Futures—Megatrends impacting Australian agriculture over the coming twenty years.](#)' This work highlighted five trends that were expected to be key influencers to 2035—a hungrier world, a wealthier world, choosy customers, a bumpier ride, and transformative technologies.

Six years later, in 2021, the impacts of many of these predictions are clear. It is also clear that the speed of change is increasing, as is the level of uncertainty and diversity of opportunities.

This report was written and produced by Institute for the Future (ITF) and Agthentic Advisory to promote thinking and preparation based on five social, environmental, and technological future forces, namely:

- › Viral disinformation in the food system
- › Interconnected digital infrastructure
- › Rewiring the grid
- › Domesticating the cell
- › New geographies of climate change

By combining these forces with emerging trends and innovations, the report illustrates potential futures:

- › The war for the consumer relationship
- › Regional redesign
- › Outside solutions to climate problems
- › Divorcing flavour, nutrition, and form
- › Supporting full-spectrum producers
- › The searchable food web
- › Biology goes digital

The report is not a prediction of the future, but rather it extrapolates from the current state and provokes a conversation for agriculture, fisheries, and forestry.

This report has been produced under AgriFutures Australia's National Rural Issues (NRI) Program. Part of the National Challenges and Opportunities arena, NRI focuses on thought-provoking and horizon-scanning research to inform debate and policy on issues of importance across rural industries.

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Michael Beer
General Manager, Business Development
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Executive Summary

This report was written and produced by Institute for the Future and Agthentic Advisory with support from AgriFutures Australia as part of the AgriFutures National Rural Issues Program to examine potential future opportunities, risks, and disruptions to the Australian agricultural system on a ten-year horizon.

The report introduces five future forces that describe major directions of change for Australian agriculture. The forces are defined by measurable shifts that are already happening in the world today. They were selected to represent some of the most pressing disruptions across a broad category of social, technological, environmental, and economic domains. These are:



Viral disinformation in the food system

Food issues become increasingly susceptible to disinformation campaigns



Interconnected digital infrastructure

An interconnected system of digital capabilities unleashes new opportunities in agricultural supply chains



New geographies of climate change

Movement of people, climate regions, and crops define an era of uncertainty



Rewiring the grid

Distributed energy production is made possible by advancements in renewable and alternative technologies



Domesticating the cell

New products, experiences, and concerns will arise from our ability to design biology

The report presents seven Forecasts for Australian agriculture. The Forecasts take into account the Future Forces and include signals of change and insights for key stakeholders.

The war for the consumer relationship

Many new stakeholders, including actors who have never before been in the agricultural system, will seek to influence and capture consumer interest as digitisation of every step of the food system increases.

Regional redesign

Driven by new energy systems and automation technologies, there will be a fundamental redesign of individual production systems and regions as everything from genetics to irrigation to layout of farm operations will be optimised for automation.

Outside solutions to climate problems

New technologies such as advanced sensing, machine learning, and synthetic biology will help mitigate climate change volatility.

Divorcing flavour, nutrition, and form

Synthetic biology technologies will allow for the design of food products untied from natural production systems, and commercial competition will drive development of new foods through cellular agriculture, molecular engineering, and 3D printing.

Supporting full-spectrum producers

Producers of the future will rely on a wide mix of income streams through broadly defined resource conversion: not only converting grass to meat or fibre, but also converting sunlight to solar power, soil to carbon sequestration services, or data collection to useful models.

The searchable food web

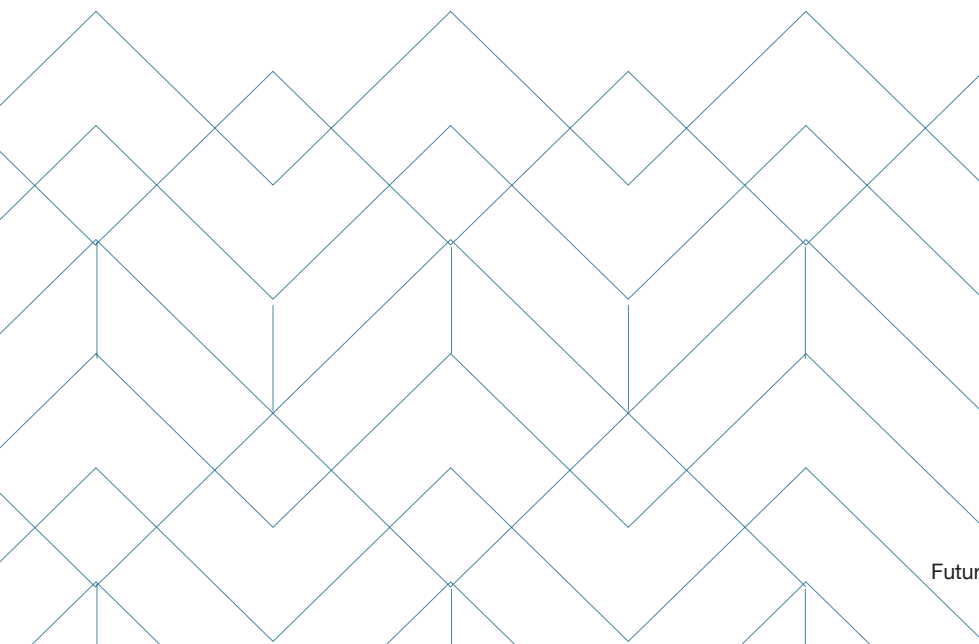
Measurement and tracking tools, in combination with molecular tags and the internet of things (IoT), will allow for individual food products to be tracked and traced, increasing the importance of managing trust in food systems.

Biology goes digital

Genetic therapies and gene editing tools such as CRISPR (a set of DNA sequences that allow for relatively easy gene editing) will become democratised through commercially available products, and biological manipulation will be possible for new organisations and producers.

While these forecasts are not predictions about what is most likely to happen, they provide insight into the ways that the future forces may plausibly shape Australian agriculture. By outlining these possible futures in detail, this report serves to expand the scope of strategic thinking for decision makers across industries and along the value chain. The goal of the overall report is to start new conversations, challenge current-day views on the state of food and fibre in Australia, and serve as a jumping-off point for productively discussing the future.

The best point of entry into this report is the set of “What if?” [Scenarios \(page 10\)](#). These are imaginative vignettes of what life might be like for different individuals in various aspects of the future informed by the forces and forecasts. They bring the research to life and encourage a closer consideration of just how different the future might be.



Introduction

The past decade has seen seismic shifts in how we produce, consume, and use food and fibre. For example, drones went from expensive playthings to commodity equipment, and crop genome sequencing went from high-cost research to an affordable service. E-commerce and social media marketing allow consumers to buy food online and have it delivered to their front door, often directly from the producer.

The next 10 years are likely to see similarly drastic changes due to the intersection of significant forces both inside and outside the agriculture industry. Increased digitisation of our lives, our information, and our tools will alter how we move agricultural products from producer to consumer. Climate change will affect where we produce crops and livestock, impact our ability to move goods worldwide, and change the dynamics of labour forces and buyers in urban centres. Even forces seemingly unrelated to food and agriculture, such as how people communicate through the internet, will have cascading consequences for food safety and consumer behaviour as they shape data flows and inform decision-making.

Looking at the future of Australian agricultural production demands a cross-organisations approach. We must look beyond emerging technologies and businesses toward the type of world within which those technologies and businesses will operate.

This report offers a perspective on the agri-food system's emerging landscape over the next decade. It aims to start new conversations about opportunities and risks for players along the value chain and within the agricultural system. Rather than providing probabilistic answers about the future, we aim to provide a set of plausible—yet provocative—possibilities that stretch our preconceived notions about the future.

Methodology

The foresight and insights in this report were developed using IFTF's futures-thinking methodology consisting of a mixed-method process of scanning for signals of change (small, present-day experiments or disruptions that have the potential to scale), conducting research, facilitating small group interviews with experts, conversing with participants along the value chain and in related industries, and conducting STEEP analyses (to explore how Socio-cultural, Technological, Economical, Environmental, and Political trends could affect the future of an enterprise or organisation). While no forecast can address every change that may take place, futures-thinking focuses on those that sit between plausibility and provocation.

Futures-thinking is distinct from other forecasting methods in that its primary aim is not to be strictly "correct." The goal of these forecasts isn't to determine what exactly will happen in 10 years—because attempting to predict the future with accuracy tends to be more harmful to strategic decision-making than it is helpful. Instead, we aim to widen the set of possible consequences that we consider in long-term planning, based on early-stage changes we can already observe. People and organisations who use futures-thinking can prepare to respond with more agility to the unexpected changes that arise in the future.

In essence, futures-thinking is a tool for changing the way we develop strategies we can use today.

The practice of futures-thinking leads to clarity in multiple ways: it explores potential futures that we might not have otherwise considered; it examines the unintended consequences of new changes rather than just the logical consequences; it moves us away from focusing too heavily on technological or business innovation by pushing us to consider human and more abstract changes; and it challenges our assumptions about what is possible in the future.

How to use this report

The report starts with a set of scenarios from the perspective of different individuals living 10 years from now. Seeing through the eyes of a hypothetical character makes it easier to develop the look and feel of a particular future.

STEP
1

Start by immersing yourself in the future through the four scenarios. They're meant to provoke new ideas for navigating future opportunities or dilemmas. Each scenario is tagged with corresponding Future Forces and Forecasts, which provide a deeper look at key changes in agricultural and food systems.



The War Room

A future food brand manager scrambles to manage her brand and supply chain relations when a viral disinformation attack threatens their reputation.

Paddock to Plate

Transparent digital food information can enable virtually anyone to have outsized influence on food decisions.

Buzz

A farmer in the future who manages a wide range of income streams takes on a variety of non-traditional roles.

Not So Crazy After All

Investment will use emerging technologies to disrupt existing industries.

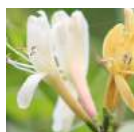
STEP
2

Next, tour the the five Future Forces that describe the global shifts that will grow over the next decade. These are bigger than Australian agriculture—indeed, they're bigger than the global food and fibre system. Each future force is evidenced by a set of **drivers**—data that point towards the change indicated by the future force.



STEP
3

Finally, review the Forecasts that are windows into how the future might look very different. They are micro-scale futures to which intersecting future forces could lead.



Below each forecast is a set of **signals of change**. The signals are real, present-day innovations, technologies, or specific changes that could plausibly lead to the future described in the forecast if they scale and catch on. Signals indicate niches where these futures are already starting to play out.



Below these signals are a set of **insights**. These are key ways that stakeholders might need to think differently, given the possibilities presented in the forecast. While the forecasts are meant to provoke new considerations, insights are intended to help draw out stakeholders' strategic actions in similar futures.

Questions to ask as you read this report

You may well disagree with some of the forecasts within this report. Likely, most of these forecasts won't play out in the same way they're described here. That's alright—in fact, it can be quite useful to disagree with some of them if you spend the time to consider why you disagree and to understand how that stance might be challenged. As you read this report, ask yourself how you might adapt to or take advantage of the new opportunities and risks presented by the forecast, and what early signs to look out for that would alert you that something like this future is—or is not—starting to happen.

To develop a clearer understanding of the future, it is important to pull out insights from this work that draw on your own expertise, experience, and knowledge. One way to develop these is to ask yourself a series of questions as you consider this report:

› **The future may seem ridiculous.**

Whether or not you fully believe that a certain technology, social change, or forecast is likely to come true in the future, take that key change at face value for a moment. Ask: What are the second-order consequences that logically follow if that change does come to pass? Then, repeat the process: If the second-order consequence comes to pass, what are the logical consequences of that?

› **The future is complex.**

Part of what makes the future so hard to know is the overwhelming amount of interacting forces, agents, and random events. Beginning to understand that complexity can help inoculate against it. Ask: How would your role or value change in the future if you considered new partnerships? What additional technologies, companies, or people might interact with the forecasts here in new ways?

› **The future is not yet determined.**

It's a common but unproductive mindset to assume that the future is something that we discover. Instead, the future is undetermined, something that everyone has a hand in making, which means that despite unknowns, you can steer towards a preferred future—as long as you've defined it with clarity (but not certainty). Ask how you can build a “future, now, next” strategy based on the preferred aspects of this report. That is, if you identify a preferred future, what can you do now, and what will be the immediate next step to set you on the right path to get there? What must be true for that future to exist, and do you have agency in making it happen?

“What if?” Scenarios



The future is not something predetermined, waiting to be discovered. Instead, the future is something over which we have agency. It can be difficult to imagine future possibilities and opportunities fully based on quantitative information alone. One way to understand, and then steer toward, the futures we desire is to illustrate what life may be like a decade from now. By personalising and humanising the future, it becomes easier to consider what actions you might need to take, or what outcomes you might want to avoid.

The following four scenarios each take a look at what a person might be doing in 2030. They imagine the work of a future brand manager dealing with a new type of attack, a streamer (the curator and host of an online show) experimenting with new digital tools, a farmer managing a diversified automated production system, and an investor riding the next wave of fisheries development. Each of these lenses hints at various forces and forecasts by starting with human-oriented, ground-level futures.

THE WAR ROOM

“WHAT IF?” SCENARIOS



THE WAR ROOM

Zoe sees the alert pop up again in the corner of her screen and can only sigh. She can't ignore it now—there's a DDoB attack underway. Distributed Disparagement of Brand. It happens often enough that there's jargon for it. It's not some crank posting shouty videos on YouTube or some irritable young radicals just being obnoxious, it's a wide-spectrum attack on the brand, Licious Foods. She pulls up the full report: coordinated social media posts accusing Licious of ignoring *E. coli* warnings, casual insulting references on TikTok, a paid opinion piece running on the most popular streaming site. Ah, they've even layered in some blog posts for the older generation. Whoever's doing this, they're spending a tidy sum.

Zoe is familiar with both sides of the conflict. Back in 2025, she was hired to do some “guerilla marketing” for a farm's direct-to-consumer brand. She knows the tricks used to undermine the perceived value of the competition—which means she knows where those tricks are weak. Pushing back on the DDoB should be straightforward but tedious.

She sends a ping to the rest of the war room (the “Brand Management Response Team” to the folks in budgeting) and starts assigning tasks. Consumer side will rebuild the charm of the brand with “personality-driven” social media posts, a few mildly subversive (but ultimately friendly) memes on Reddit, and a few stories that demonstrate Licious' transparency strategy for the newsfeeds. It all sounds easy-peasy, but it's not—the war room spends most of its time watching culture shifts, figuring out how to speak in ways that are persuasive this week, learning which comments on the brand are indicators of falling trust and which are just noise. The director calls it “weaponised sociology” as a laugh, but she's not far off.

Zoe knows coordinating the company's response with its supply chain is going to be tough, but it's the most important defence she's got. She has already discovered the DDoB is attacking some of the ag distributors who provide raw inputs to Licious Foods. Zoe's going to need to figure out how to redirect that ASAP without hurting potential future partners—she can't simply shift the blame. She sends a message to the Brand Management Response Teams at the distributors. This fire is going to take a coordinated effort to put out.

What a mess.

FUTURE FORCES



Viral misinformation in the food system



Interconnected digital infrastructure

FORECASTS



1 The war for the consumer relationship



6 The searchable food web

PADDOCK TO PLATE

"WHAT IF?" SCENARIOS



Paddock to Plate

Janie isn't the first to stumble on the lifecycle app, but she's the first to really raise awareness about it. The “Livestock Process Cycle” app is clearly meant for people in the business of processing and selling meat, not for consumers, but she just finds it fascinating. With a couple of taps (and an easily discovered retailer code for the local Maccas) she can watch the path the beef in her burger takes from paddock to plate. She's a bit surprised at how quickly it all happens. A few more taps and she can see the genome test results on the product, even trace lineage back to the cattle embryo supplier. Amazing.

A few days later, she shows off what the app can do on her livestream, and her followers love it. Within a week, it's in the top five “most downloaded” apps. Folks in the food industry are concerned at first—a demand for transparency isn't unusual, but consumer access to the added biological info certainly is. Is showing consumers that much information a liability or a selling point?

Janie and her online group believe they can connect certain genomes to certain health outcomes. Their bodies react differently to different sources. She starts to post videos about how to “eat the right genome” for weight loss, better skin, and even Crohn's disease. Her followers become ardent believers without waiting on any real scientific evidence supporting Janie's diet guides.

With all of this, Janie isn't surprised when restaurant chains start to offer up their own apps to trace food pathways, and not just for meat. Even some third-party apps pop up, produced by everyone from teenage environmental activists to celebrity chefs. Real research is being done on the particulars of how different genetic lines might have different health effects. But in the meantime, people aren't waiting—they're clamouring for as much transparent information as they can get.

FUTURE FORCES



Viral misinformation in the food system



Domesticating the cell

FORECASTS



4 Divorcing flavour, nutrition form



7 Biology goes digital



Buzz

Oliver still gets up at 4am out of habit. He doesn't have to go outside first thing, but he does it anyway. He likes to see first-hand how things are going on the farm. Screens make it harder to catch the details, what's out of place. Oliver will admit that he's grown fond of the low buzz of drone swarms taking off to carry out the day's tasks.

He makes note of the 4:30am temperature. He's obsessive about temperature trends now—he has to be. Each season seems to move further and further, setting new records, shifting what can happen and when. Used to be that he'd just worry. Now he's doing something about it, making his farm part of the larger climate battle.

He thinks about leaving the region, but whether he stays here or moves to a marginally more stable climate, he'll have to deal with learning new crops, seasons, and income streams. Oliver's already invested in his land here, and has begun building a vertical farm system that allows him to produce more suitable crops with less water during the longer and longer hot season when he can't grow crops in the field.

A quarter of his acreage is re-vegetated for carbon sequestration. It's a modest part of Oliver's income mix now, but it's likely to get bigger. Some of his drones are dispatched to do spot sampling for model calibration on the way to do solar panel maintenance checks.

There's another income stream—he's part of the local distributed energy grid. He's even signed up for a platform that lets him rent out temporary use of his storage spaces for distributed logistics companies. A friend of his who runs a winery is trying to sell the rights to their unique soil microbiome as a “branded terroir package.” These days, everything is an opportunity for more economic resilience.

Oliver tells his friends he's a “fourth generation farmer, but a first generation solar energy producer.” It's not the future Oliver imagined, but he realises he'll have to adjust—and then adjust again, and again.

FUTURE FORCES



Rewiring the grid



New geographies of climate change



Interconnected digital infrastructure

FORECASTS



2 Regional redesign



5 Supporting full-spectrum producers

NOT SO CRAZY AFTER ALL

“WHAT IF?”
SCENARIOS



Not So Crazy After All

Anthony took a risk. A crazy risk, really. Crazy enough that his investment firm gently pushed him out about 10 years ago. But Anthony held tight, putting his own funds in even after the firm dumped the investment. He managed to get a couple of partners onboard from outside the usual group of financiers and industry types—folks managing investments with the insurance industry. Turns out they pay close attention to this kind of stuff.

Many of the people operating in fisheries were sticking to their guns, eking out profits while struggling to work within stringent new catch limits, emissions standards and labour regulations. Many investors had turned to closed-loop fish farms inland, but as long as there was a demand for wild caught fish, Anthony knew there would be people out there fishing.

The risky new venture depended on automation, to maintain a competitive edge in catching and processing the fish, but also thrived on the connectivity of the world. Every fish they take out of the ocean is tagged and entered into a digital database with an easy-to-navigate web portal, open to the public. If he wants to, Anthony can watch sales in real time: a restaurant chain in Sydney just bought 50 kilos of mackerel that had been landed an hour ago; a cannery just placed a bid on a shoal

of tuna that the satellites picked up, but hadn't even been caught yet; a mother in Melbourne placed an order for a single seabass to be delivered to her doorstep for dinner on Friday.

Anthony will talk at great length about the technical details—the solar-cracked hydrogen fueling the autonomous fishing boats, the undersea shepherd drones ‘pre-sorting’ the fish to avoid illegal catch, even the side-business of gathering ocean-borne microplastics to sell to biocyclers back onshore.

But what really puts the shine in Anthony's eye is when you ask him about his former partners in the firm. They really couldn't see the waves of change coming in, and told him he was wasting time and money. Anthony is now considering whether to buy what remains of his old firm.

FUTURE FORCES



Interconnected digital infrastructure



New geographies of climate change

FORECASTS



2 Regional redesign



3 Outside solutions to climate problems

Future Forces

As we enter the decade of the 2020s, major forces of future change are already in motion. These forces are high-level and reach across categories; they include environmental changes, technological developments, and new infrastructure. In order to understand the operating environment of the future, it's critical to look at these underlying directions of change. They lay the groundwork for developing more specific future forecasts.



Viral disinformation in the food system

Food issues become increasingly susceptible to disinformation campaigns



Interconnected digital infrastructure

An interconnected system of digital capabilities unleashes new opportunities in agricultural supply chains



New geographies of climate change

Movement of people, climate regions, and crops define an era of uncertainty



Rewiring the grid

Distributed energy production is made possible by advancements in renewable and alternative technologies



Domesticating the cell

New products, experiences, and concerns will arise from our ability to design biology



Viral disinformation in the food system

Food issues become increasingly susceptible to disinformation campaigns

As social media permeates the lives and communities of virtually everyone around the world, there is also a parallel increase in the spread of disinformation—intentionally misleading, incorrect information—and an associated decline in trust. The coming decade will see an acceptance of an environment of constant disinformation as a new norm, and a continual back-and-forth between those who sow mistrust and disinformation via media technology and those who seek to mitigate it.

While propaganda is certainly nothing new, we're seeing the emergence of technologies that allow bad actors to do their work much more rapidly and effectively, but also with less control over the effects. Deepfakes (photos and video manipulated with artificial intelligence to create nearly undetectable fake media), conversational AI like GPT-3 (a neural network that can write and converse indistinguishably from a human) and cheap, accessible botnets (systems of software applications that run automated tasks on the internet) that can manipulate online discussions will all contribute to a future where average people won't be able to verify information for themselves.

Many food issues are also highly politicised, making them prime targets for disinformation campaigns. Food safety and reliability are easy targets for viral disinformation because they're a universal and sensitive topic.

This type of disinformation will also be used by industry groups, lobbyists, or even companies for commercial gain. The tactic of directing public discourse about a particular food product or industry via overwhelming viral disinformation will only become easier to orchestrate, meaning more actors will manipulate public perception of previously unassailable institutions like established scientific publications.

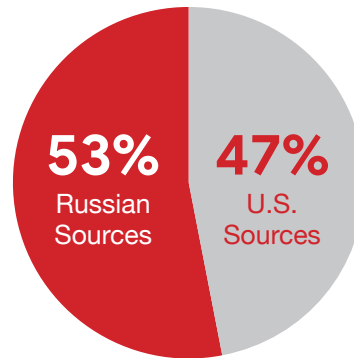
However, not everyone will simply allow these tactics to reshape the way information is spread. New ways to detect inaccurate information online will help expose "bad faith campaigns" as early as possible. New preventative measures and fact-checking tools will allow the public to boost their collective immunity to such campaigns. Viral information campaigns will become a standard tool for influencing any public decision. There will also be a normalisation of addressing issues like viral conspiracy theories propagated by disinformation attacks early on by building in response plans and preventative measures.



drivers

Research published in *GM Crops & Food: Biotechnology in Agriculture and the Food Chain in 2019* found that ‘Distinctive patterns in Russian news provide evidence of a coordinated information campaign that could turn public opinion against genetic engineering, with a significant portion of GMO coverage coming from Russian sources.

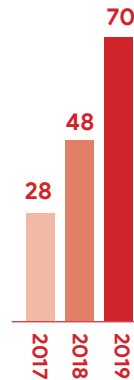
Major English-language media outlets, coverage of GMOs



The Oxford Internet Institute found that “organised social media manipulation has more than doubled” [between 2017 and 2019], with 70 countries using computational propaganda to manipulate public opinion.

Increase in social media manipulation campaigns among countries surveyed by the Oxford Internet Institute

Number of Countries



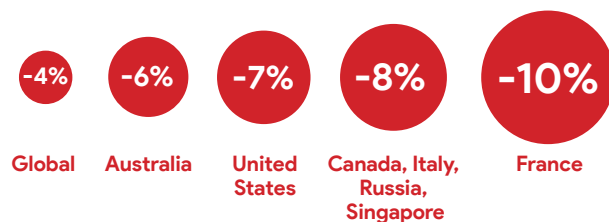
150%
increase
in countries using
organised social media
manipulation campaigns
over 2017–2019.

The 2020 Edelman Trust Barometer found that 66% of people globally worry that “technology will make it impossible to know if what people are hearing or seeing is real.” Australia had one of the largest recent declines in trust in technology, with a six-percent point drop from 2019.

In 2020, two out of three people worried about technology’s impact on trust.

66% of people worried that technology will make it impossible to know if what people are seeing or hearing is real.

Trust in technology declines 2019–2020





Interconnected digital infrastructure

An interconnected system of digital capabilities unleashes new opportunities in agricultural supply chains

The boundaries that informed efficiency over the past century will no longer be the same boundaries that dictate efficiency in the future. In the same way that the transformative power of automobiles was only truly unlocked when subsequent infrastructure linkages—freeways, petrol stations, footpaths, and the like—were made, we are on the brink of transformative new possibilities as digital technologies and infrastructure rapidly mature.

Over the coming decade, we will continue to see new organisational systems enabled by a suite of emerging technologies which are powered by AI and high-resolution, real-time monitoring, such as decentralised administration and modular production lines. In the next decade, however, we will also push into a new frontier as these technologies give rise to the simulation and networking of entire systems. These interconnected systems of digital capabilities will allow for entirely new opportunities.

In agriculture, these highly networked systems will begin to include not only individual farms but also entire value chains, crop-breeding programs, and whole groups of consumers. Increased connectedness to global information and monitoring networks will allow businesses to optimise their logistics, sales channels, and production systems. Thanks to improvements in the speed and power of biological simulation and AI-powered logistics, organisations will be able to test and control more variables related to how they grow, harvest, process, and sell their products.

As farms continue to consolidate over the next decade, these connected technologies will allow producers to manage a broader set of operations by themselves. This will change the skill set and involvement needed to operate in new levels of the value chain, be that agronomy, accounting, storage, branding, and beyond.

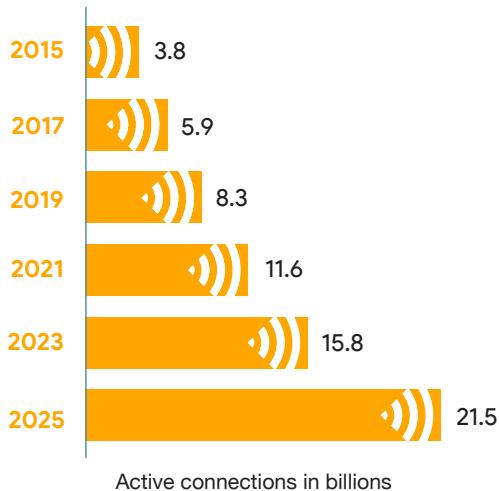
Organisations along the supply chain will be able to reduce the information gap between themselves and consumers. This will enable signals to flow seamlessly back up the supply chain. This will flag changes that are needed to grow and process products that are better-suited to current markets. With a granular understanding of demand, organisations along the supply chain will produce a finely tuned mix of products for specific buyers rather than depending on selling into the commodities market. With a strong network of high-resolution sensors and monitors, and autonomous equipment that closes the loop between insight and action, organisations will be able to optimise their products for economic and climatic resilience. These choices will create a market and infrastructure very different from the current agriculture system's landscape, breaking the current paradigm limited by today's infrastructure, transportation, and labour costs.



drivers

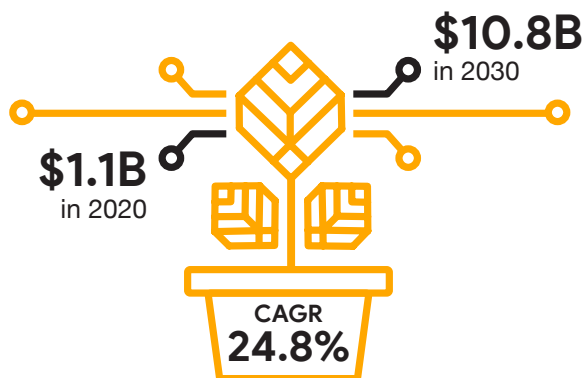
By 2025, more than 21 billion things will be connected using IoT technology. Growth in IoT and cloud-based platforms, the surge in the adoption of 3D printing technology in the manufacturing industry, and the reduction of project cost are major factors driving the increase of IoT devices and systems.

Growth in IoT-connected devices worldwide



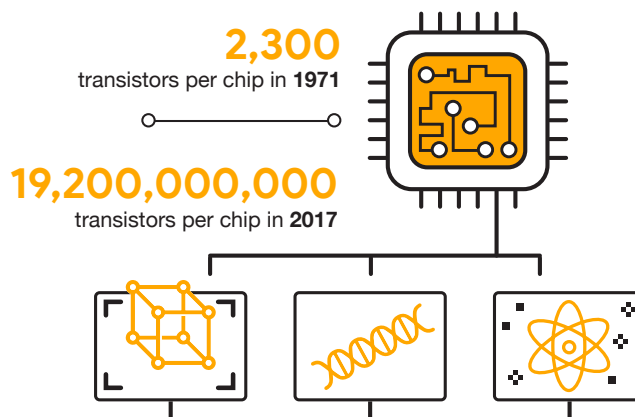
Globally, the revenue for artificial intelligence in agriculture is anticipated to see a compound annual growth rate (CAGR) of 24.8% between 2020 and 2030. This technology's application has a range of impacts, from automating weed and pest control to facial recognition for livestock.

Global growth in market for AI in agriculture



Moore's law, which says the number of transistors that can fit on a computer chip doubles about every two years, has mostly held up for the past 50 years. While many experts think we will reach Moore's law's physical limits by 2025, new technologies will likely continue to increase the world's computing power. These include 3D computing, DNA computing, and quantum computing.

Growing computing power, new potential for sustaining growth





Rewiring the grid

Distributed energy production is made possible by advancements in renewable and alternative technologies

Globally, renewable and alternative energy is set to grow significantly as political, economic, and environmental forces drive a reshaping of how we produce energy. Rather than looking to a single energy source to replace fossil fuels, the next decade and beyond will see significant investments in radically remaking the energy system.

The shift away from fossil fuels is accelerating around the world, driven by social pressure for change and economic forces such as institutional demand for compliance with environmental, social, and governance (ESG) requirements.

The cost of renewable energy is dropping, quickly becoming competitive with fossil fuels. In much of the developed world, wind and solar provide a rapidly growing portion of electricity generation, and some regions in North America and Europe expect to be 100% renewable (with storage backup) by 2030. While wind and solar at utility-scale are not drop-in replacements for fossil fuels in terms of space requirements and production cycles, they have several features that differentiate them from fossil-fuel-based production.

Solar power can be readily adapted to a distributed energy grid. Individual structures, from homes to parking lots, can employ solar panels for on-site energy production. Depending upon grid infrastructure, this could be added to total available grid energy, used solely for the site, or be part

of a local microgrid at a neighbourhood or community level.

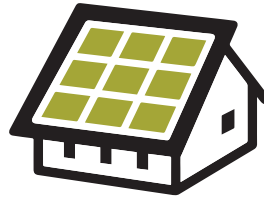
Aside from traditional renewables, developments in next-generation nuclear power such as sodium cooling and small modular reactors mean that this power source will become simultaneously safer, more efficient, and a better possible avenue for climate-change mitigation. Hydrogen energy systems are seeing increased interest from investors and industry as a green energy possibility. While hydrogen fuel cells are a proven technology, they currently only excel in specialised use cases. Investors seeking a wide portfolio of alternatives to fossil fuels will pave the way for renewed interest in building the infrastructure for hydrogen power.

All of these alternative systems lend themselves to more distributed production systems. For example, around the world, experiments in self-managed microgrids indicate the interest and possibility in small communities managing their energy production and markets.

drivers

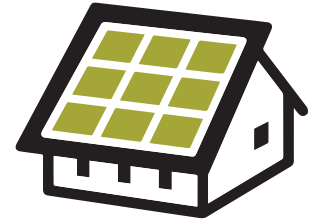
Energy Networks Australia's [Electricity Transformation Roadmap](#) estimates that by 2050, up to 45% of electricity generation in the country will come from distributed energy production sources (such as rooftop photovoltaics). This will result in more than \$2.5 billion paid to distributed energy producers.

Energy ownership in Australia by 2050



45%

of electricity generation from **distributed** energy production

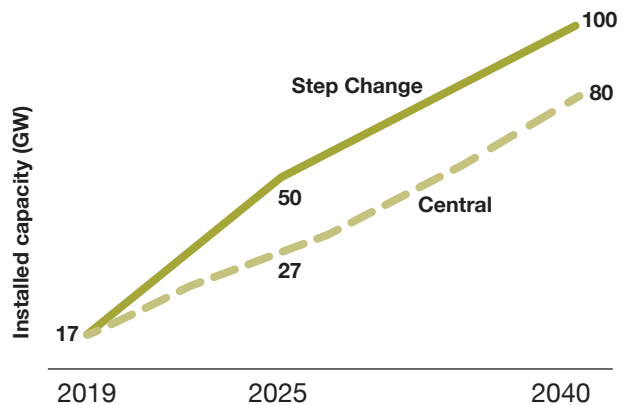


55%

of electricity generation from **centralised** energy production

An Australian Energy Market Operator (AEMO) [Renewable Integration Study](#) projects that Australian renewable energy (wind and solar) production will increase from 17 GW in 2019 to 27 GW in 2025 under their more conservative scenario, and over 50 GW in their "Step Change" scenario. This would mean more than 75% of the grid would be running on renewables. By 2040, those production rates could double again.

Forecasts for renewable energy generation in Australia



The [global hydrogen energy storage market](#) is expected to expand at a compound annual growth rate (CAGR) of +5% from 2020 to 2027. This is one critical component of a functioning hydrogen energy system. Infrastructure development in transportation, management, and end-user tools will similarly help overall adoption grow.

Forecasts for renewable energy generation in Australia

global hydrogen energy storage market

[+5%]

CAGR from 2020 to 2027



Domesticating the cell

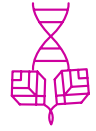
New products, experiences, and concerns will arise from our ability to design biology

Synthetic biology has developed rapidly, and researchers and industry alike are building tools for molecular manipulation. In the next wave of innovation, we will see both the natural and the built world transformed through synthetic biology. Some of it will be familiar, such as engineering individual soil microbes or designing plants and animals to have desirable traits. But advances in synthetic biology will also extend throughout the whole supply chain, such as embedded biosensors, bioproducts produced in culture, and living compounds for packaging and building materials.

We will see a change in the way agricultural work is done as production happens increasingly in labs or biofactories with the aid of robotics and artificial intelligence. Today, synthetic biology (or “synbio”) companies such as Zymergen and Ginkgo Bioworks are already amplifying the manufacturing of flavours, enzymes, and biofilms using entirely automated facilities. They design novel molecular products using vast metagenomic libraries powered by machine intelligence.

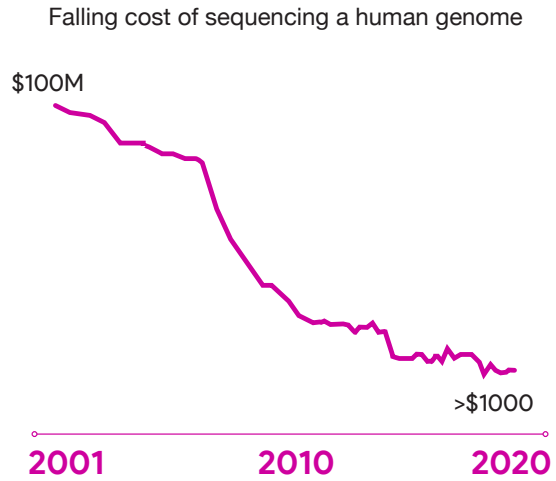
The science of programming—or domesticating—biology is still relatively new and promises to influence nearly every sector. Over the past 10 years, some schools have begun to teach students as young as secondary school age practical programmable biology. As these children grow up and emerge as leaders in business and the agricultural marketplace, they will bring synthetic biology into the mainstream.

The products of synthetic biology will challenge consumers on issues of ethics and safety. Urgent needs will also drive demand for more food and resilient production systems as the population grows and the planet warms. Medicine will be a bellwether of innovation and acceptance as biology is used to synthesise new antibiotics and vaccines. Tastes shaped by belief systems and social pressure will put changing demands on the food system that will be addressed using synbio. And the very meaning of genetic modification will be reshaped as gene-editing technologies such as CRISPR allow for the potential for gene-edited humans. The winners that emerge out of this complex new world will be able to carefully balance domesticating the cell while earning and maintaining the public’s trust.



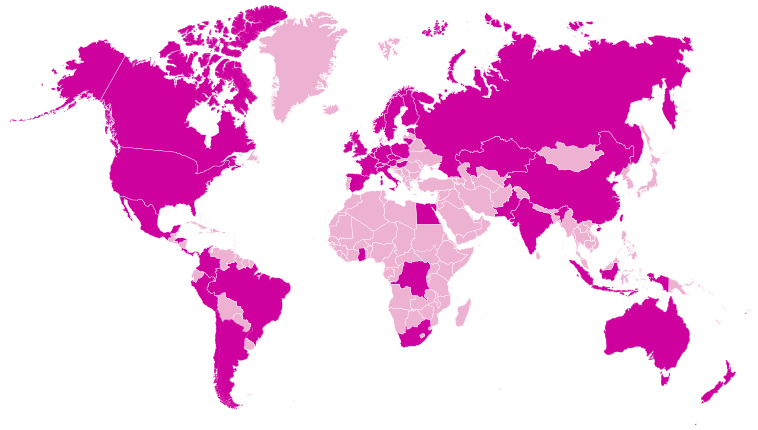
drivers

DNA sequencing is becoming cheap and drives a biological data revolution. Since the first human genome sequence was drafted in 2000, the cost to sequence DNA has dropped at a rate greater than that implied by Moore's law (i.e., costs are halved every two years), driving interest and access across industries and to consumers. We now have more data about human, plant, and animal biology than at any time in our history, creating a foundation of knowledge from which we will build new products and services.

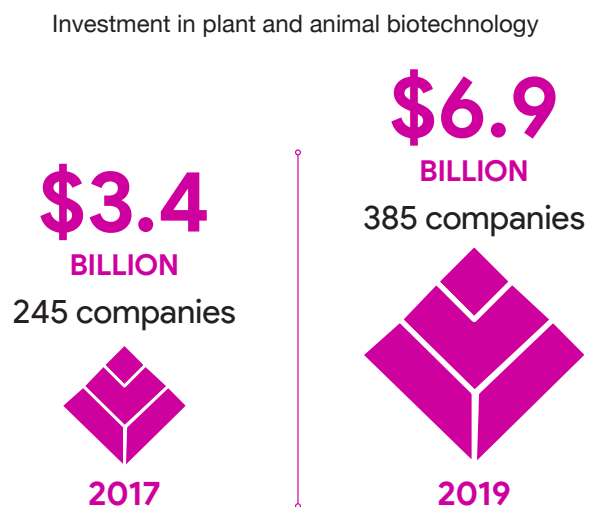


The increase in synthetic biology education in universities and even secondary schools globally will drive the next generation of leadership in synthetic biology. iGEM (international Genetically Engineered Machine), the largest organisation bringing together synthetic biology students, invites teams to build a novel living system each year. Since its inception in 2004, It has grown from 5 to over 300 teams, with total participation from over 40,000 people, and has launched some of the world's fastest growing synthetic biology companies.

Countries represented in the 2020 global iGEM synthetic biology competition.



In the past two years, there has been a doubling of investment dollars in start-ups working in plant and animal biotechnology—US\$6.9 billion across 385 companies in 2019, compared with US\$3.4 billion in 245 companies in 2017.





New geographies of climate change

Movement of people, climate regions, and crops define an era of uncertainty

As climate volatility increases the frequency and intensity of extreme weather events, the people, animals, and plants accustomed to operating in certain environments will need to adapt to new places. Migration spurred by climate change, both domestic and international, is steadily increasing, changing local demographics. Suitable production zones for fishing, farming, and forestry systems with which producers are familiar are shifting or disappearing entirely due to the disruption of established climate patterns.

In Australia, CSIRO research describes the beginning of this shift, noting that [“climate changes seem to be happening faster than expected.”](#) Today, production systems are already starting to move as a result. For example, wine producers have already had to change regions or crop calendars, despite preexisting investments in place-based infrastructure. Other producers, rather than change location, are shifting to drought-tolerant varieties of crops and livestock.

This will happen on a global scale as well. For example, some of the world’s breadbaskets will face challenges in meeting production without technological and practical interventions, while new ones will emerge in the northern geographies of the world that become suitable for grain production. The commercial and geopolitical implications will be significant and complex.

Internationally, fisheries present some of the first case studies of how these shifts conflict with human systems that have been built on the assumption of climate stability. Many species of fish, or entire fish stocks, have reacted to changing ocean conditions by migrating away from their normal geographies. However, our fishing industries aren’t designed for these changes. Entire nations will be left unsure of how to claim their quotas when their wild fisheries have gone, and the infrastructure and assets that arose out of that fishing activity—fleets, processing facilities, even entire towns—have become stranded.

This will be the ongoing story of the next few decades: as ecosystems become less hospitable, people will shift what they grow and their systems for doing so. It will be a shift from relative stability to relative volatility, but it won’t be a singular change, where producers can settle into a “new normal.” Instead, it will be an era of uncertain change, where no one solution will remain viable for the long term.



drivers

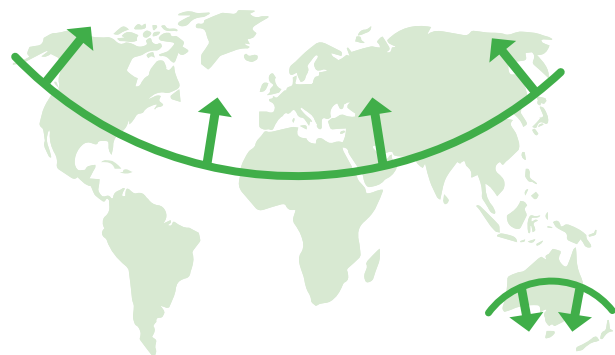
CGIAR projects that globally, most common crops will see a decrease in growth rates by 2030 while simultaneously increasing in price.

Nine out of ten crops will see a decrease in growth rates



A study published in Scientific Reports found that in the Northern Hemisphere, the northern border of the area suitable for agriculture will shift steadily northward over the next century. Similarly, in Australia, the broadacre cropping belt is moving south.

Border for suitable cropping zone shifts to higher latitudes



The Intergovernmental Panel on Climate Change (IPCC) reports with high confidence that while risks to land desertification are increasing, some technologies and practices can help avoid the risks and reduce the loss of arable land, including adopting new crops.

IPCC findings on climate change and land issues



Risks from desertification will increase



Regionally specific technological solutions can avoid, reduce, and reverse desertification.
These solutions can both increase productivity and mitigate climate change.



In a future landscape defined in part by the forces above, the roles, relationships, and outcomes of various stakeholders will look significantly different than they do today. One way to examine those changes is through forecasts, which posit possible future states. These forecasts are plausible conclusions that stem from some combination of the future forces and early signals of change—the ways that people around the world are already beginning to experiment with the possibilities afforded by new technologies, policies, social structures, and information.



The war for the consumer relationship

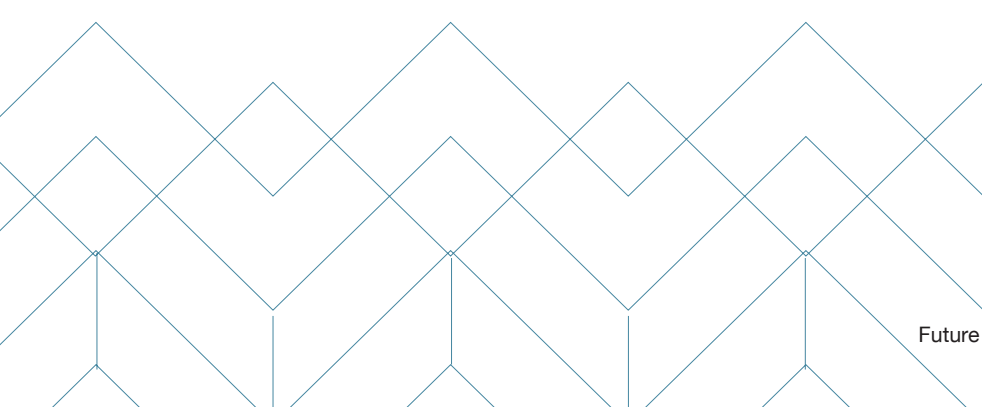
A future of competing for insights and trust

Digitisation of the food system is creating new troves of valuable consumer data. At the same time, the rise of social media has created opportunities for constant, two-way engagement with consumers. These trends have significantly increased the commercial incentives, and therefore competition, for direct consumer relationships. Changing social dynamics from the COVID-19 pandemic have accelerated this transition, with producers, processors, packers, and even tech companies selling food and agricultural products through direct-to-consumer (DTC) channels.

The next decade will see an increasingly crowded landscape of new entrants and existing actors, like producers, processors, logistics companies, or distributors, playing new roles and competing for consumers by creating their own brands, platforms, and consumer-facing channels.

Organisations that can capture consumer and food data and engage with consumers to maintain trust will be the winners in this world. But getting the right data to uncover what consumers want will be difficult, as it will come through many sources: physical retailers will race to add in-store sensors and consumer behaviour models, digital platform players will leverage their head start in data analytics to disrupt traditional sales channels, and even processors and producers will build relationships with and seek out direct channels to consumers.

The waging of this “war” will give rise to less savoury tactics as well; with so much of the consumer relationship managed online, some companies, interest groups, or even just loosely associated consumers will turn to the power of disinformation to sway opinion. Just as today the political space is flooded with hard-to-parse, rapidly spreading disinformation, the food space of 2030 may be similarly polluted. Disinformation is a quick-to-escalate game—if one brand or group starts to do it, others may feel they have no chance but to fight fire with fire and create their own campaign. However, only those with direct channels to engage with their consumers will be well placed to maintain trust.





signals

PERDUE FARMS

WHAT:

[Perdue Farms starts its own e-commerce platform.](#) The large U.S. meat processor recently launched a site where it sells both its own brands and others. They're shipping their orders in recycled packaging and tying purchases to donations to an environmental charity to build a perception of sustainability.

SO WHAT:

Not only is the move into DTC a significant change for the company, but they're also currently using outside (Nielsen) data on consumer preferences to dictate their marketing choices around brand sustainability. As brands like this ramp up their data collection through these channels, they'll quickly become even more competitive.



CHIPOTLE

WHAT:

Chipotle, a fast casual chain (i.e., a restaurant that does not offer table service but markets higher-quality, fresher food than typical fast-food chains), [started a virtual farmers market](#) where customers can shop for meat, dairy, and grains online, as well as watch video streams from producers. To incentivize producers, Chipotle is covering the costs of onboarding.

SO WHAT:

Rather than developing a new revenue stream, they're aiming to solidify their supply chain and ensure inputs. Platforming and nurturing producers is one way to make sure they have reliable access to sources and can leverage consumer-level insights to manage both their upstream and downstream relationships.



BARN2DOOR

WHAT:

[Barn2Door provides DTC platforming as a service for producers.](#) The software company essentially gives producers a turn-key option to create and manage an online brand for their products. It provides these producers with a new sales channel and opportunities for consumer communication and simple data collection.

SO WHAT:

Not only does this signal an era where DTC platforms become easy and commonplace, but it also signals new ways of creating and growing brands. The future may see a much more diverse ecosystem of brands, limited not by competition for retail shelf space, but by who lives or dies through fulfilling direct consumer desires.





insights

- › **Producers' roles will increase** within their supply chains, particularly as brand and communication managers. Producers will either need to master these new, mostly digital and consumer-facing skill sets or hire them into their businesses.
- › Producers may find that organising into cooperative, **“digital guild” structures** may be an effective way to build strong regional brands and share the cost of developing essential marketing and brand capabilities. These organisational models won't be based on shared ownership of physical assets as they were in the past, but rather on building and maintaining DTC channels and trusted brands that can effectively compete in new, digital marketplaces.
- › **Cybersecurity and consumer privacy** concerns will be amplified, and there may be regulatory implications around data security, ownership, and monetisation as the focus on consumer data for competitive advantage increases.
- › **Brands will have strong incentives to extend their influence** and reach into the upstream supply chain to promote practices (e.g., agronomy and management) that build and maintain trust with consumers. This could create competition with existing channels of advice and service provision.





Regional redesign

A future of decentralised opportunities

Today, high labour and energy costs constrain Australia's global competitiveness. In the next 10 years, a combination of cheap, decentralised green energy, advances in automation, and regionally led COVID-19 recovery strategies will unlock new opportunities, especially for regional areas.

Automated technologies such as self-driving tractors and robotic sorting facilities are laying the groundwork for an interacting ecosystem of algorithmic decision-making. Different parts of the value chain will communicate and collaborate without a human in the loop and usher in a future of disintermediated supply chains and producers who can optimise to grow goods that meet exacting market demands. Producers will be able to offload much of their decision-making to automated processes that can determine and deliver exactly who wants which products and when. Everything from genetics to irrigation to farm layout in horticultural operations will be optimised to enable automation. For example, orchards may no longer need cool rooms and grading lines as autonomous systems will manage trees in place, removing below-spec fruit before it's ripe, harvesting fruit for targeted fulfilment, and delivering different specifications of fruit to the buyers best suited to sell it.

At the same time, the increased availability of cheap, renewable energy sources will unlock opportunities for new production systems for Australia, particularly in regional areas with a lot of land away from population centres. Energy-intensive manufacturing processes, including ammonia production and metals processing, will become economically viable to conduct in Australia. Low-cost distributed energy systems will also enable new approaches to large-scale land management, such as desalination for irrigation, which are currently sub-economic.

Additional opportunities for value-adding near regional production facilities will boost local economies. For example, a cotton producer may use solar energy to pump and irrigate fields during the harvest season and then supply excess energy post-harvest to a neighbouring ginning facility. The co-location of primary production and processing will reinforce the just-in-time models enabled by automation as the physical expanse of supply chains will be reduced.

While dense urban settings may be able to handle the effects of automation and cheap green energy with only minor infrastructure redesign, regional operations will undergo more profound physical and systemic changes as they begin to take full advantage of these opportunities. New infrastructure and integrations will be required to support newly competitive industries and just-in-time supply chains. For example, physical spaces like warehouses may be less important in autonomous, adaptive, and shorter supply chains of the future. Instead, built spaces will evolve to fit the needs of this new system. On the retail end, the emergence of "dark stores"—essentially regionally distributed mini-warehouses that serve automated supply chains and don't need to be in residential areas—signals this new infrastructure. Regional infrastructure will also need to evolve to accommodate new industrial activity and opportunities as regions become exporters of green energy—whether directly or in the form of vertically integrated products created with zero-carbon systems.



signals

GRATTAN INSTITUTE

WHAT:

[Grattan Institute](#) makes a case for using proposed hydrogen energy developments for green steel manufacturing in the regions. They argue that using the potential manufacturing power of the energy supply will help position Australia globally as a green energy superpower as well as develop opportunities in the regions.

SO WHAT:

Agriculture could follow a similar path. As more green energy systems are brought online, the real global advantage is in using it to produce valuable products and positioning Australia as a potential global “electrostate.”



JAMES TYLER

WHAT:

Australian firm [James Tyler](#) has built a supply chain to deliver fresh produce from Australian farms to Chinese consumers within just 72 hours. By removing intermediaries and implementing tech-enabled logistics infrastructure, they are able to sense and fulfil consumer demand faster than ever before.

SO WHAT:

This type of logistics simplification, in combination with automation, will pave the way for supply chains that operate in real time and on demand, even across borders. In order for these streamlined supply chains to deliver optimally, however, logistics and market infrastructure will also need to evolve.



FIRST SOLAR-POWERED ROBOTIC DAIRY FARM

WHAT:

A New South Wales dairy became the [first solar-powered robotic dairy farm](#) after reconsidering its energy source because of the high cost of traditional sources. The farm is now working with a herd of 210 and growing.

SO WHAT:

While advanced technologies already exist in some cases, the prohibitive dual costs of both the technology itself (e.g., batteries) and the energy required to run it are holding back the transformation of some operations. As technology costs fall and autonomous machines’ power rises, low-cost and abundant renewable energy will combine to empower advanced operations.





insights

- › **An agri-food marketplace that is fundamentally controlled by algorithms will raise important policy and regulatory questions** about ensuring fair and competitive dynamics. The public sector will need to keep pace and stay ahead of developments in the private sector.
- › Autonomous, closed-loop, **algorithmic processes will also change the retail supply chains** for farm products and services. For example, a piece of farm machinery will be able to schedule its maintenance, drums of chemicals will be able to order refills automatically, and automatic pest detection will self-schedule biologic spraying. The role and business models of service providers, including agrochemical companies and agronomists, will need to keep pace as these capabilities evolve.
- › **Australia's ability to compete in manufacturing and processing** on a global scale will create new economic opportunities and have important geopolitical implications, providing insulation from potential trade dependencies and risks. A shift from exporting raw goods to processed goods, and towards increased sovereign manufacturing capabilities, will also enable Australia and regional areas to capture and retain more economic value. For example, ammonia production onshore might shift Australia's import dependencies for agricultural inputs.





Outside solutions to climate problems

A future of managing for viability amidst climate variability

By 2030, the world is on track to hit a 1.5° C increase in average temperatures—a level that marks a likely but dangerous change in the Earth's systems. Some of the changes will include not just the physical—increased bushfires, hail, floods and droughts—but also the social: consumer demand for environmentally sustainable options and the increased pressure on the license of agriculture and food companies to operate. The approaches we've used in the past to manage variability will need to rely on new technological capabilities, including from outside agriculture, in order to succeed in the future.

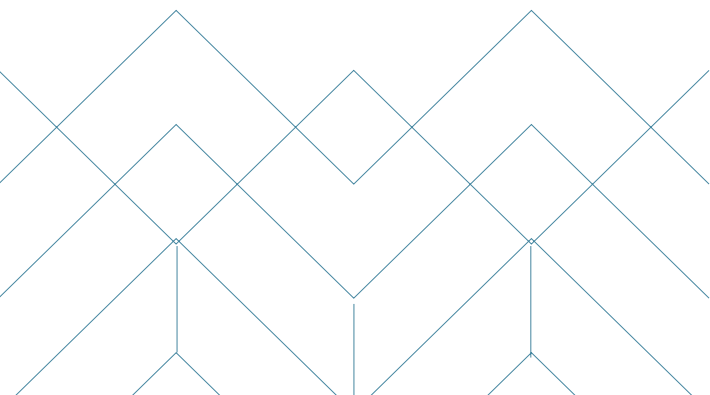
While the past century has seen agricultural production optimise for yield while managing for climate and market variability, as environmental and consumer pressures increase, the tools and skills needed to respond will change. Actors along the value chain, from input companies to producers to brands, will need to look to new technologies and alliances to solve climate-related challenges as we shift from managing variability to ensuring viability.

Seed and input companies may need to partner with advanced sensing and data science companies so they can more rapidly identify traits and products that enable customers to manage risk better. For example, shorter season varieties may be preferable to higher-yielding, longer-growing varieties (or perennial/natural landscapes capable of providing nutrient outputs) that extend seasonal climate risk. In other cases, protected cropping and technology-enabled controlled environment solutions—enabled by cheaper, more robust renewables—may be necessary to continue to produce in some regions.

Where it's impossible to develop new, viable production solutions, technology-enabled retrospective fixes may be required. Some problems caused by volatile climate effects may be retroactively fixed with synthetic biology manipulation and bioremediation (improving soil microbiota or water through natural systems).

For example, it may be possible to remove smoke taint from produce near a bushfire or improve low nutritional yield incurred by higher levels of atmospheric carbon by introducing tailored microbes into the soil.

Given the complexity and speed of the challenges producers will face, and as organisations and governments recognise that many climate effects are too large and systemic to deal with alone, we will see an increase in pre-competitive and cross-sector collaborations. For example, as the demand for net-zero carbon operations increases, transport and processing companies will need to partner with NGOs to develop socially trusted solutions. Similarly, they may need to partner with resources companies to develop viable alternatives to the current fuel and energy systems.





signals

OREGON SOLIDARITY WINE

WHAT:

[Oregon Solidarity wine](#) was created by a group of grape growers in the northwestern United States, where wildfires exacerbated by climate change caused their buyer to reject a large portion of their yield. In response, a group of the affected growers created a new brand to process their harvest into a wine that not only tasted good but had a strong brand story behind it.

SO WHAT:

This type of pre-competitive collaboration will become increasingly useful as a tool when the effects of climate change demand severe trade-offs. Current technologies such as social media enable actors to control more of their value chain, and future technologies will expand this reach.



NEW HYDROGEL MATERIAL

WHAT:

A [new hydrogel material](#) allows for self-watering soil that can give farms in arid regions more resilience to droughts as well as expand potential growing regions. The gel works by pulling down atmospheric water at night and releasing it during the day.

SO WHAT:

Technology fixes will play a crucial role in redefining how producers can adapt to climate change. Some of them will merely help slow down yield reductions while others will redefine the limits of where certain crops can be grown.



CLIMATE CHANGE-DRIVEN DROUGHT

WHAT:

A [study](#) from researchers at Cornell University and Washington State found that climate change-driven drought forces farmers to choose between yield or reliability. In Australia, [potential wheat yields have declined](#) by 27% since 1990 due to climate change.

SO WHAT:

This indicates the need for an approach based on balancing both yield and stability in increasingly volatile climate systems. However, the need for both increased yields and resilience may be at odds.





insights

- › There will be no silver bullet solution, and the pace of change will continue to accelerate. This means research and **industry organisations will need to adapt their processes** to keep pace with commercial realities.
- › The importance of **soft skills**, including communication, facilitation, and collaboration, will increase as cross-sector, cross-industry, and cross-geography partnerships become necessary in both the private and public sectors.
- › As a **wide range of solutions**— including producing in different places, producing in other ways or with different technologies or retroactively “fixing” production—are developed to ensure viability, there will be important questions raised about **access and ownership to intellectual property** (e.g., what should be considered as public or industry goods versus private).
- › As **production** occurs in different places and with new methods and infrastructure, there will also be an innovation opportunity in **rescuing otherwise stranded assets**. These assets might include land, equipment and machinery, processing facilities, and logistics infrastructure that could be used to support new business models or industries altogether.





Divorcing flavour, nutrition, and form

A future of moving beyond conventional categories

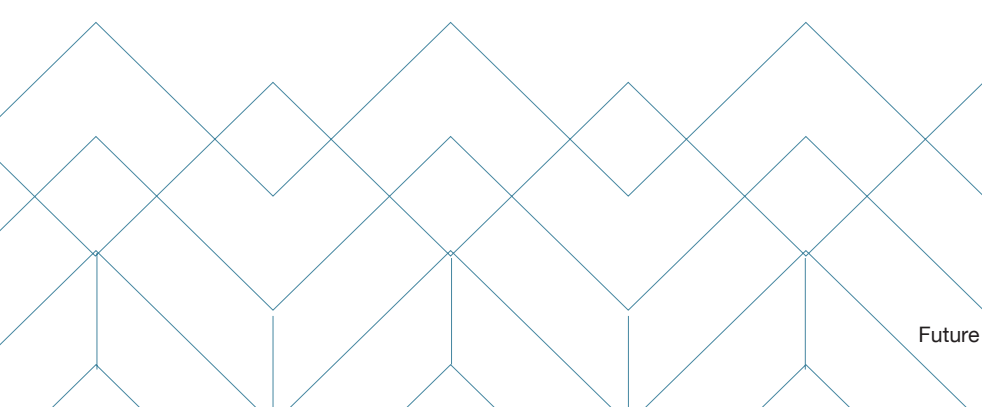
For the entirety of human history, the aspects of food that make it what it is—the flavour, the nutritional elements, and the physical form—have been more or less inseparable. A banana tastes like a banana, is made up of a banana’s molecular components, and looks like a banana. Even in the past century, with the advent of synthetic flavours and genetic engineering, the facets of a basic food item have remained bound together.

Today, we are beginning to see the boundaries of traditional food products and categories blur with the rise of blended products. These are foods whose inputs are mixed to meet the messy array of consumer demand: a latte made from half cow milk, half almond milk that caters to taste, health, and environmental concerns, for example. But advances in gene editing and biological programming over the next 10 years won’t just blur these boundaries; they will completely disrupt them. Cultured meat, customised molecular production, 3D printing, and powerful artificial intelligence will allow companies to use various inputs to design products that look like one thing, taste like another, and have a tailored nutritional profile.

The ability to manipulate all of these factors independently of one another will mean that food will be tailored to delivering the best experience and results for consumers and won’t be bound to conventional definitions or categories based on inputs. Companies will compete to own and

define these new category-agnostic products and the experiences they create for consumers. For example, “sausage” of the future won’t be differentiated along the lines of pork or beef as we see today. Instead, we will see a range of branded products that use a mix of traditional animal meat, cell-grown meat, vegetable proteins, and proprietary molecules to compete based on mouthfeel, signature flavours, and nutritional profiles.

The ability to engineer the nutritional profile of foods becomes even more powerful when considering the possibilities of personalised nutrition based on genetic composition and microbiota. Today, start-ups are offering services that provide diet recommendations based on individual genome and biome analyses. Once they’re able to pair those services with tailored and distributed food creation, it will enable a pipeline of creating food customised to an individual’s dietary needs, taste preferences, and practical demands of form factor.





signals

VOW

WHAT:

[Vow](#), an Australian start-up, is changing the concept of meat by building a library of cell lines and genetic traits to help redesign cultured meats. Similarly, [NotCo](#) in Chile uses AI to design ingredients for their animal product substitutes to produce the best version of milk, ice cream, or mayonnaise.

SO WHAT:

As more food makers develop this approach, they'll not only blur food category lines but invent entirely new ones. For these food designers and makers, the most valued inputs aren't traditionally grown animals or crops, but rather the potential traits that those products offer.



BRIGHTSEED

WHAT:

Brightseed uses [artificial intelligence discovery tools](#) to identify and catalogue phytonutrients that impact human health in a vast array of plants. By understanding the molecular-level nutrients in plants, producers will create foods that contain the healthiest balance of nutrients or begin to breed new varieties that optimise for specific health outcomes.

SO WHAT:

Creating highly customised or entirely new foods is a massive combinatorial problem from the perspective of a producer working at the molecular level. AI tools will be one of the accelerators of this process, and virtually all new entrants in the field will rely on them.



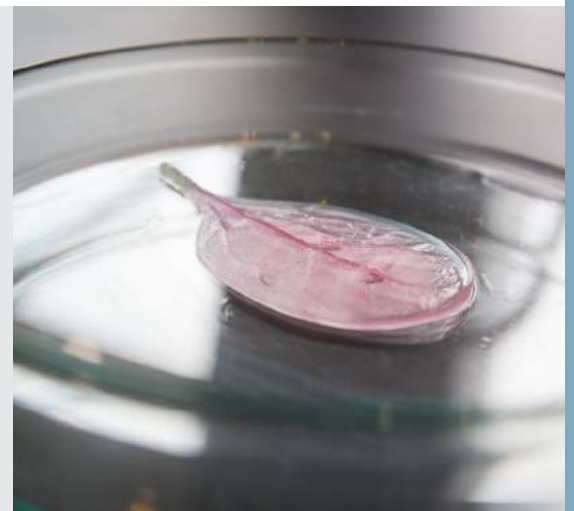
BIODESIGNER KAROLINA SULICH

WHAT:

Biodesigner Karolina Sulich created lab-grown meats such as chicken on the scaffolding of a [decellularised spinach leaf](#). She similarly created scaffoldings out of apples and flowers, which retained their physical form while their cells were replaced with meat cells.

SO WHAT:

The science-fiction fantasy of giving your children spinach that looks and tastes like their favorite snack may not be so far-fetched after all. The ability to manipulate food at the molecular level won't just allow for nutritional tailoring but also the very form factor that food "comes in."





insights

- › **Product categories will undergo fragmentation** and proliferation, meaning that agricultural “commodities” are no longer interchangeable or undifferentiated. Instead, new inputs (e.g., protein and flavour molecules, genetic material, and growth factors) and processes (e.g., fermentation and extrusion) will undergo commodification to support new production modes across supply chains.
- › Our **ability to control the nutritional value of processed and “natural” food products** could change consumer and scientific perceptions of what is considered healthy, desirable, or premium. Of course, these perceptions will be susceptible to social engineering and manipulation and will have implications for marketing and product positioning strategies.
- › In a **category-agnostic world**, food and fibre brands will gain power, and their roles in consumers’ eyes will change. **Consumers will follow brands’ product releases in food as they do in tech today** (e.g., the iPhone). Brands and producers will also be challenged with maintaining consumers’ trust and confidence as the food system becomes increasingly complex to navigate and understand.
- › Everything from regulations around food safety and standards to nutritional guidelines to the layout of grocery stores to marketing and communications is built on **definitions and classifications that are on the verge of being disrupted, requiring adaptation**. The public sector will need to ensure that food standards, labelling regulations, and public health guidance keep pace with new product/category innovation.





Supporting full-spectrum producers

A future of diversifying income streams

Over the next decade, a confluence of several critical drivers will precipitate a shift from the producer as someone who is solely rewarded for producing a food or fibre product to someone who is also rewarded for resource management services. The future's primary producer will be managing income streams from their crops and livestock, but also potentially from energy leases, social media channels, carbon and ecosystem service payments, and data collection.

A set of new, viable energy systems like wind and solar that are by nature more distributed than fossil fuel production will increase demand for land on which to produce that energy. Climate change effects on policy pushed by governments and citizens alike will heighten the need for ecosystem services and carbon sequestration. Pressure from insurers on companies and local governments to account for climate risks will create additional economic incentives for participating in sustainable practices. Finally, new technologies that enable cost-effective validation and verification for energy and ecosystem services will enable new income streams, new business models, and new stakeholders to participate in a marketplace that connects that mix of services with financial incentives.

Taken together, all of these factors will work to redefine the producer as a full-spectrum producer. Whereas branching out into multiple revenue streams was once prohibitively costly or risky, technology and outside interest in natural resource conversion more broadly will open the door for producers to extract value in many new ways.

As blended production and synthetic foods ramp up, there will be more channels into which the producer can sell. For example, the hypothetical pork industry of the future might include raising pigs alongside providing sugar as a feedstock for fermentation technologies that produce heme, vegetables that go into meat substitutes, or the hydrogen-based energy systems that power cell-ag systems. The industry could even breed pigs purely for their DNA, earning a price premium for the genetic information that performs best in a bioreactor. Producers can seize the opportunity to use the same or overlapping assets to provide more value to manufacturers through blended product lines rather than commodity lines.

One consequence of all this will be that the narrative and culture of what it means to be a farmer will change. As producers or regions take on more of these varied income streams, and as we see maturation of outside market signals that are driving things like ecosystem service payments, consumers and institutions will exert increasing influence over the incentives that impact producer decisions. Even if it's uncomfortable to do so in principle, there will be an increasingly viable opportunity to expand or alter the enterprise mix, get closer to consumers, and/or tap into entirely different supply chains.



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FARMERS EDGE

WHAT:

Farmers Edge is one of several companies [bringing carbon sequestration services onto existing platforms](#), in this case, a precision ag software tool. It links farmers to carbon markets and does the heavy lifting of measurement and verification.

SO WHAT:

Using this type of tool, a producer can plug into a new value chain with little friction. As more technology like this makes it easier and more viable to sell carbon credits without a high cost for verification, it will become part of a new enterprise mix.



SOLAR ENERGY

WHAT:

New South Wales company WYNERGY is developing [1 GW of solar energy projects](#) through agrivoltaics—the mixed land-use of solar PVs and grazing. The company builds the solar installation and then resows the land with native perennials so that ruminants can graze and producers can maintain two income streams.

SO WHAT:

Agrivoltaics are starting to become viable, and the first farms in the world using this system are going online. If proven viable, this system will be a critical part of a new energy grid.



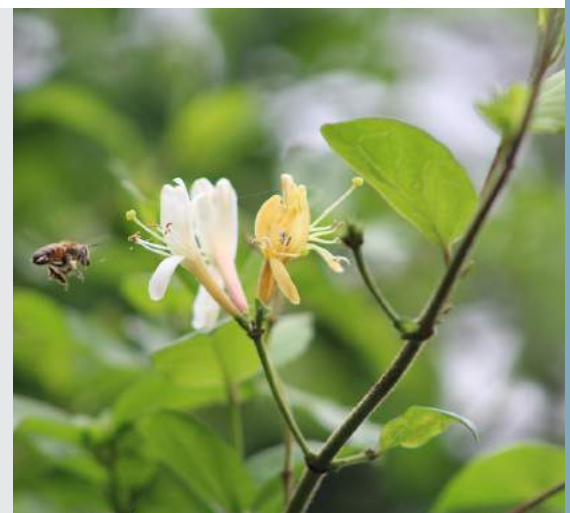
BIODIVERSITY

WHAT:

A new fund for a [biodiversity stewardship program](#) is setting aside \$2 billion to help producers gain certification for beneficial practices like maintaining wildlife corridors. The certifications will be used to leverage benefits for producers that may help reduce costs and encourage rewards for ecosystem services by improving borrowing capacity or price premiums.

SO WHAT:

One of the critical incentives for producers to overcome the barriers to being a multi-income-stream enterprise is available capital. Funds like this will be part of the solution, along with private-sector economics.





insights

- › The way we **train the agricultural workforce will need to change**, as today's traditional education and even vocational training systems will no longer be fit for purpose. Producers will need a broader skill set and access to support services with expertise across areas that are somewhat siloed today.
- › As **agricultural landscapes and job descriptions change**, producers and regions will need to manage an identity shift. Some will adapt to and thrive in this new world, while others will fight a losing battle to maintain the status quo.
- › Opportunities are created for unique public/private partnerships where **producers are paid to provide services that create experiences**. Examples include regeneration of sensitive ecological areas for the benefit of the tourism industry and "showcase" farms that educate visitors about historical farming practices. While not all producers will decide to participate in these opportunities, some will see the commercial benefits (e.g., diverse income streams) and jump in.





The searchable food web

A future of opening food data to everyone

Imagine a world where the same processes that track your every digital move are also embedded in the food web. As we move into the 2030s, synthetic biology technologies will allow food makers to embed natural, molecular-level tracking and analysis capabilities into their products. Meanwhile, digital tools like machine vision, advanced spectrometry, and AI will enable a robust “internet of food,” a distributed database that allows for visibility into food products, production, and distribution. Essentially, the development of a fully digital food system will usher in the same capacities as the internet, chief among them a searchable, indexable web of all components of the system and how they’re connected.

Such an internet of food will allow for making connections between previously untethered effects. Producers who can track individual goods end-to-end may be able to draw insights about which produce sells best at the grocery store and then make evidence-based changes based on ultra-specific designations. For example, the manager of a greenhouse tomato operation could directly correlate metrics like time in transit, brix level (amount of sugar and mineral content), or storage temperature with sales. Distributors will gain efficiencies by quickly checking for fraud or early signs of spoilage at the unit level.

Companies will face new challenges in both establishing and managing trust. For example, downstream buyers will have increased insight into the origins and quality of the products they receive, which means that the link between producers and consumers will be closer, but not in the more personal, managed way that DTC platforms allow. Instead, more people will make judgements and decisions on their food that they previously left to institutions or simply didn’t question. Just as people buy branded products

based on trust, they may start to scrutinise the inputs to those food products: in a future where people can see the full story behind each piece of produce, they’ll start to scrutinise things like the exact type of fertiliser used, the logistics chain, or the supplier. Every measurable aspect of a product will become part of its brand.

At the same time, the set of individuals and groups of actors who have newfound abilities to influence individuals, entire societies, and nations will grow to include just about anyone with the technical know-how. New influencers, who today are insignificant, will have outsized power over swaying public opinion. While today the protestor who decries certain food industry practices, or the food blogger who makes a side income by posting about products, might be able to effect little actual change, once a searchable food web and nudging tools are democratised, they’ll be able to rally societal opinions that have real-world impacts. Ten years from now, a social media influencer might be able to shift global markets or have appreciable effects on a brand’s valuation.



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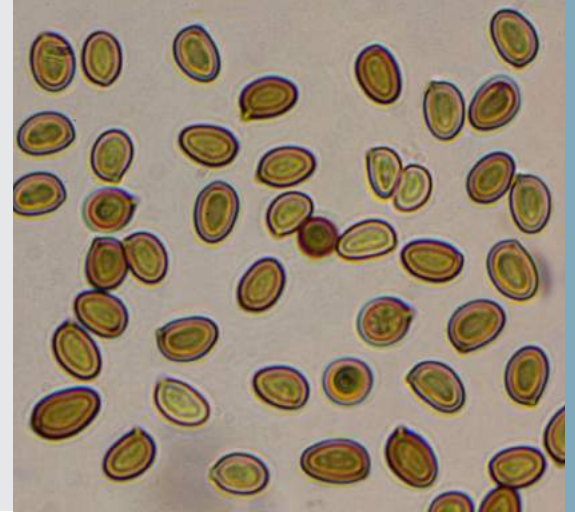
SYNTHETIC DNA TAGS

WHAT:

A research team developed a way to add trackable [synthetic DNA tags](#) to any item by spraying it with engineered spores, allowing them to be uniquely identified.

SO WHAT:

This paves the way for biologically encrypted traceability. When a food's identity is inherent to its genome, foods can essentially be branded by their exact varietal. Fraud of specialty foods will be significantly harder, while traceability for commodities will be considerably more manageable.



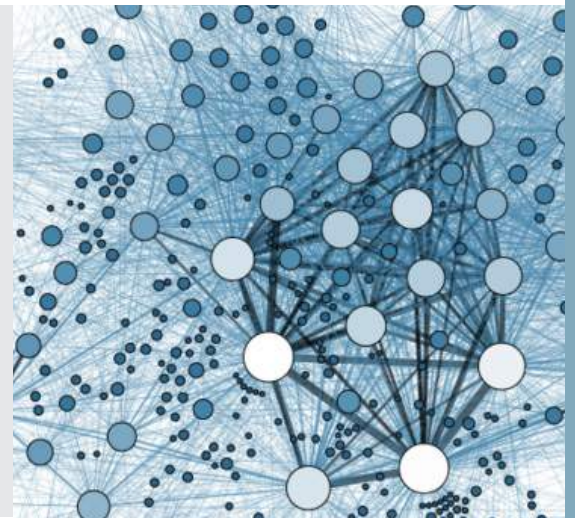
INTERNET OF FOOD

WHAT:

The Internet Society created a special group to design a so-called [internet of food](#), which they propose as a free, open and secure database for food tracing. Part of this internet's critical infrastructure is the universally unique identifier, which would act as a digitally readable identifier without requiring a central registration.

SO WHAT:

A cohesive group like this will intentionally design ethical and open flows of information into a future searchable food web. Such a system would allow all stakeholders to manage trust more reliably, up and down the value chain.



ARTIFICIAL INTELLIGENCE

WHAT:

[Suggestic](#) uses [artificial intelligence](#) to help people make food choices. Their chatbot can help users find recipes and plan meals based on that person's specific needs, whether they're diabetic, allergic to certain ingredients, or just trying to lose weight.

SO WHAT:

This type of personal diet management has the potential to influence millions of people's food choices and can be optimised for any number of outcomes. As food choices are codified, and control over them is centralised, it becomes proportionally easier to manipulate them.

Low Carb + Keto Snacks





insights

- › The intersection of **transparency and disinformation can provide opportunities** for both trust and deceit: radical transparency can help guard against disinformation attacks or make everyone more susceptible to disinformation because everything will be analysed under a microscope. Trust in public and private institutions will be fragile, and debates on both power and responsibility with respect to information censorship will intensify.
- › As information about supply chains becomes more accessible, there will be **more noise and strong opinions about what is 'right' or 'good'** in food and fibre production. This narrative will be shaped by stakeholders of all kinds as everyone has access to more information that makes them feel like an expert. The scientific community, in particular, will face challenges in establishing and differentiating data-backed evidence from opinion.
- › In this world, the potential for **geopolitical strategies and responses to be carried out through private and social media-enabled channels**, rather than sanctioned policy channels, will increase. The tools we'll need to respond to national risks in these cases will be very different. This could make producers quite vulnerable; they could lose a market at the whim of an influencer or through fake news.





Biology goes digital

A future of democratising biology

While today, desirable traits are most commonly propagated through breeding and heritability—at the whole animal or plant level—in the future, trait selection will occur at the sub-cellular and digital levels, rapidly manifesting what used to take generations to unfold.

Today's genetic therapies and CRISPR editing techniques open the doors for direct manipulation of crop and animal traits. Over the next decade, these technologies will evolve from high-tech health and efficiency solutions into everyday tools that organisations and perhaps even individuals can use to alter the biology of crops, livestock, and microbes for applications specific to the needs of customers or even their individual operation. A grazer who wants to sell into the premium beef market will be able to alter the genome of their cattle directly to optimise for marbling and taste within local production conditions; a rice producer who faces geographically specific pests will be able to develop the just-right biological pesticide for their region.

The accessibility of technologies that enable the manipulation and optimisation of biology at such a granular level will certainly drive efficiencies, such as the ability to alter production opportunistically and rapidly in order to meet consumer and societal demands, but it will also create new social and ethical dilemmas with which the industry must grapple.

Players old and new will be able to download, edit, and produce pharmaceuticals, genetically engineered yeasts, and bespoke microbes. Spurring this on will be the digitisation of biological information and techniques—the ability to read, code, transfer, and alter genetic information on digital platforms. Digitisation will lead to greater access, not only for traditional producers but also for disrupters of all sorts, be they start-up companies or entities intent on stealing or manipulating newly available biological data. Success in this arena will require knowing how to protect oneself digitally as well as biologically and genetically. It will also require navigation of a marketplace of biotech providers whose services will range from basic technical work to full-stack production of novel organisms.

As is the case today, producers of “altered” foods will face scrutiny from consumers concerned with ethical production and those fearful of “unnatural” foods. However, there will be new opportunities to solve ethical issues in food and fibre production: ruminants will be altered to produce less methane, crops will be manipulated to improve local soil health, and engineered microbes will improve health, safety, and traceability along the supply chain. Stakeholders will have opportunities to share these stories and stand out by building brands based upon their ethical solutions.



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HOME BIOREACTOR

WHAT:

Biotechnologist Will Patrick [developed an easy-to-make home bioreactor](#) for pharmaceuticals. The reactor uses engineered spirulina to produce desired compounds, meaning that anyone who can build the reactor and has the know-how to source or develop genetically engineered spirulina can grow their own pharmaceuticals.

SO WHAT:

Quite soon, the same process could be used to develop not only drugs, but nutrients, microbes, biopesticides, and more. As the creation tools for molecular compounds move out of the lab and into easy-to-use products, it will kick off a proliferation of basic synthetic biology as a widespread skill.



SMART INCUBATION SYSTEM

WHAT:

Soos uses a [smart incubation system](#) that identifies and manipulates the sex of embryonic chicks, turning males into “functional females.” This allows them to bypass the ethically fraught traditional system of sexing and then culling male chicks.

SO WHAT:

The thorny ethical issues that some consumers now cite as a need for change in animal processing will become more easily averted through the tools that allow biological manipulation through digitising information.



THE GRASS TO GAS INITIATIVE

WHAT:

A collaboration between UK, Norwegian, and New Zealand research groups called the [Grass to Gas initiative](#) quantifies the link between genetic traits and methane emissions in sheep. They aim to understand how to manipulate sheep genes to reduce overall emissions.

SO WHAT:

The same process may be used in cattle and other ruminants—genetically modifying animals to reduce their environmental impact. As ESG investing and increased consumer concern for sustainability drive these issues to the fore, using genetic tools to solve these problems will become more viable and attractive.





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- › **Democratisation opens new opportunities for partnerships in supply chains** (e.g., brands using their supply-chain genetics as a differentiating factor with their consumers). For upstream suppliers and producers of what used to be “behind the scenes inputs” (seeds, genetics), this is an opportunity.
- › Traditionally, the need for specialised knowledge and expensive infrastructure has confined fundamental biological research to the realm of academia. The role of **academia and publicly funded research could change** as it becomes increasingly feasible—and perhaps more viable—for private actors to carry out the same work.
- › Manipulation or **alteration of the “natural” world through digital systems could fuel further distrust and alienation** with consumers; however, there are also opportunities to build deeper connections and more trust by delivering products that address ethical and sustainability concerns. Communications and positioning of these new production practices will need to be intentionally and carefully handled, and industry should draw on lessons learned from experience with GMOs.



Conclusion

As the next few years unfold, the future forces and forecasts described here won't stand still. They'll evolve and change. Some will follow a predictable trajectory; others will bend on a different path. And, of course, unexpected, unpredictable black-swan events will potentially change everything.

The function of foresight is not to predict, but to prepare for the predictable, the surprising, even the shocking. The future is uncertain and filled with challenges. The only thing we control is how we prepare ourselves to manage and sustainably benefit from change. The futures presented in this report are a starting point for strategically thinking about the future and staying ahead of the curve. Whether or not these forecasts “come true,” they can serve as tools for building a more nuanced understanding of the opportunities and risks to your sector. By continuing to monitor the drivers and signals of change on the horizon, you can update and maintain your mental model of the future, and direct how you prepare for it in the present.

Taking into consideration these changing forces, five key messages emerged from the research:

› **Future developments are combinatorial.**

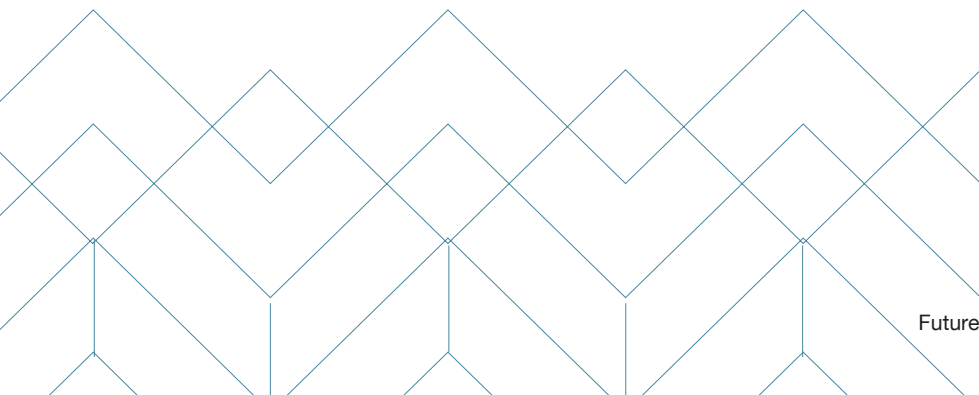
They'll take place across the supply chain and across domains, and we'll see new competitive forces and stakeholders moving into new roles. For example, if grower groups become more involved in logistics, they'll compete for access to existing transport infrastructure.

› **Tomorrow's producers may be categorically different than today's.** New technologies and systems will shape the role of the future farmer, fisher, or grazer into something quite different from that of today. For example, they may look more like generalist technology managers than traditional farmers.

› **The future will require new methods of support, education, and training.** We'll need to approach training and upskilling in different ways than we currently do in order to make sure people thrive in the future. Existing producers will need new training delivered in new ways; meanwhile, new entrants to the food and fibre system—whose roles may not even exist today—will need access to support as well.

› **There is no “one-size-fits-all” approach.** Solutions to future challenges will need to be based on localised R&D, emphasise communication between consumers and producers, and draw on social capital. At the same time, other challenges will play out at a global level, which will demand organisations that take the high view.

› **The future will favor collaboration, not competition.** Especially post-farmgate, we will need systems that are characterised by collaboration in order to solve complex problems.



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