Sir John Crawford Memorial Address 2019

Australia can be a superpower in a low-carbon world economy

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Abstract

To John Crawford, the role of economics was to illuminate real world conditions and improve policy options. At a time of historic change in climate and Australia's international environment, we need Crawford's approach to economics as never before. Growth in global population and incomes, and climate change, are putting pressure on land and water resources. Transformation of land use and food consumption are important dimensions of the response to climate change. Australian research skills in agriculture, biology, botany, engineering and economics can secure the Australian transformation and extend it internationally. The challenges of climate change are especially acute and the opportunities exceptionally large in Australia. The drying and warming of southern Australia is undermining established agricultural and pastoral activities. But rural and provincial Australia have global comparative advantage of considerable value in activities the value of which will be greatly increased in the zero-carbon emissions world that is necessary to limit damage from climate change: renewable energy resources; opportunities for biomass production as a zero-emissions source of inputs into industrial activities; and the opportunity for sequestration of carbon in Australian soils, pastures, woodlands and savannahs, and forests.

My wife Jayne and I have spent the last two weeks travelling through the Murray–Darling Basin. Down the Murray from Swan Hill to Mildura and Wentworth. A couple of days at Lake Mungo, where the ice age overflow from the Lachlan once filled lakes and supported communities that left us with what may be the oldest record on Earth of complex human mind and spirit. Then up the Darling to the Menindee Lakes; cutting across through Broken Hill to Wilcannia, once the bustling third port in Australia; then back south, across the Lachlan at Hillston, and the Murrumbidgee near Griffith, finally reaching the Murray again. Beautiful Australian country. Rich with the human heritage of 50,000 and 200 years.

It is also a personal heritage for many Australians. John Crawford spent his early years at Grenfell, in the catchment of the Lachlan; and most of his professional life here in Canberra in the catchment of the Murrumbidgee.

Jayne's father, Tom Potter, lived in Wentworth and the lower Darling until he and many others in the bush rode to Melbourne on the news of war in 1914. That ride led to a beach in Turkey as the sun rose above the coastal hills on

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Professor Garnaut's address quotes extensively from his latest book, *Superpower. Australia's low-carbon opportunity*, which was published in November 2019, three months after the 2019 Crawford Fund conference.

25 April 1915. When we visited Wentworth nearly a decade ago, a board in the RSL Club remembered Tom and his brother. The building that housed the Club and its memorabilia is now empty beside the Darling.

What value do we place on Australian heritage? The question kept coming back as we travelled up the Darling. For about 30 kilometres the bottom of the riverbed is wet from the flow-back from the Murray. From there, the sand between the rows of grand old river gums is dry, except for scattered stagnant pools. By one pool, the skeletal head of a Murray Cod gaped wide enough to swallow whole the biggest carp. The dried flesh on the cod's back had been depleted by wild pig bites when it was still fresh – by pigs that were able to wade into the shallow pond and drag out the helpless survivor of decades.

Around a big fire on the riverbank one night, we were told of a plan to ride a motor bike along the dry Darling bed from above Wentworth to the dry Menindee Lakes. It was the first time anyone could have made the ride.

We were travelling through an Australian tragedy. A tragic consequence of denial of knowledge and of its role in public policy. A denial, I had been thinking, of the life's work of a man from the Lachlan. And then, last Wednesday, between Menindee and Broken Hill, I received a call asking if I would address this dinner.

Policy used to be based on research and understanding

I recalled a conversation with Sir John as we travelled around the south-east Asian capitals in 1979 at the request of Prime Minister Malcolm Fraser. We were recruiting participants in the Pacific Community Seminar, precursor of the Pacific Economic Cooperation Council and then APEC.[1] I asked about his time as Director of Research in Minister Dedman's and Secretary Coombs's Department of Post War Reconstruction, when there was early discussion of the Snowy Mountains Scheme. He told me that an early concern with Snowy was whether there would be markets for increased production from irrigation on the Murrumbidgee and the Murray, so he set people onto research into the global markets for dried fruits and wine.

John Crawford – Jack to most of his contemporary friends, and Sir John or Professor Crawford to young members of staff – was an important part of a remarkably productive period in Australian government, scholarship and public life, stretching – with ebbs and flows – from the war years through to a decade or so beyond the end of Sir John's life.

Crawford's special contribution over four decades was to insist that sound policy began with knowledge; that sound knowledge emerged from research; and that expanding an understanding of policy choices through public education was an essential part of the policy-making process.

Here at the Crawford Fund we remember especially Crawford's role in the establishment of the International Food Policy Research Institute, the system of international agricultural research centres, the Indian Green Revolution; the

[1] APEC, the Asia–Pacific Economic Cooperation, is a forum of over 20 economies.

Australian Centre for International Agricultural Research; and, for those with longer memories, the Australian Bureau of Agricultural Economics. His policy and institutional legacy also includes more productive cooperation amongst peoples and countries of different and sometimes divergent cultural and political backgrounds. Examples include Australian contributions to the early and temporarily successful policy-making in the new Independent State of Papua New Guinea; economic relations with Japan after a horrific war; economic and educational exchange with China after the Cold War; and the most expansive era of trade and other economic relations across an emerging Asia–Pacific community.

Today, public policy based on the marshalling of knowledge through research and analysis, followed by a nurturing of public understanding of the issues, seems a distant dream. That it is dream and not contemporary reality is the essential problem behind the tragedies of the Murray–Darling Basin and of policy on climate change and the energy transition. At an international level, it is an essential problem in global trade and development.

Tonight, my talk is mainly about land and agriculture and regional development in Australia as we respond to the challenge of human-induced climate change. As always, on every development issue, but more on climate change than others, an Australian development question has an international context.

The 2008 *Garnaut Climate Change Review* drew attention to the historic lift in world food prices in the first decade of the new century. This broke a half century of declining relative prices, as increased yields, partly resulting from international public sector agricultural research, outran rising global population and living standards. An acceleration of the lift in living standards in the populous countries of Asia would make this an expanding opportunity over a long period for Australian farmers and therefore for Australians — unless climate change at home damaged Australian supply capacity.

Unfortunately, Australian farm capacity would be reduced by any failure of global climate mitigation. The atmospheric physics was telling us that the southerly movement of climate patterns, and therefore the drying as well as warming of the southern Australian latitudes that had been the home of most Australian agricultural value, would be a feature of climate change. Irrigation output in the Murray–Darling Basin was likely to decline by 90% in the absence of effective global mitigation.

New knowledge has reduced uncertainty without much changing the mean expectations about global warming.

We can now see in empirical observations the effects once anticipated from the atmospheric physics. Average temperatures across Australia so far this century are over a degree higher than in the first half of the 20th century.

We now see that streamflows into Perth dams, like for like, have contracted from an average of 336 GL per annum in the first three-quarters of last century, to 59 GL p.a. over the decade after I presented my first Report to State Premiers and the Prime Minister. That has made that city of over 2 million people mainly reliant on desalination and depleting groundwater. The south-west agricultural areas are facing great challenges.

We have reliable records of inflows into the Murray since 1892. After taking out the Snowy and inter-valley transfers, and the highly variable and currently zero flows from the Darling, average inflows averaged a bit over 9 teralitres (TL) per annum for the first 40 years of the record. The next 40 years, the annual average was over 9.5 TL. In the four decades commencing 1972, as a warming trend emerged more strongly and clearly, the annual average was 9 TL. In the 7 years since then, the average was a bit over 7 TL – a quarter below the first century of observation.

The controversial Murray–Darling Basin Plan does not take account of declining inflows as a result of climate change. Even this modest Plan, built on hope in contradiction of scientific analysis, has proven to be too demanding to implement as designed.

Hotter in Australia

The most ambitious of the Paris objectives would see average global temperatures increase by about 1.75°C from pre-industrial averages over the whole of the Earth's surface. The atmospheric physics tells us that temperatures over land will increase by more than that – for Australia, by more than twice the increase we have already experienced. To have good prospects of holding the temperature increase down to this level – something like 2.5°C increase on land – would require zero net global emissions by the middle of the century. That is not impossible. But it would require many things to go well.

The international community has accepted that some developing countries will take longer than developed countries to achieve complete decarbonisation. So Australia's fair share will be zero net emissions before mid-century – earlier still if we start serious reduction slowly, as we have done.

Even 1.75°C on average over the Earth's surface – the most optimistic outcome from the global mitigation effort – would present a massive adaptation challenge for Australia. It is a challenge for what we must do in Australia which, of the developed countries, is the most vulnerable to damage from climate change. It is also a challenge for managing the consequences of climate change in highly vulnerable countries in south Asia, south-east Asia and the south-west Pacific. Many of our neighbours will face extreme problems of adjustment, and their problems will certainly and quickly become shared problems.

We cannot be certain of success in holding global temperature increases to 1.75°C. The whole world, with Australia contributing its full share, would have to move quickly to zero net emissions to hold the adaptation challenge to 1.75°C. Continuation of current tendencies in Australia, if reflected elsewhere, would see us adjusting to temperature increases two or three times that level. One has to hope that proximity to the consequences of weakly mitigated climate change will lead to more realistic policies.

I have spent my life on the optimistic end of the Australian spectrum in discussion of many policy and development issues. That optimism has mostly been vindicated by the unfolding of history. On the challenge of adapting to weakly mitigated climate change, I am not optimistic. I fear that the challenge would be beyond the capacity of contemporary Australian society and polity. I fear that things would fall apart.

The bad news is that the passing of time, the results of new research and the accumulation of evidence are all broadly confirming the conclusions towards which the atmospheric physics led us a decade ago.

The good news is that the economic challenge of mitigation to reduce the damage from climate change now looks much less costly and daunting – for the world and especially for Australia, and above all for rural and provincial Australia. The good news is very good.

Improved economics now

The improvement in the economics has two main sources. One is an extraordinary fall in the cost of solar and wind energy and of storage to balance its intermittency. The second is realisation that there is opportunity for capturing and sequestering, at relatively low cost, immense quantities of atmospheric carbon in soils, pastures, woodlands and forests.

My 2008 Review for the Prime Minister, six Premiers and two Chief Ministers presented the results of comprehensive modelling of the costs and benefits of Australia participating in a strong global mitigation effort. It suggested that there would be some noticeable sacrifice of Australian current income until early in the second half of this century, but that average incomes would have regained lost ground by around the end of the century. The income benefits of strong mitigation were strongly positive beyond the 21st century. Effects on values beyond current incomes powerfully favoured strong mitigation.

Developments in the cost of renewable energy, energy-intensive transport and industrial processes, and carbon sequestration through changes in land

use would turn those calculations around if repeated today. Rapid shift to renewable energy within an appropriate policy and regulatory framework today would enhance Australian incomes. This would support Australian comparative advantage in energy-intensive manufacturing, including many processes that add value to mineral and agricultural products. Systemic incentives equivalent to the true cost of carbon emissions would lead to carbon sequestration via land use change becoming a major rural industry. I said in the 2011 Climate Change Review that the opportunity to sell farm carbon credits into the proposed emissions trading scheme would create a new rural industry as large as wool.

The 2008 modelling suggested that it would be cheaper for Australia to import large quantities of carbon credits from abroad rather than to achieve its targets entirely from reducing emissions at home. The Australian emissions trading scheme was due to be integrated into the European scheme from 1 July 2014. If those arrangements were in place today, with current understanding of renewable energy costs and opportunities for land-based sequestration in Australia, we could now expect Australia to be a major exporter of carbon credits.

This means that Australia could receive insurance against severe climate change impacts and at the same time enhance its own economic development by moving strongly and early towards decarbonisation of its economy. Both the climate change and economic benefits would accrue disproportionately to rural and provincial Australia.

More detail

Let me say a bit more about the two big changes affecting the cost of reducing emissions – the fall in the cost of zero-emissions energy; and the realisation of expanded opportunity in land-based sequestration of carbon.

First, **renewable energy**. The cost of capital goods for generating zero-emissions energy has fallen much more rapidly than had been anticipated in my 2008 Report, and there is no sign yet of deceleration of the decline. Interest and other costs of financial capital – the supply price of investment – represent the main cost of renewable energy and storage. This is unlike thermal energy, where recurrent costs of fuel are much more important. The supply price of investment has fallen dramatically over the past decade – with negative real yields on low risk bonds in all developed countries. The fall in the supply price of investment is disproportionately powerful in reducing the costs of zero-emissions energy. These two factors reinforcing each other – lower costs of capital costs for renewable energy and a lower supply price of investment – have caused the cost of renewable energy from wind and solar generation in favourable locations plus storage to be lower than the recurrent cost of thermal generation. They are lower than the total cost of thermal generation in many countries.

The fall in the cost of zero-emissions electricity also lowers the cost of decarbonisation of transport and industrial processes. There have also been large cost-reducing improvements in zero-emissions technologies to replace fossil coal, gas and oil in transport and industry.

The **potential for carbon sequestration** in soils, pastures, woodlands and forests figured prominently in my 2008 and 2011 Reviews. This led to the establishment of the Carbon Farming Initiative, later folded into the Emissions Reduction Fund. Australian research has surrendered the leading position it occupied on land-based sequestration at that time, but the international effort has been expanded. Recent reports from the US Academy of Science, the European Academies, and the August 2019 IPCC report[2] all point to a substantial proportion – a third or more – of required reductions in emissions to come from changes in land use at relatively low cost. CSIRO, the University of Melbourne and some other Australian research institutions have continued the effort, and the continued interest of former Governor-General Michael Jeffery has raised the possibility of substantial government support for this effort. It is a worthy and appropriate subject of major effort by ACIAR and some Institutes of the CGIAR.

Many opportunities for carbon sequestration through changes in land use involve high initial capital and relatively low subsequent recurrent expenditure. They are therefore also beneficiaries of the decline in the supply price of investment.

There is also good fortune for the global mitigation effort in changes over the past decade in the framework of global cooperation on climate change mitigations. These are reflected in the outcome of the Paris meeting of the UNFCCC[3] in late 2015, which defined a path to realisation of strong outcomes. The new approach, which I called 'concerted unilateral mitigation', was supported initially by all members of the UN except Nicaragua and Syria, and eventually by those two countries as well. Within this framework, all major countries were committed to major change in the trajectory of their emissions. Most, including the US and China, have made early progress on implementing their commitments.

Australia so far has been a drag on the international effort. Its initial target was 26–28% reduction in emissions on 2005 levels by 2030. Australian emissions have been rising since 2014, raising questions about achievement even of this unambitious target. However, the initial targets at Paris were subordinate to the overarching goal of holding temperature increases as far as possible below 2°C and as close as possible to 1.5°C, with peer assessment leading to progressive tightening of the targets over time.

What Australia does is influential. What the US and China do is much more influential. Regrettably, both China and the US, having made large contributions in the period up to and in the year after Paris, have since then been contributing less positively. The decisive change was the election of Donald Trump as President of the United States, with commitments to withdraw the US from the Paris Agreement, to reverse the trend towards declining coal use in the US, and more generally to retreat from action on climate change. This has weakened pressure on other states including Australia to raise their initial Paris targets.

[2] Intergovernmental Panel on Climate Change, August 2019, *Climate change and land.*
[3] United Nations Framework Convention on Climate Change

It has not immediately increased emissions in the US, where market pressures and private sector and state and city government activity continue to keep emissions on a downward path. However, an extended period in office of Trump or others of similar mind would eventually throw US emissions back onto a rising trajectory.

China's emissions had been the major source of increases in global emissions through the first decade of this century. Changes in the overall model of economic growth, as well as energy and industrial and climate change policy after 2012, fundamentally changed the trajectory of emissions reduction. There was no increase in emissions from 2013 to 2016. Policy change in the US did not prompt climate policy change in China. However, the Trump trade war that began in 2017 introduced uncertainty into Chinese policy-making, and reduced export, investment and output growth. China's response was fiscal and monetary expansion to offset negative international influences on growth. This reinforced the old emissions-intensive pattern of growth. The immediate effect has been the reassertion of the old model of economic growth based on investment in infrastructure and heavy industry with its high emissions intensity.

So the chances of reaching ambitious outcomes for global emissions have declined over the past two years. Australia's social and political capacity to manage major adaptive adjustment may be tested.

Transforming land use and agriculture in Australia

The 2008 (Chapter 22) and 2011 (Chapter 10) Reviews drew attention to the exceptional contribution to global as well as Australian mitigation that could be made by changing Australian land use.

Australia's comparative strengths have two sources.

The first is our exceptionally large endowments of woodlands, forests and other land relative to population. This has given Australia its historical comparative advantage in land-based products.

The second is our exceptional expertise in the land-based industries – from agricultural and forestry science, through agricultural and resource economics to public and private knowledge and institutional arrangements supporting commercial success.

I noted in 2008 that innovation in rural production and in regulatory arrangements was going to be necessary for Australia and the world to take full advantage of opportunities for mitigation through changes in land use. Rules for measuring and accounting for land use emissions were immature, and had to be developed on sound principles to make the most of global opportunities, and to recognise Australian contributions. Other developed countries which had shaped the rules did not share Australia's opportunity, or interest. Australian expertise could help to develop environmentally and economically efficient international rules. Our knowledge on land use transformation could be of particular assistance to Australia's neighbours in south-east Asia and the south Pacific.

The special Australian place in the absorption of carbon in the landscape was the subject of remarkable commentary eight decades ago by the first Distinguished Fellow of the Australian Economics Society, Colin Clark. In his 1940 book, *Conditions of Economic Progress*, Clark helped to found development economics and the use of national accounts for production and income. Clark sought to allay concerns that the dependence of modern economic development on fossil energy, and the finite nature of coal and oil resources, would bring economic growth to an end. He noted that we can calculate the likely amount of undiscovered fossil fuels from the carbon that was once in the atmosphere. He said:

> However, we must not set out to burn them up too fast, even if we do find them, at any rate not faster than the rate at which the carbon dioxide can be converted by photosynthesis...

But he reassured us that keeping the use of fossil fuels within the limits of what can be absorbed by photosynthesis need not be the end of economic growth. There is an abundance of solar energy falling on the Earth, if we know how to tap it. The best method at present, he said, is the proven process of photosynthesis in trees, and he calculated that the eucalypt is the most productive agent for conversion of solar energy into biomass at present. Algae had the potential to do better. The silicon battery and other recent discoveries, he said, may do better still some day (Clark, 1957 pp. 488–489).

So the importance of the Australian eucalypt to sustaining economic growth without excessive carbonisation of the atmosphere was recognised 80 years ago, at the beginning of development economics.

In 2008, I brought into the mainstream discussion some early work by the CSIRO and state departments of agriculture on the immense mitigation potential of changes in land use. The nurturing of vegetation on the dry degraded mulga country where rainfall was spasmodic in western Queensland and the rangelands of New South Wales could be transformative. Innovative uses of the properties of Australian eucalypts included farming of the mallee on the arid boundaries of crop cultivation for subterranean sequestration of carbon and for harvesting biomass. I referred to the adaptability of Australian meat consumption choices: per capita consumption of high-emissions products (beef and mutton) had fallen, and of low-emissions products (chicken and pork) had increased markedly in response to price increases in the former and reductions in the latter over the past half century. A passing reference to reducing emissions by partial return to traditional Australian patterns of meat consumption – substituting some zero-emissions kangaroo meat for high-emissions beef and lamb, in production and consumption – received exaggerated but ill-directed attention at home and abroad.

Research and regulatory development was warranted, to make the most of opportunity for mitigation in farming and land use.

The Carbon Farming Initiative was legislated in 2011 alongside the Clean Energy Future package. These arrangements were carried into the Abbott, Turnbull and Morrison governments' Emissions Reduction Fund (ERF). The ERF was a clunky,

truncated and less adequately funded version of the emissions-trading-scheme-linked Carbon Farming Initiative. It required resources from general revenue, rather than from sales of emissions permits. Clunky or not, Abbott's ERF kept alive the sale of offsets as a way of providing incentives for farm-sector carbon sequestration. The arrangements developed by the Clean Energy Regulator showed how an offsets scheme related to land use could work, and that there was strong private response to incentives.

It has only become clear since 2011, at least to me, that Australia's potential strength in low-cost production and use of biomass can provide the most cost-effective path to zero-emissions production of many manufactures from chemical processes. This is necessary to end emissions from gas, oil and coal used in chemical manufacturing processes. Capacity to produce low-cost biomass can be a source of Australian comparative advantage in zero-emissions industry.

Recent IPCC reports, most importantly last week's report on agriculture and land use,[4] have elevated the importance of natural climate solutions to achieving global mitigation ambitions. Sequestration of carbon in soils, pastures, woodlands and forests can make a major contribution to holding temperature increases significantly below 2°C and as close as possible to 1.5°C.

Expansion of knowledge in all these ways points to the need for transformation to reduce the size and weight of the human footprint on the planet: to consume less land- and emissions-intensive food, including through reducing consumption of red meats; to reduce the amount of land under cultivation; to increase forested areas and their diversity; to economise on use of water; and to do this while drawing on biological sources of the chemicals for industrial processes that were previously supplied by coal, oil and gas.

At the same time, knowledge has been expanding about how we can achieve these outcomes: knowledge of nutritious and palatable substitutes for old foods that have less damaging ecological impacts; knowledge of farm and land management systems to improve the trade-off between environmental cost and value in use; knowledge of regulatory arrangements that can encourage the necessary transformation.

There is rising awareness of the need for fundamental change, and the beginnings of knowledge that fundamental change is feasible. The short-term costs of change in some of these areas are still high, but increases in the scale of the new are starting to bring costs down. Transformation is unfamiliar, and daunting, but beginning.

The decarbonisation of electricity and the electrification of industry and transport can remove about two-thirds of global emissions. The land use, agriculture and food transformation can deliver most of the rest. Meinshausen and Dooley (2019) have shown that we can get most of the way to the global Paris goals through renewable-based electrification and the land use transformation.

[4] *Climate change and land*. IPCC, August 2019.

Australia is uniquely well placed to lead and prosper from the land use transformation, just as it is in energy. As with energy, Australia's own transition in managing land should be seen in the context of global opportunity.

The land use mitigation opportunity and agriculture

Australia stands out amongst developed countries and globally for its large endowment per person of woodlands and forests. This gives us massive advantages for carbon sequestration and for production of biomass for industrial use.

Sequestration potential is affected by rainfall. The applied atmospheric physics is still coming to grips with the effects of warming on rainfall in particular locations. In the world as a whole, average rainfall rises but the distribution changes. Scientific advice to me in 2008 and 2011, reported in the Reviews, said that southern Australian latitudes were likely to experience lower rainfall, and, on the whole, northern latitudes higher. This pattern is largely supported by subsequent work.

The southern latitudes have long been the source of most Australian agricultural value. With agriculture challenged by the combination of drying and warming, there will be shrinkage in the area of cultivation. Newly submarginal farmland may be more productive as a source of carbon sequestration and biomass. Wetter northern areas will be able to sustain more intense concentrations of living plants, making them potentially larger sources of biomass for harvesting or long-term carbon sequestration.

The 2008 Review set out in Table 22.2 the main opportunities for large-scale sequestration in changed land use.

Most discussion of sequestration potential has focused on fast growing plantations in higher rainfall regions that are suitable for relatively intensive agriculture. That undersells the potential for abatement via changes in land use.

The general story is of immense potential for storing more carbon in the vast rangelands – but of great uncertainty about the potential and what is needed to secure it. Research to define the possibilities and how to access them more closely would have great value. To maximise value of production from this land across all possible uses would require a reward for carbon sequestration, and separate fiscal incentives for biodiversity. It would leave landowners to judge how much of their land should be subject to destocking for sequestration and biodiversity purposes.

The mallee is a eucalypt marvellously adapted to the fire-prone arid Australian environment. The mallee trunk grows beneath the land surface, where it is not affected by fire. A bushfire can consume the multiple branches, and with leaves sprouting from the trunk below the surface the branches will quickly grow again. This allows regular harvesting for processing of large tonnages every four years. Sequestration continues through increases in the mass of the trunk (the 'mallee root') while the branches and leaves provide a periodic harvest of biomass.

Savannah covers about one-fifth of the Earth's surface. Much of northern Australia is covered by savannah. The savannah country generally is experiencing increased rainfall, and this is supporting more dense vegetation there. This change is happening naturally, and there are opportunities for human intervention to increase the carbon stock.

The large land area and increased rainfall of the Australian savannah warrant systematic research on defining and utilising such immense carbon sequestration potential. Yet the general story is of immense potential for sequestration of carbon through changes in Australian land use, but of small and diminishing effort to define the potential and the means of unlocking it.

There is considerable potential for emissions reductions through use of agricultural, woodland and forest output for bioenergy production. In the zero-carbon economy of the future, however, biomass is likely to be reserved, by its price, for high-value uses in civil aviation and inputs into chemical industrial processes. The value would be large, but it may not contribute directly to reducing Australian emissions as it replaces emissions from fossil energy throughout the world.

The food challenge

The twenty-first century has seen strong economic growth in developing countries even as incomes have stagnated in developed countries since the global financial crisis. In developing countries, rising incomes have led food consumption patterns to move rapidly towards those of the rich. Meat consumption in China rose more than tenfold over 40 years of reform and development, to almost 70 kg per capita per annum, or about the average of the developed countries. Chinese consumption is dominated by non-ruminant meats – pork and chicken – which are more efficient in converting grain into animal protein and do not emit methane from enteric fermentation, but nevertheless place great pressure on land and the natural environment. Chinese direct and indirect demand for grain has pushed up global prices and reversed a strong tendency through the second half of the twentieth century for food prices to fall.

South Asia, with its religious and cultural constraints on eating meat (particularly beef) will not see levels of meat consumption similar to those in China. But the pressures on land resources will still be large. Successful development in Africa is also likely to place similar pressures on food production and the natural environment.

The extension of something like the developed world's pattern of food consumption to the whole of humanity with successful global development in the twenty-first century is inconsistent with climate stability, and more generally with the stability of ecological systems. It would also be unhealthy.

The convergence of economic development, climate, biodiversity and general ecological and health imperatives will create strong momentum towards changes in global diets. Rising absolute and relative prices of meat in general and especially ruminant meat will modify consumption patterns.

Changing personal preferences will play an important role. The health story will become more influential everywhere – following trends amongst better educated and higher income people in the developed countries. Larger numbers of people in high-income nations will be influenced by the climate, general ecological and animal welfare cases for greater reliance on plant-based foods.

And changing personal preferences, relative prices and technological opportunity will open the way to a revolution in production of meat-like substitutes from plant biomass. In taste, texture and nutrition these will become indistinguishable from meat from the killed animal – superior in nutrition, if that is preferred. The price of substitutes will fall, eventually, to below the rising price of farm-based meats.

More generally, there will be a shift in demand to higher quality, safer and more expensive food. Australia has exceptional comparative advantage in supply of the higher value products that will dominate demand – especially in supplying the world's largest and most rapidly growing markets in Asia. The main meat substitutes make intensive use of biomass and energy and less use of water than the animal competitors. Australia is well placed as a supplier to international markets, especially to what will become the main centre of global demand, Asia.

Capital and expertise will be more important, and water less so, in food production. This will enhance Australia's advantages in this new food world.

Carbon Farming Initiative, Emissions Reduction Fund and the international rules

From Kyoto to the Paris Rulebook

The 2008 Garnaut Review concluded that full realisation of the potential for mitigation in the land sector required comprehensive carbon accounting. The inclusion of land under the Kyoto Protocol framework was incomplete. With the adoption of the Paris Agreement in 2015, and the subsequent implementation rulebook adopted at the end of 2018, all countries will be required to report emissions under the same UNFCCC reporting framework, applying the latest IPCC guidance, which includes a more comprehensive approach to land-based accounting.

Key elements of the Paris Agreement raise the possibility of unprecedented reliance on land-based mitigation. While reliance on land-based mitigation in the Kyoto Protocol was subject to strict limitations and caps, in the Paris Agreement land-based sinks are now prominent (Dooley and Gupta, 2017).

From the Carbon Farming Initiative to the Emissions Reduction Fund

The Carbon Farming Initiative allowed farmers and land managers to earn Australian Carbon Credit Units (ACCUs) which each represented one tonne of carbon dioxide equivalent (CO_{2e}) reduced by storing carbon or by reducing GHG emissions on their land. The ACCUs could be sold to clear obligations under the carbon-pricing rules. In July 2014, the carbon price was repealed. On 31 October 2014 the new Coalition government's climate strategy, the Direct Action Plan, was passed as part of the *Carbon Farming Initiative Amendment Bill 2014*.[5] The 2014 amendment established the Emissions Reduction Fund to provide a transition for the Carbon Farming Initiative by amending the *Carbon Credits (Carbon Farming Initiative) Act 2011* to provide for the Clean Energy Regulator to conduct auctions and enter into contracts to purchase emissions reductions. The 2014 amendment therefore oversaw a shift from a carbon price to government-purchased abatement, and an expanded Carbon Farming Initiative, moving eligible projects beyond the land sector to include energy and transport. In the ERF, $2.55 billion was made available for direct purchasing of abatement under the reverse auctions, of which $226 million remained in May 2019. The Government's Climate Solutions Fund was announced on 25 February 2019 to appropriate an additional $2 billion from 2020–21 onwards to fund auctions to 2030.

Agriculture and land use were spared the general removal of incentives for reducing carbon emissions under the Abbott–Turnbull–Morrison governments by the establishment of the ERF. This kept alive important features of the Carbon Farming Initiative, including its administrative framework.

Growing the future

It is now clear to the international community, as it was not 11 or 8 years ago, that changes in land use and agriculture will have a central role in avoiding high costs of climate change. Perhaps two-thirds of the global movement to zero emissions will come from decarbonisation of electricity and electrification of transport and industry. Nearly all of the remainder will come from changes in agricultural and pastoral activities and land use, with some help from decarbonised energy. If we move too slowly and overshoot the Paris targets, plant-based carbon sequestration – including through the capture of carbon wastes from plant-based industrial processes and storing or using them in ways that keep them out of the atmosphere – will be the main avenue for achieving negative emissions.

The transformation of food, agriculture and land use that is necessary for climate change mitigation is also necessary to allow the maturation of global development, to improve human health, and to maintain a stable global ecology

[5] http://www.aph.gov.au/Parliamentary_Business/Bills_Legislation/Bills_Search_Results/Result?bId=r5280

more generally. There will be one agricultural and land use transformation to serve these four great purposes.

It is now clearer to me than it was 11 or 8 years ago that Australia has great advantages in this new zero-emissions world. The opportunities for zero- and negative-emissions land use lower the cost of doing our fair share in a global mitigation effort, and open new areas of comparative advantage in a zero-emissions world economy.

To make good use of this opportunity, Australia will need to put in place systematic incentives for reducing emissions in agriculture and land use, and provide good reasons to believe that they are here to stay. And it will need to restore old national strengths that have been allowed to decline in recent years: namely, our strengths in research and education on agricultural, pastoral, forestry and related industrial activities. The combination of low-cost renewable energy and abundant land for biomass will be powerful in the synthetic food production industries in a zero-carbon world.

Alongside our industrial opportunity in renewable energy, our strength in growing and using biomass will set Australia up as the 'Superpower of the low-carbon world economy'.

To conclude: a forecast

The low-carbon world economy will be especially favourable for rural and provincial Australia. Energy will be produced mainly outside the large cities, much of it in remote locations. This will make it commercially attractive to process many Australian mineral, agricultural and pastoral products into higher value, close to the places in which the basic commodities are produced. A new carbon farming industry, prospering exceptionally in less agriculturally productive regions, will add substantially to rural incomes. Biomass will have additional value as a base for new industry, especially when combined with low-cost energy. The new activities on average will make fewer demands on water than the old. And low-cost energy will improve the economics of recycling, desalinating, transporting and otherwise increasing the value of limited water resources.

Rural and provincial regions will be the engine room of the 'Superpower of the low carbon world economy'.

References

Clark C. 1957. *Conditions for Economic Progress* (3rd edition). London: Macmillan.

Dooley K., Gupta A. 2017. Governing by expertise: the contested politics of (accounting for) land-based mitigation in a new climate agreement. *International Environmental Agreements: Politics, Law and Economics* **17**(4): 483–500.

Garnaut R. 2008. *The Garnaut Climate Change Review*. Commonwealth of Australia, Canberra, and Cambridge University Press, Port Melbourne.

Garnaut R. 2011. *The Garnaut Review 2011: Australia in the Global Response to Climate Change*. Commonwealth of Australia, Canberra, and Cambridge University Press, Port Melbourne.

Garnaut R. 2019. *Superpower. Australia's low-carbon opportunity*. La Trobe University Press with Black Inc. https://www.blackincbooks.com.au/books/superpower

IPCC. 2019. *Climate change and land*. Report by the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2019/08/4.-SPM_Approved_Microsite_FINAL.pdf

Meinshausen M., Dooley K. 2019. Mitigation scenarios for non-energy GHG. Pages 79–91 in: Teske S. (ed.) *Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5C and +2C*. New York: Springer Publishing.

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