Beyond Zero Emissions Inc.

Kindness House
Suite 10, Level 1
288 Brunswick Street
Fitzroy, Victoria 3065

Office: Monday - Friday, 9:30 am - 6 pm
Phone: +61 3 8383 2232
info@beyondzeroemissions.org
www.beyondzeroemissions.org

29 September 2012

Submission to the National Food Plan

Green paper response

Andrew Longmire and Adele Neale

Chapter 1 – A National Food Plan for Australia

1.1 Do you agree with the possible overall approach outlined in this green paper to create a more strategic, better-integrated and transparent approach to food policy?

A safe climate is an important natural resource and is a necessary condition for reliable, productive food supplies. The definition of safe food should include maintenance of a safe climate for continued food production. The agriculture sector must be prevented from harming itself by jeopardising the stability of the climate system in which it operates. Additionally, close attention should be paid to making the food system resilient to other changes that are likely to occur in the coming decades, including peaks of supply in energy, fertiliser, fuel, and land. Moreover, we advocate that the period of foresight considered by the National Food Plan be extended well beyond the fifty-year period currently projected.

The green paper is dismissive of the impact of human-induced climate change on Australian agriculture, suggesting that agricultural productivity might increase with more rain in some scenarios, and generally that innovation and the market will correct supply deficits with little change to 'business as usual' practices. Somewhat incongruously, the paper also recognizes that climate change could reduce agricultural productivity to 2050 by almost 20% (p. 63), yet proposes the target of doubling Australia's food exports by 2030. The National Food Plan must take seriously the prospect of dramatic negative impacts on productive landscapes in the period to which the plan itself refers – from now to 2050.

Beyond Zero Emissions understands that climate change has great potential to alter conditions for agriculture in Australia, and that some of the variability in current conditions is likely linked to anthropogenic global warming. Modelling indicates great uncertainty but alarming possibilities for future climate scenarios, and studies confirm a decades-long drying pattern along the agriculturally important east coast, south-east and south-west regions[1]. With direct reference to agriculture, a number of reports have found that shifting climatic regimes, which result largely

[1] ABARE, *Australian Commodities March Quarter.* (Australian Bureau of Agricultural and Resource Economics, Canberra., 2007).

from human activity, are likely to affect all aspects of food production in Australia[2]. Recently, a study by the University of Melbourne and CSIRO argued that adaptation to climate change would need to be transformational rather than incremental[3]. A large body of literature indicates that human interference in climate systems has already committed the planet to warming in excess of 2°C relative to pre-industrial; progress to date on mitigating emissions has not inspired confidence that a political solution is at hand. Worse, in a world where 2°C is surpassed, progress toward and beyond 4° of warming is almost assured and would lead to major disruption[4]. These mileposts may also be closer than we have so far supposed[5].

Many of Australia's productive landscapes may already be at the outer limit of their productivity potential[6]. The capacity of agriculture to mitigate climate change, and the urgent development of resilience in agricultural systems should therefore be a priority consideration of the National Food Plan, but the plan must also push for analysis of risks to agriculture in the long-term.

There is little consideration in the green paper of agriculture as a strong source of greenhouse gases and therefore as a driver of climate change. Greenhouse emissions from agriculture also have a strong influence on climate, contributing a large proportion of Australia's emissions. This stems largely from the strong weighting of methane (CH_4) among the emissions produced by agriculture. The vast majority of CH_4 comes from enteric fermentation in sheep and cows. Although the National Inventory Report (NIR) attributes just 16% of Australia's total greenhouse gas emissions to Agriculture[7], a number of sources put this figure much higher. According to the Victorian Eco Innovation Lab, the food system produces at least 23% of Australia's carbon emissions[8]. In a CSIRO/Sydney University study, Foran and colleagues (2009) attributed 33% of national greenhouse gas emissions to agriculture and food production[9].

Research conducted by Beyond Zero Emissions attributes to agriculture emissions currently reported under Land Use, Land Use Change and Forestry (LULUCF) in the national greenhouse accounts. These emissions, *Cropland, Grassland, Agricultural Lime* CO_2 and N_2O *from Conversion to Grasslands*[10], are clearly the result of agricultural activities. Using a twenty-year global warming potentials (GWP)[11], more than half of Australia's greenhouse gas emissions

---

[2] PMSEIC, "Australia and Food Security in a Changing World", 2010, http://www.chiefscientist.gov.au/wp-content/uploads/FoodSecurity_web.pdf.

[3] L. Rickards and S. M. Howden, "Transformational Adaptation: Agriculture and Climate Change," *Crop and Pasture Science* 63, no. 3 (2012): 240–250.

[4] K. Anderson and A. Bows, "Beyond 'dangerous' Climate Change: Emission Scenarios for a New World," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 369, no. 1934 (2011): 20–44.

[5] R. A. Betts et al., "When Could Global Warming Reach 4 C?," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 369, no. 1934 (2011): 67–84.

[6] A. P. Hamblin and G. Kyneur, *Trends in Wheat Yields and Soil Fertility in Australia* (Australian Government Pub. Service, 1993).

[7] DCCEE, *Australian National Greenhouse Accounts National Inventory Report 2009 Volume 1: The Australian Government Submission to the UN Framework Convention on Climate Change April 2011*, vol. 1, 3 vols. (Canberra, Australia: Department of Climate Change and Energy Efficiency, 2011), http://www.climatechange.gov.au/~/media/publications/greenhouse-acctg/national-inventory-report-2009-vol1.pdf.

[8] Kirsten Larsen, *Sustainable and Secure Food Systems for Victoria: What Do We Know, What Do We Need to Know? VEIL Research Report No. 1.* (Victorian Eco-Innovation Lab, University of Melbourne, 2008), http://www.sustainable.unimelb.edu.au/files/mssi/VEIL_Sustainable-and-Secure-Food-Systems_Apr-2008_0.pdf.

[9] B. Foran, M. Lenzen, and C. Dey, "Balancing Act-A Triple Bottom Line Account of the Australian Economy," *Internet Site Http://www.Isa.org.usyd.edu. Au, CSIRO Resource Futures and The University of Sydney, Canberra, ACT, Australia* (2005).

[10] DCCEE, *Australian National Greenhouse Accounts*, 1:.

[11] D. T Shindell et al., "Improved Attribution of Climate Forcing to Emissions," *Science* 326, no. 5953 (2009): 716.

come from the agriculture sector (Figure 1). These emissions include tropospheric ozone and its precursor gases, which have recently been allocated a (GWP)[12]. Given the likely impact within decades of severe climate disruption, including feedbacks and tipping points, a twenty-year horizon is much more appropriate than 100 years.

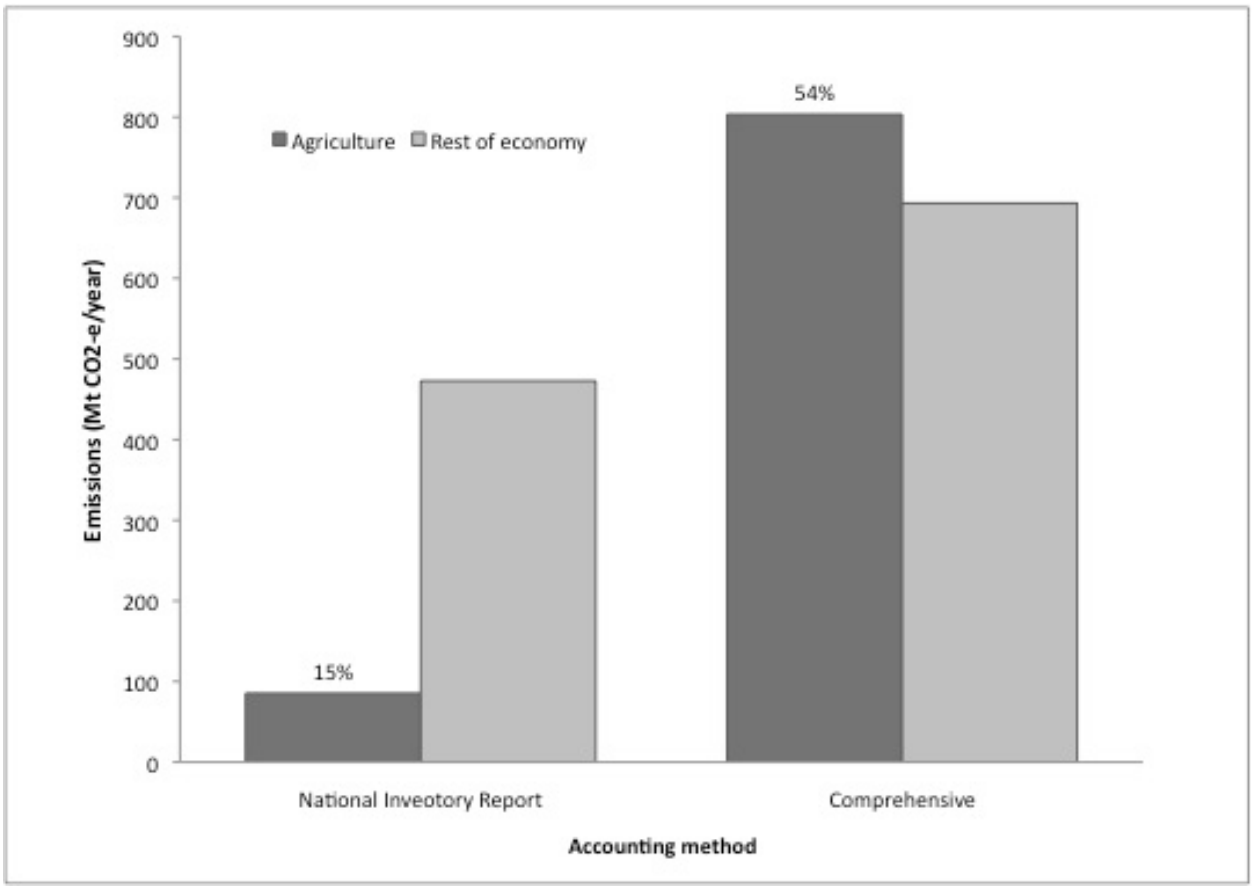

Figure 1: Comparison of standard National Inventory Report[13] and Beyond Zero Emissions' comprehensive accounting methods[14], inclusive of both *Agriculture* and *LULUCF* emissions, precursors to tropospheric ozone and carbon monoxide, and using 20-year global warming potentials. Five year average emissions for 2006-2010 are used.

Agriculture (especially rangeland grazing) is acknowledged in the green paper as occupying 59% of the Australian continent. With this huge area, it is unsurprising that agriculture has a strong greenhouse signature, but also evident is the large capacity of agriculture to sequester carbon, and hence to reduce risks of damage by mitigating global warming. A 2009 report from the CSIRO *Sustainable Agriculture Flagship* found that "as much as 140 MT each year, or 77% of Queensland's [2007] (182 MT per year) carbon dioxide equivalent (CO_2e) greenhouse emissions, could be offset by rural land use change that either stores carbon or mitigates

[12] Ibid.

[13] DCCEE, *Australian National Greenhouse Accounts*, 1:.

[14] Beyond Zero Emissions, unpublished.

emissions"[15]. The national potential for capturing atmospheric carbon in plants and soil is of course far greater than these figures from Queensland alone and represents an opportunity that the National Food Plan should embrace in the name of a safe climate for food production.

The National Food Plan should consider the greenhouse footprint of our food production system and advocate for urgent and comprehensive research and the adoption of measures to reduce emissions and draw down carbon already in the atmosphere. Such strategies may include transformational adaptation such as large-scale changes to production systems.

Emissions from food production

As detailed above, the vast majority of emissions from the food sector result from animal agriculture. These emissions are mainly methane from enteric fermentation in sheep and cattle. As methane has a relatively short atmospheric life but a very high global warming potential, mitigation of this gas offers an opportunity for a short-term win. A significant reduction in methane emissions represents a low-cost opportunity to mitigate total emissions, and and opportunity to buy time for concurrent emissions reduction in other areas.

Diets high in animal products are closely correlated with obesity, heart disease and other morbidities. As the world's second most obese nation, it is difficult to argue that our current dietary habits are serving us well. There is also a strong positive correlation between the greenhouse gas profile and energy content of foods[16].

While the green paper (p. 241) recognizes that the shift to diets high in animal proteins increases the risks to global food security, it emphasises the market opportunities for high price/high value food exports and proposes to double exports of such products to Asia.

The national food plan should recognise the need for a fundamental shift to a healthy and climatically sustainable diet, and acknowledge Australia's capacity and moral obligation to share this knowledge and to assist developing nations in finding a pathway toward this objective. We may need to learn from other countries what has served them well in terms of diet rather than selling our questionable dietary habits to them. We note also that the export of 'high value', animal-based foods and food products, as advocated in the green paper, also entails the effective importation of other countries' carbon liabilities.

There is a need for greater use of peer-reviewed scientific research in the National Food Plan. This would add credibility and transparency to the plan and should be used to identify important issues in food production and offer solutions.

---

[15] S. Eady et al., *An Analysis of Greenhouse Gas Mitigation and Carbon Biosequestration Opportunities from Rural Land Use* (CSIRO Sustainable Agricultural Flagship, Brisbane, Qld, 2009).

[16] L. Reijnders and S. Soret, "Quantification of the Environmental Impact of Different Dietary Protein Choices," *The American Journal of Clinical Nutrition* 78, no. 3 (2003): 664S.

Chapter 3 – Australia's food policy framework

3.1 Do you agree with the proposed outcome and objectives outlined in this green paper to guide the Australian Government's development of food-related policy and stakeholder consultation mechanisms?

The green paper seems to advocate the provision of a conduit for consultation between different sectors of the food industry, without seeking to guide the discourse or intervene to ensure positive outcomes for the Australian community. Such intervention will be necessary if we are to achieve a food system that does not damage itself by jeopardising a safe climate.

3.2 The Australian Government is seeking feedback on a number of alternatives to improve leadership and stakeholder engagement on food policy issues. These alternatives are set out in Section 3.4.1.
Do you have a preference for a particular alternative or a specific suggestion for another mechanism that would provide better leadership, coordination and stakeholder engagement on food policy issues in Australia?

Whatever body is established, it must include among its personnel experts in climate and in the adaptation of agriculture to climate change. The brief must include material such as that presented in our response above, in relation to the sharp cuts to emissions needed to mitigate the most destructive aspects of climate change. This would permit the formulation of food policy that takes account of the likely disruption.

Chapter 4 – Australia's food security

4.1 Do you agree with the analysis that, broadly speaking, Australia is food secure? If not, why not? Please be specific and provide evidence to justify your position. What additional data could the government draw on to measure Australia's food security?

In a narrow sense and right now, Australia is relatively food secure from many, though not all, points of view. The National Food Plan green paper, however, suggests that our society look as far as 2050.

As detailed in our response to Q 1.1, we risk our food security by failing to seriously tackle climate change. Australia's food security is at risk because of the effects of anthropogenic global warming. Our agricultural systems are exposed to first-order effects of changing patterns of rainfall and temperature. Changes to both timing and spatial distribution of rainfall have the potential to severely disrupt agricultural production. Increasing incidence of temperature extremes and of unseasonal conditions will also provoke crop damage, likely at higher rates than previously experienced. Prolonged drought in the first decade of the 21st century was probably worsened by global warming, and the projected increasing frequency of temperature extremes has the potential to disrupt food supplies by knocking out whole crops or regions.

The green paper's assumption of a 'market fix' (p. 63) to climate-related deficits is likely to prove a delusion. Resources must urgently be committed to preventing the worst of climate change.

Most Australian soils are relatively poor in plant nutrients, though a few exceptions exist where volcanoes have cast new rock onto the land surface in the recent geological past[17]. Agriculture is already established in most areas where it is viable, and has little space for expansion, meaning that climate change is likely to push some food-growing activities beyond their physical limits. Some of Australia's major crops, including cereals, are unlikely to undergo further yield increases because they have reached their potential even before factoring in potential disruptions due to changing climatic conditions[18].

Energy

Declining supplies of fossil fuels are treated cursorily in the green paper, with the explanation that "Australia is the world's ninth largest energy producer with abundant renewable and non-renewable energy resources, which will allow Australia to reliably meet its future energy demands" (p. 70). Unfortunately most of this energy is exported as coal and gas, and combusted with the release of large volumes of greenhouse gases.

The green paper goes so far as to mention that Australia possesses "at least a century of coal". It is utterly unacceptable for the National Food Plan to pretend that food production is somehow isolated from Australia's reliance on fossil fuels for domestic energy and export earnings. Climate change provides a direct connection between these concepts – the combustion of fossil fuels, whether in Australia or elsewhere, increases the risk of dangerous climate change as detailed above (Q 1.1). The National Food Plan must confront the issue of climate change with vigour, championing the cause of renewable energy sources and the nation's complete withdrawal from fossil fuel markets.

Coal seam gas (CSG) also rates a mention in the green paper (p. 67), but its potential to negatively affect agriculture is severely underplayed. Claims that less than 1% of the nation's farmland will be affected by CSG misses the point that exploration leases commonly coincide with highly productive landscapes (for example, the Hunter Valley and Surat Basin), and that the extent of groundwater they may contaminate is often poorly understood.

The expansion of CSG exploration causes productive land to be lost and groundwater to be contaminated. Worse, CSG extraction is responsible for high levels of fugitive methane emissions[19], causing a near-term climate threat. This can only lessen the resilience of our food production systems. As CSG extraction competes directly with food production (as indeed does coal mining), the National Food Plan should take a strong position in support of a ban on these activities, especially in food-producing regions.

We may have abundant renewable energy resources, also noted on page 70 of the green paper, but we are doing little to exploit these and bring them to market to displace fossil fuels. This represents an opportunity that Australia ought to grasp to develop in the near-term clean energy

---

[17] P. Wellman and I. McDougall, "Cainozoic Igneous Activity in Eastern Australia," *Tectonophysics* 23, no. 1–2 (1974): 49–65.

[18] A. Hamblin, G. Kyneur, and Australia. Dept. of Primary Industries and Energy. Bureau of Resource Sciences, *Trends in Wheat Yields and Soil Fertility in Australia* (Australian Government Pub. Service, 1993).

[19] R. W. Howarth, R. Santoro, and A. Ingraffea, "Venting and Leaking of Methane from Shale Gas Development: Response to Cathles et al.," *Climatic Change* (2012): 1–13.

industries capable of displacing fossil fuels in our energy mix. However, the production of biofuels should never be prioritised over food where the two compete for land, water, nutrients or other resources, as has happened in North America and Europe. Biofuels are not likely to significantly displace fossil oil; the alternative is large-scale renewable energy. Peak oil is addressed below.

High CO_2 levels decrease food production

Elevated atmospheric CO_2 concentrations themselves have great potential to affect food production, independent of changes to climate resulting from anthropogenic carbon emissions. Carbon dioxide fertilisation, where plant growth is boosted due to high levels of CO_2, is often cited as a benefit of carbon emissions. Indeed some limited modelling demonstrates that wheat yields, for example, may increase under elevated CO_2[20]. However, these models did not account for the changes to rainfall, temperature and evaporation both predicted and observed under climate change. A 2005 report, centering on wheat in South Australia, projected that median yields would "decrease across all locations from 13.5 to 32% under the most likely climate change scenarios (as of 2005)"[21]. Although it is true that plants can use both water and nitrogen more efficiently under high CO_2, and that any positive yield effects would be greatest in arid areas[22], there are also strong downsides. Grain protein levels are an important determinant of the value, both economic and dietary, of cereal crops. As plants are able to photosynthesise more efficiently at high atmospheric CO_2 levels, they require less protein in their leaves, and this translates to lower grain protein levels[23] [24]. Uncontrolled carbon emissions therefore have the capacity to directly reduce returns to farmers independent of climatic change[25].

Finite resources

There is some reference in the green paper to the finite nature of other natural resources needed for continued agricultural production, such as phosphorus (P). This is pertinent, but the green paper appears instead to indicate that market forces will make viable P reserves which currently are not, and that increased costs might be "offset by increased efficiency and R&D" (p. 70). Whichever way you look at it, agriculture and our food supply are based on plants. Plants have a non-negotiable physiological requirement for a number of nutrients, some of which are in limited supply. We suggest proactive research and the dedication of resources to ensuring the long-term availability of finite mineral nutrients such as phosphorus.

---

[20] S. P Long et al., "Global Food Insecurity. Treatment of Major Food Crops with Elevated Carbon Dioxide or Ozone Under Large-scale Fully Open-air Conditions Suggests Recent Models May Have Overestimated Future Yields," *Philosophical Transactions of the Royal Society B: Biological Sciences* 360, no. 1463 (2005): 2011.

[21] Q. Luo et al., "Potential Impact of Climate Change on Wheat Yield in South Australia," *Agricultural and Forest Meteorology* 132, no. 3–4 (2005): 273–285.

[22] J. Glover et al., "Australia's Crops and Pastures in a Changing Climate–can Biotechnology Help?," *Canberra: Australian Government Bureau of Rural Sciences* (2008).

[23] D. R TAUB, B. Miller, and H. Allen, "Effects of Elevated CO2 on the Protein Concentration of Food Crops: a Meta-analysis," *Global Change Biology* 14, no. 3 (2008): 565–575.

[24] S. M. Howden, P. J. Reyenga, and H. Meinke, "Global Change Impacts on Australian Wheat Cropping," *Report to the Australian Greenhouse Office. CSIRO, Canberra* (1999).

[25] P. Högy et al., "Effects of Elevated CO2 on Grain Yield and Quality of Wheat: Results from a 3-year Free-air CO2 Enrichment Experiment," *Plant Biology* 11 (2009): 60–69.

Global availability of rock phosphorus for production of fertilisers is likely to be exhausted within the next 50-100 years[26] [27] [28]. As supplies of P are depleted, mining of less accessible reserves of phosphate rock will be more expensive, and use of lower quality reserves is also problematic because of cadmium, uranium and thorium contamination[29]. These elements are either toxic to soil, radioactive, or both, and their removal from phosphates during fertiliser production is prohibitively expensive and energy intensive. Long-term exposure to them can also pose a risk to farm workers[30]. As acknowledged in the green paper, Australia imports the majority of the phosphorus it uses as fertiliser. The increasing price of fossil fuels as oil production peaks will also reduce the viability of mining rock phosphate and transporting this and other bulk commodities over long distances.

Australian agriculture is also heavily reliant on inputs of synthetic nitrogen (N) fertiliser – more than a million tonnes are applied each year. Both manufacture and application of these fertilisers are strong sources of nitrous oxide (N_2O), a greenhouse gas around 300 times stronger than CO_2[31]. In addition, for each tonne of urea produced up to 2.5t of CO_2e are released[32]. Nitrogenous fertilisers also embody large amounts of both energy and fossil fuels[33]. Fossil gas is a key ingredient in the Haber-Bosch process used to generate ammonia in the production of urea and other fertilisers. Gas is certain to increase in price as the world consumption of fossil fuels accelerates, and will be indexed to world prices as a result of gas exports; these increases will flow through to fertilisers.

While we acknowledge that N and P inputs are currently an important part of the food production system, the climate implications of excessive greenhouse gas emissions due to fertiliser use, and the finite nature of the raw materials for their manufacture, should be taken into account when assessing the long-term sustainability of the system. This might take the form of prioritised research into slow-release fertilisers and precision agricultural techniques, but unconventional agricultural methods should equally be encouraged and alternative nutrient sources investigated, particularly the retrieval of nutrients from waste streams.

Peak oil

Conventional agriculture is literally “feeding fossil fuels to the soil”, even when only the fertiliser inputs are considered and fuel for tractors and transport are overlooked[34]. Australian agriculture and transport, and hence food distribution systems, are heavily reliant on diesel. With the decline of Australia’s freight rail system, fertiliser transport to cropping areas and produce

---

[26] Ibid.

[27] V. Smil, *Feeding the World: a Challenge for the Twenty-first Century* (The MIT Press, 2001).

[28] V. Smil, “Phosphorus in the Environment: Natural Flows and Human Interferences,” *Annual Review of Energy and the Environment* 25, no. 1 (2000): 53–88.

[29] D. Cordell, J. O Drangert, and S. White, “The Story of Phosphorus: Global Food Security and Food for Thought,” *Global Environmental Change* 19, no. 2 (2009): 292–305.

[30] Smil, “Phosphorus in the Environment: Natural Flows and Human Interferences.”

[31] S. Wood and A. Cowie, “A Review of Greenhouse Gas Emission Factors for Fertiliser Production,” in *IEA Bioenergy Task*, vol. 38, 2004.

[32] Ibid.

[33] CA Ramírez and E. Worrell, “Feeding Fossil Fuels to the Soil:: An Analysis of Energy Embedded and Technological Learning in the Fertilizer Industry,” *Resources, Conservation and Recycling* 46, no. 1 (2006): 75–93.

[34] Ibid.

transport to cities and ports for export are virtually completely reliant on trucks. Some foodstuffs, especially highly processed foods, are transported on trucks many times before final 'assembly' into a product. This situation leaves the Australian food system highly exposed to price spikes as peak oil strikes. 'Coal-to-liquids' technologies, sometimes proposed as a solution to oil shortages, are unready, would be highly polluting and would not address shortages on the scale required.

Various sources including the International Energy Agency (IEA), ExxonMobil, Cambridge Energy Research Associates and others have recently demonstrated that world oil production is in decline[35]. Clearly, demand for oil is strong and growing. As Dr. Fatih Birol, chief economist of the IEA said in 2008, "We need to leave oil before oil leaves us"[36]. The words of Dr. Birol should make it amply clear that Australia's National Food Plan must prepare the food production system for peak oil.

According to the IEA, peak oil happened in 2006[37], but the IEA has often overestimated oil reserves and underestimated the difficulties associated with extracting them[38].

Oil is becoming demonstrably more difficult to obtain, with ever more expensive equipment and techniques needed. The danger and frequency of environmental spills has increased, and these are extremely expensive to clean up; The Deepwater Horizon disaster in the Gulf of Mexico provides a stark example of this, but such spills have happened in Australia in the recent times, at Montara 2009 oil spill and associated fire. The Montara well leaked for 74 days.

For these reasons, we now live in a period of great uncertainty of oil prices, and the risks to activities and sectors that rely heavily on oil are consequently greatly exacerbated[39]. The National Food Plan must investigate alternatives to reliance on fossil oil for the future.

4.2 The Australian Government is seeking feedback on the option of working with state and territory governments and the food industry to develop strategies to mitigate risks and maintain continuity of the food supply in a major emergency. Section 4.5 of Chapter 4 outlines some options. Do you support these options? Do you have specific suggestions for other options or strategies?

Maintaining continuity of the food supply requires preparation and large changes to be made now and consistently into the future.

The risk of future natural emergencies can be reduced by combating and reducing human contribution to climate change and associated natural disasters. This means reducing greenhouse gas emissions in the agricultural and other sectors, and sequestering carbon in responsible ways (Q 7.1).

---

35 D. Fantazzini, M. Höök, and A. Angelantoni, "Global Oil Risks in the Early 21st Century," *Energy Policy* (2011).

36 "Warning: Oil Supplies Are Running Out Fast - Science - News - The Independent", n.d., http://www.independent.co.uk/news/science/warning-oil-supplies-are-running-out-fast-1766585.html.

37 International Energy Agency, *World Energy Outlook 2010* (International Energy Agency, 2010).

38 K. Aleklett et al., "The Peak of the Oil Age-analyzing the World Oil Production Reference Scenario in World Energy Outlook 2008," *Energy Policy* 38, no. 3 (2010): 1398–1414.

39 Fantazzini, Höök, and Angelantoni, "Global Oil Risks in the Early 21st Century."

To prepare for interruption to supply of fuel and/or power, large-scale investment in renewable energy is necessary, for both power plants and on-site infrastructure. See also 'Peak Oil' in our response to Q 4.1.

Preparation for storms, floods and droughts should include the adoption of responsible land use practices that promote the health and resilience of land and its produce. The practices outlined in this submission (Q 7.1) meet these criteria.

Chapter 5 – Safe and nutritious food

5.1. The Australian Government has strategies, policies and programs in place to:
- ensure all Australians have access to a safe and nutritious food supply
- support healthy lifestyles
- reformulate foods, improve food labelling and educate consumers
- improve nutritional outcomes for Indigenous Australians
- provide a comprehensive and effective food safety regulatory environment
- build capacity to control known and emerging food safety risks.
This green paper provides details of these initiatives and outlines the Australian Government's future policy directions, including the development of a national nutrition policy.
Are there additional issues the government should focus on in its future policy directions? What factors should the government consider in developing new, and reviewing existing, polices and programs?

The definition of 'safe food' should be extended to take account of the effects of food choices on global climate, as described above in our responses to Q 1.1 and Q 4.1.

Chapter 6 – A competitive and productive food industry

6.2 The government is seeking to increase the value of Australia's food exports from across the supply chain, including the value-added component.
a) Do you think that a target of doubling the value of our food exports by 2030 is achievable? If not, what target would be?
b) How could this be achieved in a market-driven economy like Australia? What would government and business need to do?
c) What would be the costs and benefits of these actions?

Our goal should be to increase the dietary value of our food exports, and to decrease their greenhouse footprint, rather than looking at the narrow definition of economic value.

6.4 One option to increase agricultural productivity to help the sector meet future export growth opportunities and challenges, such as increasing productivity growth in a changing climate, is to increase rural R&D investments over a number of years. This would be in addition to continually seeking better ways to increase the overall benefits of this investment.

a) Is this the best way to help the agricultural sector meet the challenges and opportunities of the coming decades? Why/why not?

The Carbon Farming Initiative (CFI) is a good start in that it considers the greenhouse implications of agricultural activities and recognises that producers must be rewarded for improvements in their emissions profiles. However, the CFI aspires only to weak targets and does not contemplate change on the scale necessary. Farmers would need to be rewarded for their front-line role in combating climate change and supported with research and finance to make the investments necessary to continue producing quality food at the same time. Notably, large amounts of revenue generated under the Clean Energy Future Plan are paid back to heavily polluting industries. These and other resources would be better spent improving the resilience of our food production systems, and developing ways of measuring the environmental sustainability of farming practices.

Consumers want low prices and often prefer high-energy, carbon intensive foods, but these demands may conflict with the objective of sustainable, climate-safe food production. Producers will require well-conceived, science-based policies, possibly including price signals to support best-practice environmental stewardship, as well as access to the best research. Increased investment in rural research and development is necessary, including the funding and training of agricultural scientists. Research must also be well communicated between farmers, consumers and other stakeholders in the food industry.

b) What would be the costs and benefits of this approach?

Research is a worthwhile investment, providing that the research is pursued in useful areas and is pursued for the good of the environment, the people and the food industry. Research into land management practices, waste processing, carbon sequestration, renewable energy, future climate prediction and many other fields, is necessary for improvements to be made.

The findings and recommendations of independent researchers and groups, such as Beyond Zero Emissions, should be considered for use. The objective of BZE's Zero Carbon Australia (ZCA) project is to achieve net negative emissions economy-wide, to stabilise and then reduce atmospheric CO_2 levels without sacrificing economic advance. The first of the ZCA reports demonstrated the practicality of 100% Zero Carbon Stationary Energy sector; a later report will show how net zero and negative emissions can be achieved in the Land Use sector, while maintaining Australia's contribution to the world food task.

c) How could any additional investment be targeted to achieve the greatest overall benefit to Australia?

As detailed above, investment in emission reduction, carbon sequestration and renewable energy would provide the greatest overall benefit to Australia.

6.6 One way for food businesses to add value is through increased quality, such as high product standards, new traits or nutritional attributes. Governments in Australia generally adopt little or no role in regulating quality, except where required for public health reasons.

a) What opportunities are there for businesses to add value through quality attributes?

The approaches outlined in the response to Q 7.1 add value to food products.

There may be opportunities for farmers to preferentially produce 'low emissions' or 'low carbon' foods if consumer demand encourages it. Such an approach could involve displaying emissions ratings on food labels.

b) Is there a role for government to encourage this or remove barriers such as regulation? (please explain/elaborate).

Government has a role in ensuring that farmers have access to practices that are environmentally sustainable and will benefit the Australian people long into the future, as outlined in our response to Q 6.4a. Some appropriate practises are outlined in our response to Q 7.1.

Chapter 7 – A strong natural resource base

7.1 Pressure to increase food production in coming years, in response to increased demand from a growing global population, could place additional stress on Australia's natural resource base. What further initiatives could the government consider to encourage sustainable farming and fishing practices that balance economic, social and environmental benefits?

A vast expansion of the CFI could be used to this end, as described in our response to Q 6.4.

Sustainable farming should be encouraged by providing guidance and support to farmers, who may require financial, educational and social support and who may benefit from changes in policy. This should include facilitating communication between scientists, farmers and consumers. Recognition and reward for best environmental practice would provide further encouragement.

The government should encourage collaborations between farmers and parties involved in food production. Transitions to more environmentally sustainable farming methods and practices will be easier and cheaper if done in partnerships. For example, neighbouring farmers could share solar panel infrastructure or revegetation efforts. Further, co-location of some production

streams may allow collaborations to occur; for example, the conversion of methane from livestock manure to electricity to heat glasshouses.

It is important that science guide responsible decisions about the types of farming practices encouraged. Practices need to be both environmentally and economically sustainable. More scientific research is required and should aid these decisions. However, a large amount of information about best management practices is already available. BZE supports the adoption of practices that reduce emissions, such as those that prevent emissions from soil or farming operations and those that sequester carbon in vegetation and soil. Some sustainable land use practices and approaches are outlined below.

- Renewable energy should be used wherever possible in the food production system, as in the wider economy, to reduce greenhouse gas emissions and provide secure energy supply for the future. Renewable energy should be generated on-site to assist the operation of farms, and there are opportunities for landholders to provide land for large-scale production, i.e. solar plants and wind farms.

- Reliance on synthetic fertilizers should be reduced, as noted in our response to Q4.1. Reduction of fertilizer use can be achieved by using precision agricultural techniques, by which measured amounts of fertiliser are delivered directly into plants' root zones, usually with irrigation or rain. Better, reducing reliance on synthetic fertilisers may be achieved by replacement or amendment with natural alternatives such as poultry litter biochar, wastewater sludge biochar[40] [41] [42] [43] and fertilizers derived from animal, plant, algae or mineral. This approach also promotes growth of soil fungi that intercept nutrients in runoff, retaining them in the soil, and which also build soil carbon and function. Notably, soil health is also a stated priority in the green paper, and particular mention is made of soil acidification (p. 203). In this context, continued heavy reliance on synthetic fertilisers is also brought into question because of the acidifying effects of N fertilisers on soil.

- Urban agriculture is growing in popularity across Australia's cities. It has the potential to supply large amounts of food with minimum transport and related emissions, reduce the heat island effect and promote sustainability. Initiatives include farmers markets, street plantings and community gardens and should be supported by all levels of government. Some examples of initiatives in Australia: CERES, www.ceres.org.au/; Permablitz, www.permablitz.net/; Cool Streets, www.coolstreets.org.au/; Sustainability Street, www.sustainabilitystreet.org.au/ and overseas: Incredible Edible Todmorden, www.incredible-edible-todmorden.co.uk/projects.

- Government support for the Stephanie Alexander Kitchen Garden Program is important, as acknowledged in the green paper. This program educates children and others about food

[40] Shindell et al., "Improved Attribution of Climate Forcing to Emissions."

[41] K.Y. Chan et al., "Using poultry litter biochars as soil amendments," *Australian Journal of Soil Research* 46, no. 5 (August 2008): 437+.

[42] M. K. Hossain et al., "Agronomic Properties of Wastewater Sludge Biochar and Bioavailability of Metals in Production of Cherry Tomato *Lycopersicon esculentum*," *Chemosphere* 78, no. 9 (2010): 1167–1171.

[43] M. K. Hossain, V. Strezov, and P. F. Nelson, "Thermal Characterisation of the Products of Wastewater Sludge Pyrolysis," *Journal of Analytical and Applied Pyrolysis* 85, no. 1 (2009): 442–446.

production and sustainability 'from seed to mouth'. Increased government funding and community support will enable this program to expand to well beyond the 267 primary schools currently taking part. Of seventy schools in the Geelong area, for example, just two have access to the program.

- An environmentally sustainable diet (i.e. one that does not negatively impact the environment) is a necessary step towards a secure future and this needs to be recognized in the National Food Plan. Foods for which production involves large greenhouse gas emissions are particularly threatening. Livestock production, for primarily beef, lamb and dairy, results in emission of methane (see Q 1.1), nitrous oxides, as well as deforestation and loss of soil. Methane is a vastly more potent greenhouse gas and has a far shorter atmospheric half-life than carbon dioxide[44] [45]. Methane is a precursor to tropospheric ozone (O_3), as are nitrous oxides (NO_x) and carbon monoxide (CO)[46] [47]. All of these gases are emitted by human activities, and significant amounts of methane and NO_x are produced in agriculture, especially livestock production. Ground level O_3 is directly toxic to plants and reduces growth by interfering with the photosynthetic apparatus, thereby negatively affecting crop production[48] [49] [50] [51] [52].

  Tropospheric O_3 is itself a greenhouse gas, but also contributes to a positive climate feedback by reducing the amount of CO_2 taken up by plants and hence slowing the removal of this gas from the atmosphere[53] [54] [55] [56]. Knowledge of the effect of O_3 on crops and other plants therefore lends weight to arguments to sharply reduce methane emissions.

  Therefore strategies implemented to reduce methane emissions could be much more effective than generalised programs aimed at carbon dioxide emissions reduction. Some approaches follow:

  - To seriously tackle Australia's agricultural emissions, significant reductions in livestock numbers are required. This would vastly reduce the implementation cost of climate change mitigation policies. This makes reduction of herd and flock sizes one of the very cheapest methods of reducing the impacts of climate change.

---

[44] Shindell et al., "Improved Attribution of Climate Forcing to Emissions."

[45] D. Archer et al., "Atmospheric Lifetime of Fossil Fuel Carbon Dioxide," *Annual Review of Earth and Planetary Sciences* 37 (2009): 117–134.

[46] Shindell et al., "Improved Attribution of Climate Forcing to Emissions."

[47] S. Sitch et al., "Indirect Radiative Forcing of Climate Change Through Ozone Effects on the Land-carbon Sink," *Nature* 448, no. 7155 (2007): 791–794.

[48] M. R. Ashmore, "Assessing the Future Global Impacts of Ozone on Vegetation," *Plant, Cell & Environment* 28, no. 8 (2005): 949–964.

[49] M. Gauss et al., "Radiative Forcing in the 21st Century Due to Ozone Changes in the Troposphere and the Lower Stratosphere," *J. Geophys. Res* 108, no. 1 (2003): 9.

[50] Ashmore, "Assessing the Future Global Impacts of Ozone on Vegetation."

[51] Sitch et al., "Indirect Radiative Forcing of Climate Change Through Ozone Effects on the Land-carbon Sink."

[52] Ashmore, "Assessing the Future Global Impacts of Ozone on Vegetation."

[53] Sitch et al., "Indirect Radiative Forcing of Climate Change Through Ozone Effects on the Land-carbon Sink."

[54] Gauss et al., "Radiative Forcing in the 21st Century Due to Ozone Changes in the Troposphere and the Lower Stratosphere."

[55] Ashmore, "Assessing the Future Global Impacts of Ozone on Vegetation."

[56] M. R. Ashmore and F. M. Marshall, "Ozone Impacts on Agriculture: An Issue of Global Concern," *Advances in Botanical Research* 29 (1998): 31–52.

- The importance of and demand for methane-intensive foods, including beef, lamb and dairy, in our diet needs to be reduced. This could be achieved by encouraging consumers to reduce the frequency of consumption and/or portion size of these foods.

- Changes to the balance of livestock breeds to favour the use of alternative, non-ruminant species should be considered[57]. This approach could accompanied by a meat industry based on feral or pest animals, including rabbits, kangaroos, camels, deer, pigs and goats.

- Dietary supplements and changes to gut biota can reduce methane production in ruminants by increasing efficiency of fodder digestion. Such changes can also deliver improvements in animal productivity.

- Methane from livestock manure can be used for local electricity and heat generation.

- Reduction of methane emissions from soil is important as this a potent greenhouse gas[58]. This can be achieved by aerating soil to promote the presence methanotrophic organisms[5960], by decreasing soil density and increasing porosity, using, for example, biochar.

- Regenerative agriculture systems are designed to maximise on-farm recycling of nutrients as well as be environmentally sustainable and productive. These include organic, permaculture (e.g. Milkwood farm, milkwood.net/; The Food Forest, www.foodforest.com.au/), biodynamic and biointensive approaches.

- Uses should be found for all agricultural residues. Cessation of field burning would permit a reduction of approximately 309,000 tonnes in carbon emissions[61] and would reduce emissions of black carbon (which strongly influences Earth's radiative balance). Potential markets for crop wastes include, for example: paper making; pyrolysis for energy and biochar. Cereal crop stubble is identified in the BZE Stationary Energy report as a feedstock for biomass co-firing of concentrated solar thermal plants. Also, many farmers already recognise the importance of standing biomass in preventing erosion and retaining nutrients and moisture in the soil.

- Integrated pest management is a method of insect pest control that allows reduced insecticide use (e.g. IPM Technologies, www.ipmtechnologies.com.au).

- Carbon sequestration transfers atmospheric carbon to soil and biota. The following practices promote carbon sequestration, while also benefiting ecological and farming

---

[57] R. Garnaut, *The Garnaut Climate Change Review*, vol. 13, 2008.

[58] Shindell et al., "Improved Attribution of Climate Forcing to Emissions."

[59] Andrew J. Holmes et al., "Characterization of Methanotrophic Bacterial Populations in Soils Showing Atmospheric Methane Uptake," *Applied and Environmental Microbiology* 65, no. 8 (August 1999): 3312–3318.

[60] C. Knief et al., "The Active Methanotrophic Community in Hydromorphic Soils Changes in Response to Changing Methane Concentration," *Environmental Microbiology* 8, no. 2 (2005): 321–333.

[61] Department of Climate Change and Energy Efficiency, "Australia's National Greenhouse Accounts - National Greenhouse Gas Inventory", n.d., http://ageis.climatechange.gov.au/#.

systems. It is important to note that carbon sequestered in soils would also be susceptible to re-emission to the atmosphere, most likely at a faster rate than it was sequestered, if appropriate land management methods were discontinued.

- Reduction of land clearing is a priority for conserving carbon sinks.

- Revegetation promotes the storage of carbon in long-lived sinks from which it will not be re-emitted in the short term. Revegetation also reduces soil erosion which facilitates loss of stored carbon in topsoil. There are many revegetation options, including the planting of trees on cleared land en masse, creating corridors of vegetation and various options of agroforestry. Another option is the revegetation of coastal habitats, such as mangrove, seagrass and saltmarsh habitats, which have a large role in CO_2 sequestration[62].

- Regeneration is an easy and low-cost method, by which land is fenced off to allow plants to recruit naturally.

- Healthy soil should be encouraged to increase soil carbon and reduce the need for fertilizers associated with emissions, among other reasons. The Agricultural Resource Management Survey program, mentioned in the green paper, should be continued and used to educate farmers and landholders.

- Microbial life is important for healthy soil. Soil bacteria are particularly important for vegetables, annuals and grasses[63]. Soil fungi can improve crop performance by contributing to nutrient cycling, maintenance of soil structure[64] [65] and by forming direct mutualisms with plants (mycorrhizal symbioses), enhancing plant access to nutrients and water[66] [67]. A function of mycorrhizal symbiosis is the transfer of carbon from plants to the soil[68] [69], facilitating carbon sequestration. Mycorrhizal fungi also give plants better access to phosphorus and both organic and inorganic nitrogen in the soil[70], reducing the need to apply fertilizer. A number of practices common in conventional agriculture have a negative impact on soil fungi, including tillage and use of fungicides and fertilisers[71].

---

62 Elizabeth Mcleod et al., "A Blueprint for Blue Carbon: Toward an Improved Understanding of the Role of Vegetated Coastal Habitats in Sequestering CO2," *Frontiers in Ecology and the Environment* 9, no. 10 (June 20, 2011): 552–560.

63 J. Lowenfels, W. Lewis, and E. Ingham, *Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web* (Timber Press (OR), 2010).

64 B. J Atwell, P. E Kriedemann, and C. G.N Turnbull, *Plants in Action: Adaptation in Nature, Performance in Cultivation* (Macmillan Co of Australia, 1999).

65 T. R. Cavagnaro et al., "Functional Diversity in Arbuscular Mycorrhizas: Exploitation of Soil Patches with Different Phosphate Enrichment Differs Among Fungal Species," *Plant, Cell & Environment* 28, no. 5 (2005): 642–650.

66 A. Fangmeier et al., "Effects of Elevated CO2, Nitrogen Supply and Tropospheric Ozone on Spring wheat--II. Nutrients (N, P, K, S, Ca, Mg, Fe, Mn, Zn)," *Environmental Pollution* 96, no. 1 (1997): 43–59.

67 M. F Allen, "Mycorrhizal Fungi: Highways for Water and Nutrients in Arid Soils," *Vadose Zone Journal* 6, no. 2 (2007): 291.

68 Ibid.

69 S. E Smith and D. J Read, *Mycorrhizal Symbiosis*, 3rd ed. (London: Academic Press, 2008).

70 Allen, "Mycorrhizal Fungi: Highways for Water and Nutrients in Arid Soils."

71 J. Jansa, A. Wiemken, and E. Frossard, "The Effects of Agricultural Practices on Arbuscular Mycorrhizal Fungi," *Geological Society, London, Special Publications* 266, no. 1 (2006): 89–115.

- Minimum tillage and no tillage are widely used methods that reduce soil erosion[72] and reduce physical damage to fungal mycelia[73]. This increases the levels of organic matter, including organic carbon.

- Biochar is a type of charcoal created for use in agriculture for the purpose of soil augmentation and improvement. Biochar is what remains of organic matter that has been partially burnt in a low oxygen environment, a process called pyrolysis. The soil-improving qualities of biochar combined with its long-term stability in soil present a significant opportunity to capture and store atmospheric CO_2 in a form that will remain stable for thousands of years[74]. Biochar also has the potential to reduce emissions through the reduction of methane and N_2O emission losses from soil and through improved fertilizer use. Biochar has also been shown to enhance mycorrhizal colonization[75]. Importantly, biochar production systems need to be engineered carefully so that by-products are handled responsibly.

- Pasture cropping is a technique whereby crops are integrated into perennial pastures and usually alternated with grazing. This has a regenerative effect on the land, increasing soil carbon as well as improving soil structure and nutrient cycling[76].

Rotational grazing involves the division of landholdings into smaller paddocks which are intensively grazed for relatively short periods, and left unstocked for long periods to allow regrowth of pasture. This method has the potential for significantly greater productivity as well as carbon sequestration[77], soil health and other environmental benefits[78].

7.2 Australian society places high expectations on the environmental and social responsibility of Australia's food industry, although this is not always reflected in purchasing behaviour. What is preventing markets from encouraging (via price signals) the food industry's responsible management of the production base?

Consumers have difficulty accessing reliable information about the climate impacts of food they eat. Simple, effective food labelling could be used to remedy this.

---

[72] S. Li et al., "Tillage and Water Erosion on Different Landscapes in the Northern North American Great Plains Evaluated Using< Sup> 137</sup> Cs Technique and Soil Erosion Models," *Catena* 70, no. 3 (2007): 493–505.

[73] T. P. McGonigle and M. H. Miller, "Mycorrhizal Development and Phosphorus Absorption in Maize Under Conventional and Reduced Tillage," *Soil Science Society of America Journal* 57, no. 4 (1993): 1002–1006.

[74] P. Taylor, "The Biochar Revolution: Transforming Agriculture and Environment," *Victoria: Global Publishing Group (see Http://biochar-books. com/TBRDetails)* (2010).

[75] P. Blackwell et al., "Effect of Banded Biochar on Dryland Wheat Production and Fertiliser Use in South-Western Australia: An Agronomic and Economic Perspective," *Australian Journal of Soil Research* 48, no. 7 (2010): 531–545.

[76] G. D. Millar and W. B. Badgery, "Pasture Cropping: a New Approach to Integrate Crop and Livestock Farming Systems," *Animal Production Science* 49, no. 10 (2009): 777–787.

[77] W. R. Teague et al., "Soil and Herbaceous Plant Responses to Summer Patch Burns Under Continuous and Rotational Grazing," *Agriculture, Ecosystems & Environment* 137, no. 1 (2010): 113–123.

[78] W. R. Teague et al., "Grazing Management Impacts on Vegetation, Soil Biota and Soil Chemical, Physical and Hydrological Properties in Tall Grass Prairie," *Agriculture, Ecosystems & Environment* (2011).

7.3 This green paper outlines a number of initiatives aimed at reducing food waste across the food supply chain in Australia. What specific further waste management measures could the government consider that would meet the multiple objectives of increasing food security, providing healthier diets, improving environmental performance and addressing climate effects?

Due to its greenhouse gas emissions, especially in the form of methane, waste disposal in Australia contributes to the threats to production as detailed above. However, waste food, crop residues, animal manures and other agricultural by-products also have value as sources of both energy and nutrients for recovery. Already in Australia some primary producers have installed anaerobic digestion systems to produce methane from waste, and are generating electricity while capturing useful organic matter. In one example in Victoria, a pig farmer has completely replaced his synthetic fertiliser inputs and is exporting from the farm a bagged fertiliser product with very significant financial returns. The National Food Plan should encourage such technologies, advocating support for producers who want to install them. This could reinforce the viability of food production while reducing reliance on increasingly expensive and greenhouse intensive inputs.

Underlying Australians' this startling waste of food however is the shocking waste of water, nutrients, energy and embodied emissions that go into producing the food itself. With a paucity of water, nutrients and clean energy, and among the world's worst emissions, Australia can ill afford this waste.

Chapter 8 – Food trade and market access

8.1 The Australian Government is seeking to expand its food trade relationships in Asia over the medium to long term. This will require access to markets and a reduction in trade barriers for food exports. This objective could be pursued in a number of ways, including through further free trade agreements, strengthening Australia's agricultural counsellor network, as well as pursuing improvements to the multilateral rules-based trading system.

b) What kind of benchmark should Australia aim for? For example, should we seek to double our food exports to Asia by 2050?

c) How could this be achieved, and what would be the costs and benefits of doing so?

Export of cattle is expected to be a major component of the plan to feed Asia in the future. As explained in the response to Q 1.1, production of beef and dairy foods contributes heavily to methane emissions. BZE envisages the complete cessation of live animal exports from Australia on the grounds that it constitutes an 'invisible' import of other countries' carbon emissions, permitting importing nations to consume meat without consideration of its greenhouse and other negative environmental implications.

Tropical deforestation is at the 'other end' of increasing atmospheric CO_2 concentrations. Australians should be particularly careful that they do not import 'climate unsafe' products such as palm oil, the supply of which entails tropical deforestation in other parts of the world. See also response to Q 6.2.

Chapter 9 – Global food security

9.1 It is in Australia's national interest to promote global food security. The Australian Government considers Australia can make the most effective contribution to global food security by focusing on: technology and expertise transfers to developing countries; trade-related development assistance; advocacy and support for appropriate policies at the global, regional and national level; and short-term emergency food assistance. Do you support the Australian Government's analysis? If not, what are the key gaps? Please be specific and provide evidence to justify your response.

Anthropogenic Global Warming will strongly influence the viability of agricultural systems worldwide as in Australia. This is likely to reduce other countries' self-sufficiency and thereby contribute to geopolitical instability. Peak oil will also have significant effects, as detailed above.

Australia can best contribute to long-term global food security by successfully decoupling agricultural production from greenhouse emissions, and by assisting other countries to do likewise. Demonstrating the feasibility of this path and assisting other nations in achieving the same goal will be a multi-decadal and multidisciplinary research and development effort that Australia is well placed to lead. As well as assisting other countries, Australia should learn from successful sustainable agricultural and dietary practices in other countries.

Bibliography

ABARE. *Australian Commodities March Quarter.* Australian Bureau of Agricultural and Resource Economics, Canberra., 2007.

Aleklett, K., M. Höök, K. Jakobsson, M. Lardelli, S. Snowden, and B. Söderbergh. "The Peak of the Oil Age-analyzing the World Oil Production Reference Scenario in World Energy Outlook 2008." *Energy Policy* 38, no. 3 (2010): 1398–1414.

Allen, M. F. "Mycorrhizal Fungi: Highways for Water and Nutrients in Arid Soils." *Vadose Zone Journal* 6, no. 2 (2007): 291.

Anderson, K., and A. Bows. "Beyond 'dangerous' Climate Change: Emission Scenarios for a New World." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 369, no. 1934 (2011): 20–44.

Archer, D., M. Eby, V. Brovkin, A. Ridgwell, L. Cao, U. Mikolajewicz, K. Caldeira, K. Matsumoto, G. Munhoven, and A. Montenegro. "Atmospheric Lifetime of Fossil Fuel Carbon Dioxide." *Annual Review of Earth and Planetary Sciences* 37 (2009): 117–134.

Ashmore, M. R. "Assessing the Future Global Impacts of Ozone on Vegetation." *Plant, Cell & Environment* 28, no. 8 (2005): 949–964.

Ashmore, M. R., and F. M. Marshall. "Ozone Impacts on Agriculture: An Issue of Global Concern." *Advances in Botanical Research* 29 (1998): 31–52.

Atwell, B. J, P. E Kriedemann, and C. G.N Turnbull. *Plants in Action: Adaptation in Nature, Performance in Cultivation*. Macmillan Co of Australia, 1999.

Betts, R. A., M. Collins, D. L. Hemming, C. D. Jones, J. A. Lowe, M. G. Sanderson, R. A. Betts, M. Collins, D. L. Hemming, and C. D. Jones. "When Could Global Warming Reach 4 C?" *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 369, no. 1934 (2011): 67–84.

Beyond Zero Emissions, unpublished.

Blackwell, P., E. Krull, G. Butler, A. Herbert, and Z. Solaiman. "Effect of Banded Biochar on Dryland Wheat Production and Fertiliser Use in South-western Australia: An Agronomic and Economic Perspective." *Australian Journal of Soil Research* 48, no. 7 (2010): 531–545.

Cavagnaro, T. R., F. A Smith, S. E. Smith, and I. Jakobsen. "Functional Diversity in Arbuscular Mycorrhizas: Exploitation of Soil Patches with Different Phosphate Enrichment Differs Among Fungal Species." *Plant, Cell & Environment* 28, no. 5 (2005): 642–650.

Chan, K.Y., A. Downie, S. Joseph, I. Meszaros, and L. Van Zwieten. "Using poultry litter biochars as soil amendments." *Australian Journal of Soil Research* 46, no. 5 (August 2008): 437+.

Cordell, D., J. O Drangert, and S. White. "The Story of Phosphorus: Global Food Security and Food for Thought." *Global Environmental Change* 19, no. 2 (2009): 292–305.

DCCEE. *Australian National Greenhouse Accounts National Inventory Report 2009 Volume 1: The Australian Government Submission to the UN Framework Convention on Climate Change April 2011*. Vol. 1. 3 vols. Canberra, Australia: Department of Climate Change and Energy Efficiency, 2011. http://www.climatechange.gov.au/~/media/publications/greenhouse-acctg/national-inventory-report-2009-vol1.pdf.

Department of Climate Change and Energy Efficiency. "Australia's National Greenhouse Accounts - National Greenhouse Gas Inventory", n.d. http://ageis.climatechange.gov.au/#.

Eady, S., M. Grundy, M. Battaglia, and B. Keating. *An Analysis of Greenhouse Gas Mitigation and Carbon Biosequestration Opportunities from Rural Land Use*. CSIRO Sustainable Agricultural Flagship, Brisbane, Qld, 2009.

Fangmeier, A., U. Grüters, P. Högy, B. Vermehren, and H. J Jäger. "Effects of Elevated CO2, Nitrogen Supply and Tropospheric Ozone on Spring wheat--II. Nutrients (N, P, K, S, Ca, Mg, Fe, Mn, Zn)." *Environmental Pollution* 96, no. 1 (1997): 43–59.

Fantazzini, D., M. Höök, and A. Angelantoni. "Global Oil Risks in the Early 21st Century." *Energy Policy* (2011).

Foran, B., M. Lenzen, and C. Dey. "Balancing Act-A Triple Bottom Line Account of the Australian Economy." *Internet Site Http://www. Isa. Org. Usyd. Edu. Au, CSIRO Resource Futures and The University of Sydney, Canberra, ACT, Australia* (2005).

Garnaut, R. *The Garnaut Climate Change Review*. Vol. 13, 2008.

Gauss, M., G. Myhre, G. Pitari, M. J. Prather, I. S. A. Isaksen, T. K. Berntsen, G. P Brasseur, F. J. Dentener, R. G. Derwent, and D. A. Hauglustaine. "Radiative Forcing in the 21st Century Due to Ozone Changes in the Troposphere and the Lower Stratosphere." *J. Geophys. Res* 108, no. 1 (2003): 9.

Glover, J., H. Johnson, J. Lizzio, V. Wesley, P. Hattersley, and C. Knight. "Australia's Crops and Pastures in a Changing Climate–can Biotechnology Help?" *Canberra: Australian Government Bureau of Rural Sciences* (2008).

Hamblin, A., G. Kyneur, and Australia. Dept. of Primary Industries and Energy. Bureau of Resource Sciences. *Trends in Wheat Yields and Soil Fertility in Australia*. Australian Government Pub. Service, 1993.

Hamblin, A. P., and G. Kyneur. *Trends in Wheat Yields and Soil Fertility in Australia*. Australian Government Pub. Service, 1993.

Högy, P., H. Wieser, P. Köhler, K. Schwadorf, J. Breuer, J. Franzaring, R. Muntifering, and A. Fangmeier. "Effects of Elevated CO2 on Grain Yield and Quality of Wheat: Results from a 3-year Free-air CO2 Enrichment Experiment." *Plant Biology* 11 (2009): 60–69.

Holmes, Andrew J., Peter Roslev, Ian R. McDonald, Niels Iversen, Kaj Henriksen, and J. Colin Murrell. "Characterization of Methanotrophic Bacterial Populations in Soils Showing Atmospheric Methane Uptake." *Applied and Environmental Microbiology* 65, no. 8 (August 1999): 3312–3318.

Hossain, M. K., V. Strezov, and P. F. Nelson. "Thermal Characterisation of the Products of Wastewater Sludge Pyrolysis." *Journal of Analytical and Applied Pyrolysis* 85, no. 1 (2009): 442–446.

Hossain, M. K., V. Strezov, K. Yin Chan, and P. F. Nelson. "Agronomic Properties of Wastewater Sludge Biochar and Bioavailability of Metals in Production of Cherry Tomato (< I> Lycopersicon Esculentum</i>)." *Chemosphere* 78, no. 9 (2010): 1167–1171.

Howarth, R. W., R. Santoro, and A. Ingraffea. "Venting and Leaking of Methane from Shale Gas Development: Response to Cathles Et Al." *Climatic Change* (2012): 1–13.

Howden, S. M., P. J. Reyenga, and H. Meinke. "Global Change Impacts on Australian Wheat Cropping." *Report to the Australian Greenhouse Office. CSIRO, Canberra* (1999).

International Energy Agency. *World Energy Outlook 2010*. International Energy Agency, 2010.

Jansa, J., A. Wiemken, and E. Frossard. "The Effects of Agricultural Practices on Arbuscular Mycorrhizal Fungi." *Geological Society, London, Special Publications* 266, no. 1 (2006): 89–115.

Knief, C., S. Kolb, P. L. E. Bodelier, A. Lipski, and P. F. Dunfield. "The Active Methanotrophic Community in Hydromorphic Soils Changes in Response to Changing Methane Concentration." *Environmental Microbiology* 8, no. 2 (2005): 321–333.

Larsen, Kirsten. *Sustainable and Secure Food Systems for Victoria: What Do We Know, What Do We Need to Know? VEIL Research Report No. 1.* Victorian Eco-Innovation Lab, University of Melbourne, 2008. http://www.sustainable.unimelb.edu.au/files/mssi/VEIL_Sustainable-and-Secure-Food-Systems_Apr-2008_0.pdf.

Li, S., D. A. Lobb, M. J. Lindstrom, and A. Farenhorst. "Tillage and Water Erosion on Different Landscapes in the Northern North American Great Plains Evaluated Using< Sup> 137</sup> Cs Technique and Soil Erosion Models." *Catena* 70, no. 3 (2007): 493–505.

Long, S. P, E. A Ainsworth, A. D.B Leakey, and P. B Morgan. "Global Food Insecurity. Treatment of Major Food Crops with Elevated Carbon Dioxide or Ozone Under Large-scale Fully Open-air Conditions Suggests Recent Models May Have Overestimated Future Yields." *Philosophical Transactions of the Royal Society B: Biological Sciences* 360, no. 1463 (2005): 2011.

Lowenfels, J., W. Lewis, and E. Ingham. *Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web*. Timber Press (OR), 2010.

Luo, Q., W. Bellotti, M. Williams, and B. Bryan. "Potential Impact of Climate Change on Wheat Yield in South Australia." *Agricultural and Forest Meteorology* 132, no. 3–4 (2005): 273–285.

McGonigle, T. P., and M. H. Miller. "Mycorrhizal Development and Phosphorus Absorption in Maize Under Conventional and Reduced Tillage." *Soil Science Society of America Journal* 57, no. 4 (1993): 1002–1006.

Mcleod, Elizabeth, Gail L Chmura, Steven Bouillon, Rodney Salm, Mats Björk, Carlos M Duarte, Catherine E Lovelock, William H Schlesinger, and Brian R Silliman. "A Blueprint for Blue Carbon: Toward an Improved Understanding of the Role of Vegetated Coastal Habitats in Sequestering CO2." *Frontiers in Ecology and the Environment* 9, no. 10 (June 20, 2011): 552–560.

Millar, G. D., and W. B. Badgery. "Pasture Cropping: a New Approach to Integrate Crop and Livestock Farming Systems." *Animal Production Science* 49, no. 10 (2009): 777–787.

PMSEIC. "Australia and Food Security in a Changing World", 2010. http://www.chiefscientist.gov.au/wp-content/uploads/FoodSecurity_web.pdf.

Ramírez, CA, and E. Worrell. "Feeding Fossil Fuels to the Soil:: An Analysis of Energy Embedded and Technological Learning in the Fertilizer Industry." *Resources, Conservation and Recycling* 46, no. 1 (2006): 75–93.

Reijnders, L., and S. Soret. "Quantification of the Environmental Impact of Different Dietary Protein Choices." *The American Journal of Clinical Nutrition* 78, no. 3 (2003): 664S.

Rickards, L., and S. M. Howden. "Transformational Adaptation: Agriculture and Climate Change." *Crop and Pasture Science* 63, no. 3 (2012): 240–250.

Shindell, D. T, G. Faluvegi, D. M Koch, G. A Schmidt, N. Unger, and S. E Bauer. "Improved Attribution of Climate Forcing to Emissions." *Science* 326, no. 5953 (2009): 716.

Sitch, S., P. M. Cox, W. J. Collins, and C. Huntingford. "Indirect Radiative Forcing of Climate Change Through Ozone Effects on the Land-carbon Sink." *Nature* 448, no. 7155 (2007): 791–794.

Smil, V. *Feeding the World: a Challenge for the Twenty-first Century*. The MIT Press, 2001.

———. "Phosphorus in the Environment: Natural Flows and Human Interferences." *Annual Review of Energy and the Environment* 25, no. 1 (2000): 53–88.

Smith, S. E, and D. J Read. *Mycorrhizal Symbiosis*. 3rd ed. London: Academic Press, 2008.

TAUB, D. R, B. Miller, and H. Allen. "Effects of Elevated CO2 on the Protein Concentration of Food Crops: a Meta-analysis." *Global Change Biology* 14, no. 3 (2008): 565–575.

Taylor, P. "The Biochar Revolution: Transforming Agriculture and Environment." *Victoria: Global Publishing Group (see Http://biochar-books. com/TBRDetails)* (2010).

Teague, W. R., S. L. Dowhower, S. A. Baker, R. J. Ansley, U. P. Kreuter, D. M. Conover, and J. A. Waggoner. "Soil and Herbaceous Plant Responses to Summer Patch Burns Under Continuous and Rotational Grazing." *Agriculture, Ecosystems & Environment* 137, no. 1 (2010): 113–123.

Teague, W. R., S. L. Dowhower, S. A. Baker, N. Haile, P. B. DeLaune, and D. M. Conover. "Grazing Management Impacts on Vegetation, Soil Biota and Soil Chemical, Physical and Hydrological Properties in Tall Grass Prairie." *Agriculture, Ecosystems & Environment* (2011).

"Warning: Oil Supplies Are Running Out Fast - Science - News - The Independent", n.d. http://www.independent.co.uk/news/science/warning-oil-supplies-are-running-out-fast-1766585.html.

Wellman, P., and I. McDougall. "Cainozoic Igneous Activity in Eastern Australia." *Tectonophysics* 23, no. 1–2 (1974): 49–65.

Wood, S., and A. Cowie. "A Review of Greenhouse Gas Emission Factors for Fertiliser Production." In *IEA Bioenergy Task*. Vol. 38, 2004.