Agricultural Emissions Mitigation in New Zealand: Answers to Questions from the Parliamentary Commisioner for the Environment

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Abstract

This paper explores how New Zealand should address agricultural greenhouse gas emissions: methane and nitrous oxide. The starting point is the internationally agreed-upon goal of limiting global warming to below two degrees, and New Zealand's commitment to contribute its 'fair share' to the international climate-change mitigation effort. The report focuses on the role of mitigating biological agricultural emissions within that, and how New Zealand could most cost-effectively mitigate its own emissions and contribute to the mitigation of agricultural emissions abroad. This paper complements a partner paper (Hollis et al 2015) that discusses the science relating to agricultural greenhouse gases.

JEL codes

Q18, Q54, Q58

Keywords

Climate change, mitigation, agriculture, New Zealand, methane, nitrous oxide, livestock, metrics, policy

Summary haiku

Farmers change slowly

Avoid pain with clear signals

Research; replace cows.

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1 Summary of key points

The starting point for this report is the internationally agreed-upon goal of limiting global warming to below two degrees[1], and New Zealand's commitment to contribute its 'fair share'. The report focuses on the role of mitigating biological agricultural emissions within that, and how New Zealand could most cost-effectively mitigate its own emissions and contribute to the mitigation of agricultural emissions abroad.

1.1 Key issues when setting mitigation goals for New Zealand

1. In order to limit global warming to below two degrees, global net carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions must reach zero before 2100. By that time, food production will need to have low N_2O emissions per unit of nutrition.
2. Mitigation of N_2O can, from a purely scientific point of view, be valued similarly to CO_2 reductions (measured with standard international metrics).
3. Reducing methane (CH_4) is valuable at all times, but because it is a short-lived gas, New Zealand could choose to put less value on CH_4 reductions than standard international rules currently imply. This choice depends on
    a. the weight New Zealand puts on the short-term path of climate change against the longer term goal of limiting peak temperatures;
    b. whether New Zealand faces strong international pressure to reduce CH_4. Not mitigating could impose high economic and reputational costs; and
    c. the recognition that giving a lower weight to CH_4 mitigation can only be justified scientifically in the near term. If New Zealand accepts the global goal of limiting warming to below two degrees, and international action is on track to achieve that goal, then the importance of CH_4 mitigation will rise steadily and significantly over the next few decades.
4. The form of New Zealand's international target can be separated from the level of ambition (and cost) and the form of its domestic policy. While these interact, each could be optimised separately.

[1] The agreed text at the 2016 Paris Conference set a goal of 'well below 2 degrees' and 'pursue efforts to limit warming to 1.5 degrees'.

5. In the medium to long term New Zealand may decide to reduce CH_4 significantly while still maintaining food production. It could prepare for this now with research into low-emission food production and continued work on technology to reduce CH_4 from livestock, and by starting a gradual adjustment process for land use and practices. Delaying the adjustment may require it to happen very quickly in the future, if climate damages and greenhouse gas (GHG) prices are even higher than anticipated.
6. Agriculture is unique as an emitting sector only because N_2O emissions cannot currently go to zero: we need food, and any food that requires inputs of nitrogen (N) – from fertiliser, biological N fixation or green manure – will result in anthropogenic N_2O emissions.
7. All other characteristics of agricultural GHG mitigation are shared by at least one other sector, though the combination of characteristics is unusual. Key features are: global concerns about scarcity of consumer products (food security concerns in the case of agriculture); that emissions are often controlled by small agents; complex mitigation and monitoring (driven by biological complexity in the case of agriculture); and that agriculture is strongly exposed to international competition (trade exposed) but not strongly subject to leakage of production. Their trade exposure means that farmers are unable to pass on much of the cost of mitigation or emissions liabilities.
8. A focus on producing low-emission nutrition would help balance emission reduction with global nutrition needs.

1.2 Opportunities and challenges

1. The emission intensity of existing products can be reduced with technologies and practices already used on many farms. Most options would also raise productivity – but not necessarily profitability. Some barriers to adoption are not financial.
2. A critical question for policy design is to what extent farmers can continue – and accelerate – their existing decline in emissions intensity beyond business as usual.
3. New Zealand could potentially use currently pastoral land to produce alternative low-emission products. This transition will occur most easily if it can happen over decades.
4. Reducing food waste and gradually changing diets toward lower-emissions nutrition sources are important parts of the solution.
5. New Zealand's past and future experiences with mitigation could help other countries lower the emissions intensity of their agricultural production.
6. New Zealand may efficiently, from a global point of view, continue to be a major producer of emissions-intensive nutrition. This would imply high costs to New Zealand if New Zealand's emissions targets don't take this into account.

7. Key challenges of mitigating agricultural emissions are: farmers' trust and capability; limited practical experience with mitigation; uncertainty among scientists and farm system experts about the effectiveness, feasibility and cost of mitigation options; limited current mitigation options within livestock systems; complex monitoring and enforcement issues; protecting rural communities and the New Zealand economy during the transition; and creating a favourable international environment for marketing low-emission products.

1.3 Potential domestic actions

1. Engage the rural sector positively
    a. Involve the rural community effectively in climate policy governance.
    b. Potentially negotiate a 'cool climate' accord with the farming sector.
    c. Use farmers to help other farmers reduce emissions domestically and internationally.
    d. Continue to support afforestation on farm land.
    e. Celebrate the low-emissions-intensity of New Zealand livestock products, and promote them through a national brand.
    f. Re-focus the national conversation on the profitability of the rural sector, not the volume of production.
2. Research
    a. Develop alternative low-emission food production for New Zealand's landscape. This is an area that needs more systematic research, field trials and development of supply chains.
    b. Continue work on low-emission technology for livestock production that is internationally applicable.
    c. Help determine appropriate absolute agricultural mitigation for New Zealand's international target setting by comparing the nutritional value of different products relative to the emissions associated with them. This may require identifying and testing the implications of different nutrition metrics for global food markets.
    d. Develop robust, user-friendly, on-farm emissions monitoring and reporting tools that can reflect the mitigation outcomes of individual farmer practice changes.

3. Increase capability to move to low-emission agriculture – on- and off-farm
    a. Educate future (and current) farmers at all levels about the need for and opportunities associated with low-emission agriculture.
    b. Engage the business sector and business schools to help build new products, complete supply chains and develop effective marketing.
    c. Include information about emissions performance of animals in or alongside their Breeding Worth.
    d. Educate consumers about low-emission food and reducing food waste.
4. Regulate outside the Emissions Trading Scheme (ETS)
    a. Through regulation, help to create an environment conducive to transition that can also act as a backstop to bring up the tail of farmers when the majority have already made a transition.
    b. Develop a capital gains tax on rural land.
    c. Continue to promote freshwater reform.
    d. Note that direct regulation of land use or practices is difficult to do well because farm situations are so heterogeneous. No significant GHG mitigation options are obviously appropriate on all farms. Some regionally specific performance benchmarks for emissions intensity and some land-use restrictions may be appropriate.
5. Consider including biological agriculture emissions in the ETS, noting that:
    a. Including agricultural emissions in the ETS with the obligation at the processor level is possible now and would have some benefits including some incentives to try non-ruminant land uses. Leakage is unlikely to be a large issue unless effective prices are high.
    b. Incorporating agricultural emissions with a farm-level obligation is a more efficient option. Better measurement tools and greater farmer acceptance are needed before a broad farm-level ETS obligation can be implemented. Offering farmers a fixed-price option that is periodically marked to market, rather than requiring that they purchase and surrender units, could facilitate compliance.
    c. The feasibility of a mixed system with larger farms (particularly dairy) regulated at the farm scale and the default at the processor could be explored as a way to transition into a full farm-level ETS obligation.
    d. Managing the rural community transition and balancing distributional impacts across diverse farmers are both challenges that might be most easily addressed through early but gradual introduction.
    e. A tax or levy system would face the same challenges as the ETS.

1.4 International contribution

1. New Zealand can continue to lead research both on mitigation technologies and mitigation policies in the agricultural sector and continue to train international students. This could extend beyond livestock agriculture to focus more on alternative low-emission food production on land currently used for livestock. There is also room for more active engagement to help developing countries begin to transform their agricultural sectors to low-emission food production – and more generally, climate-smart agriculture.
2. It is in New Zealand's interests for agricultural emissions to be included in any international agreement. As with any other sector, recognition of the potential for mitigation over different time frames will affect our targets.
3. New Zealand could potentially gain credit, and help develop new mechanisms, for transferring resources for mitigation in developing countries. This could be done by working with developing countries to implement large-scale efforts to transform their agricultural sectors, and results-based funding where rewards are determined at a national scale and are proportional to monitored emissions relative to an agreed baseline projection.

2 Introduction

In 2015, the Parliamentary Commissioner for the Environment asked nine questions relating to how New Zealand should address agricultural emissions. This paper complements a partner paper (Hollis et al 2015) that discusses the science relating to agricultural GHGs.

Within the realm of agricultural emissions, ideas and knowledge both in the science of mitigation and the design of effective actions and policies are rapidly evolving. Much research has been undertaken in the last decade, but considerable uncertainty remains.

This report draws on a variety of sources: two dialogue groups aimed at developing approaches for New Zealand to address its agricultural emissions, my own current understanding of the issues based on previous work (e.g. Kerr and Sweet 2008; Cooper, Boston, and Bright 2013; Kerr and Dorner 2013) and several strands of current research, and communication with experts and stakeholders. While many stakeholders provided extremely useful comments in conversation and on earlier drafts; they did not all wish to be named. The two dialogue groups that contributed to the report are the Agricultural Dialogue (AgDialogue), a discussion group run by Motu in 2011–2012 and the Low-Emission Future Dialogue (LEF) in 2014–2016 (Leining and Kerr, 2016). Further notes and ideas from the two dialogue groups are presented in appendices. All such ideas are proposed for future analysis and development, and some have already been partially implemented. They are not intended to be prescriptive or predictive, nor does their inclusion in this document imply any recommendation, consensus or endorsement by dialogue participants or presenters, their affiliated organisations or the programme funders.

To generate a wide range of solution ideas the LEF dialogue took the approach of broadly agreeing on a long-term, high-level goal for the agricultural sector (that New Zealand operates a highly efficient, ultra-low-emission food production system), assuming that goal has been achieved, and looking back at how that might have happened. LEF identified four key potential characteristics of that outcome (any actual outcome will involve some balance among these characteristics): New Zealand operates an ultra-GHG-efficient livestock sector; New Zealand produces zero-CH_4, low-N_2O nutrition; New Zealand reduces food waste across the chain of food production and consumption; and that consumers demand low-emission food. The LEF then identified 'milestones' – the things that have probably occurred if those characteristics have been achieved. Finally, the LEF attempted to identify the specific actors and actions that could achieve those milestones. There are already many possible paths and potential actions to the goal, and we want to create even more possibilities and keep New Zealand's options open. We hope the ideas we generated can facilitate a constructive and ever richer conversation and set of private sector, civil society, research and public initiatives.

This paper loosely follows that structure from goals through to actions in the domestic and international space. The Commissioner's questions and this report's answers are as follows:

3 Questions relating to goals

3.1 What should be New Zealand's climate goal for agricultural emissions?

This report does not suggest an overall target that New Zealand should choose in the medium term, or the appropriate level of domestic ambition for mitigation within specific time frames:

those are not questions with scientific or economic answers. Instead it focuses on the role of mitigation of agricultural emissions relative to mitigation in other sectors. Its starting point is the internationally agreed-upon goal of limiting global warming to below two degrees and New Zealand's commitment to contribute our 'fair share'. The report focuses on the role of mitigation of agricultural emissions within that, and how New Zealand could most cost-effectively mitigate its own emissions and contribute to mitigation of agricultural emissions abroad.

The AgDialogue group and a subsequent report that draws on it (McDonald and Kerr 2012) have identified three potential reasons why New Zealanders might want to reduce agricultural emissions:

1. Concern about the direct impacts of climate change on New Zealand and the world,
2. Pressure from others based on their concern about climate change (including through pressure to set and meet targets for international agreements and pressure from consumers), and
3. Environmental or social goals that are complementary to reducing emissions (e.g. freshwater quality or a desire to diversify the economy).

Low Emissions Future (LEF) Dialogue framing of goals for biological emissions:
That New Zealand operates a highly efficient, ultra-low-emission food production system, achieved through a combination of:

- Operating an ultra-GHG-efficient livestock sector.
- Producing zero-CH_4, low-N_2O nutrition.
- Reducing food waste across the chain of food production and consumption.
- Consumers demanding low-emission food

In order to stabilise the climate, ever and at any temperature, net CO_2 plus N_2O emissions must be reduced to net zero levels because both CO_2 and N_2O accumulate in the atmosphere (Hollis et al 2015). To limit warming to below two degrees, global net emissions of long-lived gases must be eliminated before around 2100. Currently all significant food production systems (including organic farming) involve some N_2O emissions, which come from soils, so globally those unavoidable N_2O emissions would need to be offset with either reforestation, afforestation and enhanced forest management (which, however, cannot continue to sequester forever), or some form of carbon capture and storage.

Based on a scientific understanding of CO_2 and N_2O, an appropriate goal for New Zealand could be to reduce them simultaneously. The relative value in climate terms of a tonne of reduction from each of the two gases is well understood and non-controversial (Hollis 2015).[2] Adrian Macey, former New Zealand Climate Change Ambassador says "The core task for all countries thus becomes getting their net emissions of long-lived gases to zero. For New Zealand this implies tackling N_2O as a priority, which is incompatible with the current blanket exemption from domestic measures for all 'agricultural' or 'biological' emissions (CH_4 and N_2O)."

Actions that reduce N_2O emissions have local co-benefits (particularly water quality) – as do CO_2 reductions (in particular air quality, congestion and reduced exposure to international oil price fluctuations). In New Zealand there are no co-benefits of CH_4 reductions though it is currently closely correlated with livestock farm productivity. In some locations these co-benefits could justify additional pressures to reduce CO_2 and N_2O. For example, concerns about freshwater quality in New Zealand could justify the conversion of pastoral land to forestry in situations where the N_2O emission reductions and carbon storage alone would not justify it. Actions that are not justified by one environmental concern alone may be justified when the effects are combined.

This suggests that within climate policy, and from a purely climate science point of view, N_2O can be treated similarly to CO_2. That does not automatically mean that N_2O should be included in the ETS; the choice of specific policies and the level of reductions targeted for N_2O depends on administrative and distributional considerations and mitigation opportunities – we discuss these below under separate questions.

Decisions about addressing CH_4 are more complex. Because it is a short-lived gas, CH_4 emission reductions today will have little impact on the highest temperature the globe experiences (peak temperature) or the cost of long-term stabilisation at or below a given level (e.g. two degrees of warming), though they do have an impact on current temperatures. Methane is a potent gas. Over 10 years, cutting out CH_4 completely would have the same effect as cutting out all CO_2 (Figure 8.32, p 719 of Chapter 8, IPCC 2013). However CO_2 cuts reduce the stock of GHGs forever. In contrast, over half of CH_4 emitted now will be gone in 12 years, though some will still be warming the planet in 60 years.

When we have controlled the long-lived gases which means that we will begin to approach peak temperature (within 20–30 years of peak), CH_4 reductions can help limit the temperature at which we stabilise; eliminating CH_4 emissions could reduce the ultimate temperature by more than 0.2 degrees even if CH_4 levels would otherwise have stayed stable.[3] As global CH_4 emissions are projected to grow in the absence of policies targeting them, the

[2] These relative values or 'metrics' compare the impact on global temperatures, over specified time periods or at specific times, of different GHGs.

[3] Bowerman et al. (2013) suggest that stringent CH_4 mitigation could reduce stabilisation temperature by 0.2 degrees; (Rogelj et al. (2014) suggest 0.3–0.7 degrees.

benefit of eliminating future CH_4 emissions could be even greater.[4] Here we focus on agricultural CH_4 only – CH_4 also comes from landfills and fugitive emissions. Technically New Zealand's agricultural CH_4 emissions can be reduced to zero, but only if ruminant agriculture is eliminated. This could be worthwhile – depending on the final stabilisation temperature and the world's ability to adapt to that - but we don't need to decide yet how much to abate CH_4 in the long term. Because CH_4 is relatively short-lived, a stable positive level of CH_4 emissions could be consistent with climate stabilisation.

If New Zealand were primarily concerned about peak temperatures, reducing CH_4 could be a lower priority for two or three more decades (the short run, or up to around 2050). After that New Zealand may need to be ready to make large reductions (the long run, or 2050–2070 and beyond). By acting on N_2O and water quality, continuing to improve the productivity of pastoral systems, and diversifying the rural economy away from ruminant agriculture, New Zealand would achieve CH_4 reductions (at least in terms of emission intensity – emissions per unit of nutrition produced – as discussed below) as a co-benefit (Daigneault, Greenhalgh, and Samarasinghe 2012; Kerr 2013). In this case, arguments for stronger short-term action on CH_4 relate primarily to our inability to make rapid change; stronger action on CH_4 would complement strong action on CO_2 and N_2O.

To make large changes in CH_4 in the long term, New Zealand would need to act now (not only through research and development but also development of policies and early adoption of new land uses, practices and technologies), in order to be ready to act fast later. Early action on CH_4 and clear signals of a future transition to low-CH_4 would avoid New Zealand being locked into a high-CH_4 pathway – and facing high levels of stranded assets if required to reduce CH_4 rapidly in future.

There are three reasons to act strongly to reduce CH_4 now (in addition to actions on CO_2 and N_2O). First, a strong concern about short-term temperature rise, i.e. the path of temperature rise towards a given long-term level, and the short-term impacts of climate change. Second, an understanding that human (and natural) systems do not adapt quickly, meaning the welfare costs of rapid climate change could be much higher than those of the same temperature change over a longer period.

Third, if New Zealand does not act strongly to reduce CH_4 (and unless the international inventory rules are changed, or looser targets to allow for ongoing high-CH_4 emissions in the short term are negotiated), New Zealand will face costs (both economic and political) based on current CH_4 metrics which value CH_4 reductions quite highly. The effect is significant: agricultural emissions, CH_4 and N_2O, using current metrics for CH_4, made up 48% of New

[4] (U.S. EPA 2012).

Zealand's emissions in 2013 (Ministry for the Environment 2015) and CH_4 alone makes up 30%. Recent modelling (Stroombergen 2015; Daigneault 2015) indicates that New Zealand will struggle to meet its Intended Nationally Determined Contribution (INDC) of lowering total emissions by 30% relative to 2005 levels by 2030 through domestic mitigation without significant mitigation of agricultural emissions or afforestation.

If New Zealand does meet its 2030 INDC without reducing agricultural emissions, other sectors would need to reduce by nearly 60% (rather than 30%) to compensate – or New Zealand would need to buy international units. If New Zealand could reduce agricultural CH_4 emissions by even 10% it would need to purchase around 2.8 million tons fewer units per year – worth around NZ$160 million per year if these reductions are valued at the United States government's 2015 social cost of carbon of US$37 (a conservative number in a world that is limiting warming to below two degrees).[5] As long as there are some low-cost CH_4 mitigation opportunities (which there are – even if limited – see discussion under question 3 below), it is cheaper for New Zealand to meet a target through a combination of purchasing international units and CO_2, N_2O <u>and</u> CH_4 reductions than without CH_4 reductions.

If we fear the world is reaching a climate tipping point, in contrast to concern about the short-run path of climate change in transition toward a given level of temperature stabilisation, we would not necessarily place a stronger emphasis on CH_4 relative to other GHGs; it would increase the pressure to reduce all gases. Extreme action on CH_4 could delay a tipping point but only reduction of long-lived gases can avoid one (Hollis et al, 2015). Similarly, a precautionary approach would lead us to act more aggressively on all gases.

To summarise, this discussion suggests that N_2O might be treated in the same way as CO_2. Taking only science and simple economics into account, our short- and long-run goal would be to mitigate until the last unit of N_2O reduction (expressed in CO_2 equivalent) costs the same as the last unit of CO_2 reduction.

A long-run CH_4 goal consistent with global targets (and cost-effectiveness in achieving those targets) would be extremely high efficiency of ruminant agriculture and lower levels of ruminant production globally than in a business-as-usual scenario. Focus on the two-degree target also suggests that CH_4 might not be a central focus for stringent mitigation in the short term, but that CH_4 reductions could primarily be seen as a co-benefit from other more urgent actions such as N_2O reduction and preparations to make long-term CH_4 reductions.

The short-term level of pressure for CH_4 mitigation could be driven by choices around N_2O and water quality but also by judgements about how best to prepare for large long-run reductions, the global value of short-term reductions in the rate of climate change, and on our

[5] (Interagency Working Group on Social Cost of Carbon, United States Government 2013). See Revesz et al. (2014) for criticism.

level of concern about international pressure based on existing rules and the fiscal costs of deviating from international metrics in our domestic policy. Below I discuss how these broad reasons and GHG-specific goals might affect the policies New Zealand chooses.

3.2 What particular features of the agricultural sector mark it as different from other sectors when it comes to mitigation?

Various arguments are put forward for why agriculture is different from other emitting sectors. Some of these relate to global issues; others to local action. Here we discuss those, the extent to which they are unique to agriculture, and why jointly they could justify differential treatment for agriculture.

People must consume food. There is no substitute for meeting basic needs, and food cannot be produced with zero emissions.

Demand for food is increasing as the global middle class expands rapidly. FAO (Alexandratos and Bruinsma 2012) forecast that between 2005 and 2050 global demand for energy supply (calorie availability) will rise 54%, the value of total agricultural production by 60%, demand for milk and dairy products by 47% by 2050, and demand for bovine meat by 52%. People's food needs can however be met in many ways – high-emission livestock products are not essential for survival and some fraction of this middle-class food consumption is wasted or overconsumed. This could mean that in a low-emission world production rises less than these projections and also that the type of food produced changes radically. We cannot however globally reduce food production to zero.

As a point of comparison, people also need energy (to heat homes, manufacture goods, cook, travel etc.) but it is technically feasible to produce energy with zero emissions so even with rising energy demand we can aim for zero energy emissions. In theory we could produce food in vats or sealed buildings in order to capture all the N_2O and CH_4, but currently this is not feasible and N_2O emissions occur even in the most efficient systems. Any food that requires inputs of N (from fertiliser, biological N fixation or green manure) will result in anthropogenic N_2O emissions.

Food in not unique in this regard: concrete is used to meet basic human needs for shelter and cannot currently be produced with zero emissions.[6] However, while concrete can be substituted with, say, timber, there is no substitute for food. Our need for food and inability to produce it with zero emissions together mean that we cannot get food emissions to zero.

[6] Tim Flannery, Head of the Australian Climate Commission, suggests in the *Guardian Weekly*, Friday 20 November 2015, that concrete might in future be produced with negative emissions. http://www.theguardian.com/books/2015/nov/20/climate-crisis-future-brighter-tim-flannery

The poorest people in the world spend a high percentage of their resources on food.

This suggests that for global equity reasons we might not want to implement policies that will raise the food prices faced by the most vulnerable populations – unless we can also raise their incomes. Simply reducing food production would reduce emissions but it may also have a high human cost because it may raise food prices.[7] New Zealand does not need to 'feed the world', however, we are part of a global system and changing our production will have some ripple effects through the wider system. Points 1 and 2 together suggest a focus on mitigation that reduces emissions per unit of useful (i.e. not wasted) nutrition rather than a focus on absolute emissions from food production. This is likely to be a mixture of more efficient production, less waste, and changes in the type of food consumed.

Stakeholders in the food industry suggest that to move toward food production that provides high nutrition per unit of agricultural emissions we need to be able to compare both the emissions per unit of food (which we already have some ability to do) and the nutrition. We need a metric to compare calories, protein, micro-nutrients and other nutritional characteristics of food, and to measure waste. One way to compare is on a protein basis. The United Nations Food and Agriculture Organization recently released new guidelines for comparing protein across nutritional sources (Leser 2013). One argument for focusing on protein is that if we reduce ruminant agriculture, protein is what we need to replace because red meat and dairy are high-protein food sources. Other aspects such as minerals and vitamins are also potentially important. Nutrient density is an alternative measure (Doran-Browne et al. 2015) in a rich literature.[8] Creating a metric to compare nutrition production for GHG-regulation purposes is similar to the problem of defining metrics across different GHGs – but in this case the challenge is not valuing the relative damage caused by each gas, but that the marginal value of producing each component of nutrition depends on the existing production mix/relative scarcity. If we could create this metric, each food product would have a weight based on its mix of nutritional components. This could be called the product's Global Nutrition Index (GNI).

A national measure of net nutrition production (adjusted for food waste controllable by the country) could be part of each country's inventory reporting and used as an input into decisions about national targets. Countries that produce increasing amounts of nutrition could face less pressure to reduce emissions. In an ETS, free allocation to farmers (or the processors) could be based on the previous year's nutrition production. This form of free allocation acts as an implicit subsidy for nutrition production; it would maintain incentives to produce nutrition while providing incentives to lower emissions per unit of nutrition.

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[7] Zilberman et al. (2013) survey literature on the impact of use of crops for biofuel production which would likely have a similar effect.

[8] A unit of nutrition could be nutrient density to represent the different important proteins, minerals, vitamins, and occasionally fat and carbohydrates for a well-balanced diet per 100 calories or grams of product.

In a world where enough food to avoid global shortages can be provided with low emissions and every person has access to food and enough income to buy sufficient to meet their nutritional needs even at higher prices, emissions from food production could be treated no differently from other emissions. Avoiding increases in food production costs from GHG mitigation is a second-best solution. Megan Owen (dairy sharemilker and leader with Rural Women New Zealand) suggests that as global food prices adjust and production costs evolve, New Zealand may, for example, replace low-intensity meat production on steep hill country with Manuka honey production or forests; and replace intensive dairy or meat production on flat or nearly flat land with maize, soya or mixed farming (e.g. barley or wheat along with poultry and pork – or insects, fungi or aquaculture) but continue to produce dairy products on rolling hill country. The goal would be to balance food provision, profitability and emissions. In a world where we do not fully price the climate effects of food production we also need to support international avoided deforestation, reforestation and afforestation efforts even more strongly to reduce the perverse effects of excessive use of land for food production.

Food production (currently) requires land, which cannot move.

This limits the extent to which food production can move across countries. If New Zealand produces less food, others will produce more but they will not fully replace New Zealand production at the same cost. 'Leakage' – the relocation of production if New Zealand regulates agricultural emissions and others don't –- is physically limited.

When thinking about the ideal mix of food production in a country, we must think in the context of its place in a global food system. Anders Crofoot, National Vice-President of Federated Farmers, states clearly that New Zealand does not 'feed the poor', but that if we provided less red meat and dairy products to our customers, it is possible they would instead purchase them (or the grain used to produce them elsewhere) from other providers, thereby competing with that provider's existing, poorer customers and ultimately pushing up prices. As long as we are not altering demand for high-emissions food through our marketing efforts, global demand will be unaffected by a reduction in our production, but supply will fall and hence prices will tend to rise. In the short run, from year to year, New Zealand's production does have an empirically identifiable effect on global prices for milk solids (Kamber, McDonald, and Price 2013). The effect is large enough to be seen because we produce a high share of internationally traded milk solids, and supply to international markets does not adjust rapidly. Our share of global production is tiny however, so in the longer term changes in our production have no identifiable effect on the prices we receive (Woods and Coleman 2012) or the prices poor people pay for food.

More positively, food production's dependence on land means that food production is less subject to leakage than other trade-exposed products. Kerr and Zhang (2009) summarised the available evidence on leakage from New Zealand pastoral agriculture. They found that for profitability within historical ranges, the New Zealand production response to prices is modest at least in the short term. To the extent that New Zealand does reduce production and thereby raise global prices, other producers are likely to respond but not completely offset our reductions. Because New Zealand is among the most efficient producers in the world, any movement of production is likely to lead to higher emissions intensity. However, as other countries face targets of their own that cover agricultural emissions (for example, many made commitments through the Intended Nationally Determined Contributions process in the lead up to the Paris Agreement in November 2015), governments will have an incentive to discourage growth in emissions-intensive agricultural production. This will reduce leakage.

Mitigation options for methane and nitrous oxide are complex.

Greenhouse gas emissions from food production are in large part the result of biological processes: methanogenesis (microbes in the gut of ruminant livestock, in rice paddies, and manure management), nitrification (microbes in soils), and photosynthesis/decomposition (soil carbon). Biological systems (e.g. the ecology of the rumen or soil microbes) are inherently complex and their responses to interventions uncertain, and there is little experience with reducing biological emissions or measuring them. Mitigating emissions from these biological processes is possible, but the nature of the biological processes involved results in specific technical challenges. Once the technical challenges are solved, implementation of solutions can be complex. Crofoot stresses that in some cases mitigation could be as simple as using an inhibitor or vaccine, but in many cases they involve farm system changes. Productivity may be affected. Resilience of the farm system may change. Even if technically feasible, mitigation may still have a high cost attached.

In comparison to the complexity of reducing biological emissions, reducing emissions from fossil fuel consumption is much simpler: use less fossil fuel. Although the technologies required to allow this are complicated, the challenges involved with understanding changes to emissions are far less so. Mitigation in other emission-intensive sectors is not difficult to measure but mitigation actions can be complex to decide and implement because they involve human behaviour and complex economic system interactions. For example, transition to a zero-emissions electricity grid or implementation of an efficient, highly utilised public transport network are both complex to implement.

Agricultural mitigation must be carried out by small agents.

In many non-agricultural cases although mitigation may be complex, the critical decisions can be taken by a smaller group of well-resourced actors. In contrast, many mitigation options in agriculture must be implemented by farmers as part of an integrated system. This may make adoption of new practices and technologies and land use change in the agricultural sector a slower process. This is comparable to implementating energy efficiency practices in small businesses, but at least in that case regulation to price emissions is easy to implement. Another emissions source with small actors that participate directly in emissions pricing is hydrochlorofluorocarbons (HCFCs) in imported vehicles. These are covered by an emissions levy at point of import rather than making all importers participants in the ETS. This fits with an existing regulatory structure and minimises paper work for these small sources.

Agricultural emissions come from processes that cannot easily be monitored (in contrast to fossil fuel emissions which can be monitored at fuel production and import).

While the average emissions from agricultural production can be priced at the processor level, providing a disincentive for high-emissions production, motivating and regulating reductions in emissions per unit of production requires farm-scale monitoring. New Zealand has a model, OVERSEER (http://overseer.org.nz/) that can be used to monitor emissions – and is already used by many farmers and some regional councils for nutrient management and regulation. However, where it is not already used for regulation, implementing it as a regulatory tool, then auditing data inputs and enforcing compliance for all farmers, is costly. This makes the transaction costs of efficient regulation much higher. Also, because it is a model it is not an accurate measure of each specific farm's emissions. This is not necessarily a barrier; regulation based on OVERSEER could provide more efficient incentives than no regulation, and it continues to be improved. While the gains that are achieved on an individual farm may be uncertain, it does not necessarily make the overall gains uncertain – if the monitoring tool is unbiased. Perfect measurement is not possible; a balance needs to be reached between the benefits of additional accuracy and higher monitoring costs. Imperfect monitoring is not a compelling argument for delayed regulation but is likely to justify further development of the monitoring tool.

Mitigation options are limited and expensive.

Within New Zealand, information on the cost of agricultural mitigation is poor. (Anastasiadis and Kerr 2013) synthesised the available studies within the dairy sector and were unable to come to strong conclusions on mitigation costs. Information for the meat sector is even more limited. This does not mean that mitigation is necessarily expensive – rather that the cost is unknown. We do know that mitigation options – without changing land use – are still relatively limited, though farm trials and observation of considerable variation in emissions intensity across existing farmers suggest some reductions are possible. But limited mitigation options in itself is not a reason for a different policy approach – current options to reduce transport emissions are also limited. Emissions pricing will encourage farmers to find the low-cost opportunities that do exist; investment in research may also eventually reveal new opportunities.

Many of the farmers who will have to take mitigation actions are also sole owners.

The number of farms that have sole owners (combined with the trade exposure of the sector) means that the distributional impacts of any liability for emissions or mitigation could be highly concentrated on a few individuals and families. In contrast, emissions liability in the energy or industrial sectors can generally either be passed on to many consumers who each bear a small cost or, where companies are public, shared across many shareholders. Megan Owen points out that until global agricultural emissions are regulated more widely or consumers on a large scale recognise the value of low-emission sources of nutrition, farmers are unable to pass on the cost of mitigation or emissions liabilities. Corporate-owned farms would share the costs across many owners but they are only a fraction of New Zealand farms. This means that some farmers could experience high costs and losses of asset value if full emissions costs were imposed on them suddenly. These costs would fall as options to mitigate and change land use develop and the costs could be eased through gradual introduction leading to a smoother adjustment in land values. If we do not start this adjustment now, it may have to happen fast in the future when emission prices are likely to be much higher.

One of the key gases emitted from agricultural production is methane, a potent but short-lived gas.

Other sectors, such as waste, produce CH_4. If the short lifetime of CH_4 were the basis for exclusion from mitigation efforts, including emission pricing, it would logically apply to these sectors also.

None of these factors alone are sufficient justification to exclude the agriculture sector from mitigating emissions, but together they do make regulation of agricultural emissions more complex than most other sectors, and may justify a more gradual introduction of regulation.

4 Questions relating to opportunities and challenges

4.1 What are the greatest opportunities for reducing agricultural emissions over the next several decades?

New Zealanders can reduce agricultural emissions in four ways: reduce emissions per unit output; shift food production to lower-emission products; reduce demand for high-emission products; and help improve the emissions efficiency of international food producers.

4.1.1 Reduce emissions per unit of production in existing uses

Through productivity improvements, New Zealand farmers have reduced their emissions intensity on-farm by 20% since 1990. Efficiency gains based on existing technologies and knowledge will likely continue to lead to emission intensity gains, but at an uncertain and possibly declining rate into the future as existing opportunities for improvement are exploited and the emission returns from additional efficiency diminish. New knowledge and technologies could however sustain or even accelerate improvements. The critical question for policy design is the extent to which farmers can take additional steps to reduce emissions – beyond the steps they would take without external pressure or action, or at a faster rate. Generally, improved efficiency in farm management can continue to reduce both N_2O and CH_4 while also improving economic performance. New research allows farmers to more effectively move herds and flocks toward high-genetic-merit, low-emission animals, which may result in significant emissions gains. Continued improvements are possible through increasing productivity per animal (milk yield per cow; increased lambing rates, and higher growth rates of beef cattle and lambs through optimised pasture use); optimisation of fertiliser; soil management – particularly moving animals off poorly drained soils in winter; careful management of irrigation, and effluent management. Clark, Kelliher, and Pinares-Patino (2011) and Eckard, Grainger, and de Klein (2010) provide a technical discussion of options. If productivity improvements do provide economic gain, there may also be increases in production. In this case emissions intensity will fall but absolute emissions in New Zealand may rise.

Table 1: Ideas from the Low-Emissions Future Dialogue on milestones for ultra-GHG-efficient livestock production

Sector characteristic 1: New Zealand operates an ultra-GHG-efficient livestock sector.			
A Technology milestones	**B Policy and regulatory milestones**	**C Business milestones**	**D Behavioural milestones**
1. Real-time measurement tools are available for farmers to see the impact of their decisions on GHG emissions (and co-benefits). 2. We have credible research on the cost-effectiveness of capping effluent ponds and biodigesters/ energy. 3. New feasible and cost-effective mitigation technologies have been found for livestock N_2O and CH_4. 4. Methane-neutral systems for dairy have been created.	1. Pricing mechanisms are established to reward efficiency and discourage inefficiencies – poorly performing farmers have incentives to become more efficient. 2. Water use and nutrients that reduce water quality are priced to reflect other environmental externalities. 3. Regulation on land-use change is built into council/local government planning, with mitigation considerations for appropriate land use. 4. Regional councils and Resource Management Act facilitate transition to low-emissions food. 5. An effective rural extension programme is implemented to improve farmer training in ultra-efficient livestock production. 6. New mitigation technologies for livestock N_2O and CH_4 (e.g. inhibitors or vaccines) have been approved internationally	1. Efficiency across the curve has increased; farmers still producing dairy and sheep/beef are ultra-GHG efficient. 2. An industry group has developed tools to measure and verify GHGs on farms. 3. Barriers to take-up of new technologies have been overcome. 4. Precision agriculture tools are widely used. 5. Milk company business models have changed from provider to value-added consumer products (value from quality not quantity). 6. Reform in the sheep–beef sector has improved coordination within supply chains. 7. Traceability mechanisms have been set up to facilitate value from low emissions. 8. Improved supply chain management has created close connections with consumers.	1. Networks and communications channels are fully utilised to share accurate information and debunk myths and misperceptions. 2. Sector regularly discusses efficiency measures and technology uptake. 3. Trust is established between government (central and regional) and the farming community. 4. Consumer demand for low-emission livestock products (recognition of nutrient density – or other measure of nutrition) makes them profitable. 5. Herd homes are aesthetically appealing. 6. A new generation of smart export-focused entrepreneurs and marketers manages livestock value chains.

Sector characteristic 1: New Zealand operates an ultra-GHG-efficient livestock sector.			
A Technology milestones	**B Policy and regulatory milestones**	**C Business milestones**	**D Behavioural milestones**
	and in NZ regulations and are acceptable to consumers. 7. A methodology has been agreed internationally to compare GHG efficiency across countries and farm systems. 8. A metric for comparing nutrition from different sources has been agreed globally. 9. Farm-level reporting of GHGs is mandatory. 10. Regulation requires specific practices, e.g. gas from effluent ponds must be captured. 11. Regulation requires that farms must meet specific performance benchmarks. 12. Regulation limits conversions to high-GHG production or places a moratorium on increasing ruminants.	9. New Zealand companies are exporting expertise in low-emission technology.	

4.1.2 Existing options to reduce methane

Productivity improvements.

Methane emissions are closely linked to total feed intake. If farmers can raise the physical productivity of livestock systems they can lower the GHG-intensity of production. These are the key currently available CH_4 mitigation options in New Zealand. Some evidence (e.g. Anastasiadis and Kerr, 2013; White, Vibart, and Smeaton, 2011) suggests there could still be significant (10–15%) low-cost mitigation. Dynes et al. (2011) identify that on selected sheep and beef farms, feed conversion efficiencies (kilogram of dry matter intake per kilogram of meat and fibre produced), ewe-weaning percentages and ewe-replacement rates are critical leverage points, since farmers achieving these were able to reduce emissions intensity while improving profitability. Higher productivity/lower emission systems require more skill, for example, systems with fewer, larger cows are harder to manage. When there is an identified production benefit, farmers will be faster to adopt. For example, starting in the late 1990s, the local community in Raglan began to fence and replant areas around the estuary for water-quality reasons; apparently many farmers then chose to also fence streams, as they discovered benefits for stock as well. But some emissions efficiency improvements will not raise profit – they will come at a cost. For example, if a farmer immediately replaced their entire current herd with high-breeding-worth animals, emissions intensity of the farm's production would be lower but this would come at a high cost. These changes will not occur without encouragement or incentive.

Manure management – plug-flow digesters and covered anaerobic lagoons.

These could trap the CH_4 produced by fermentation of livestock manure during its storage and eliminate it by combustion. Landcare Research are working on 'biofilters', although for covered lagoons, capture and flaring would be a cheaper option. These options are limited in New Zealand because our animals graze in paddocks most of their lives. They would also be costly; requiring some form of encouragement or compulsion.

4.1.3 Existing options to reduce nitrous oxide: productivity and soil management

1. Nitrogen inhibitors.

Fertiliser additives like dicyandiamides (DCDs) have a significant relatively certain impact on N_2O but the impacts are highly variable across locations, varying especially with temperature. They also have uncertain effects on profitability and severe problems with international acceptability (currently unusable). New application methods are being developed to try to make DCDs more economically attractive. When we talk about implementation of policy over several decades however, a CODEX for DCD may have been established, making it at least legally acceptable – consumer acceptability may be an ongoing issue.

2. Reduced N fertiliser use per animal and optimising the way fertiliser is applied.
3. Effluent management.
4. Grazing off poorly drained soils in winter.
5. Feed pads, allowing urine and manure to be collected and managed.

In France two additional on-farm options for CH_4 and N_2O are considered (Pellerin et al. 2013)[9]:

1. Changing the composition of the diet of cattle to reduce CH_4 production: 'increasing the amount of unsaturated fat (in the form of oilseed) in the diet in place of carbohydrates; incorporating an additive (nitrate) in diets with a low fermentable nitrogen content (based on silage maize).'
2. 'Reduce the amount of protein (nitrogen) in the diet to limit the quantity of nitrogen excreted in manure, corresponding to the fraction of protein ingested that the animals do not retain since it is surplus to their requirements.'

These may not be effective in New Zealand conditions except in the most intensive dairy systems. Lipid supplementation (e.g. oilseed) has not be shown to be effective in New Zealand systems. Reducing the intensity of production per hectare is often suggested as an option. This does reduce absolute emissions from a given area but also reduces production. Evidence in Ledgard and Falconer (2015) suggests the effects of intensification of New Zealand farming systems on GHG intensity may be ambiguous.

US research (e.g. Eagle et al. 2012) explores a much wider set of options including greater focus on precise timing and placement of N fertiliser – which is most relevant for horticulture, and changes in irrigation practices. They focus heavily on carbon sequestration in soils which has not been a significant focus in New Zealand to date though its value has been heavily promoted in Australia where they have ancient soils and the US where soils are degraded.

[9] Macleod et al. (2015) also review the cost of supply-side mitigation measures in agriculture.

Anders Crofoot explains that because New Zealand soils already have high organic matter content by international standards there is much less potential to increase soil carbon. There is some potential for use of soil sinks in arable land according to David Wratt (Chief Scientist, Ministry for the Environment), and biochar remains a possibility but research is still in progress.

New technologies and practices that improve productivity continue to be developed and adapted for New Zealand and, in particular, the New Zealand Agricultural Greenhouse gas Research Centre (NZAGRC) and the Pastoral Greenhouse Gas Research Consortium (PGGRC) are developing options that focus specifically on agricultural mitigation. Some promising technologies that specifically target agricultural emissions are coming through from new research and may be applicable in the next decade. These would reduce emissions intensity significantly if adopted widely, but their availability, cost and consistency with market demands is still uncertain. Even so, they may not reduce absolute emissions if the production of high-emitting foods continues to grow substantially. Reducing emissions intensity does not necessarily reduce the cost to the New Zealand economy from purchasing emission units to cover emissions, but it does increase the value New Zealand and the globe gets from our emissions.

Crofoot also emphasises that one final approach is to work to improve the value of the products New Zealand does produce from pastoral agriculture. Then, even if New Zealand and farmers do pay a high cost for the emissions they also get high value for their products. If New Zealand can convince consumers that our products are relatively low emission (which they are currently relative to other dairy products) we may improve our access to the most valuable markets (Gerber et al., 2010; Lees and Saunders, 2015). If we can improve the quality of our products so that consumers are willing to pay more for them, and further develop our food processing sector to produce more products for high-value niche markets, the emissions cost to the New Zealand economy from a sustained pastoral sector will be offset by high economic value in other dimensions.

4.1.4 Shifting food production to lower-emission products

Table 2: Ideas from the Low-Emission Future Dialogue on milestones for producing zero CH_4, low-N_2O nutrition

Sector characteristic 2: New Zealand produces zero-CH_4, low-N_2O nutrition.			
A Technology milestones	**B Policy and regulatory milestones**	**C Business milestones**	**D Behavioural milestones**
1. Real-time measurement tools are available for farmers to see the impact of their decisions on GHG emissions (and co-benefits). 2. Profitable non-ruminant land use options have been found and tested (e.g. horticulture; crop production to feed poultry, insects or aquaculture; petri-protein). 3. Water-quality issues with aquaculture have been solved. 4. New feasible and cost-effective mitigation technologies have been found for fertiliser use and other N_2O emissions from cropping. 5. Biosecurity issues for insect production have been solved.	1. Pricing mechanisms are established to reward efficiency and discourage inefficiencies – poorly performing farmers have incentives to become more efficient. 2. Seed money is available to develop and implement alternatives to livestock production and use of N fertilisers. 3. A metric for GHG intensity of nutrition is agreed upon globally. 4. Farm-level reporting of GHGs is mandatory. 5. Regulation requires specific practices – e.g. fertiliser management plans to optimise timing and method of application. 6. Regulation requires that farms must meet specific performance benchmarks. 7. Considerations for climate-appropriate land use are built	1. Efficiency of performance across the curve increases. Use of N fertilisers is optimised. Precision agriculture tools are widely used. 2. Traceability mechanisms are set up to facilitate value from low emissions. 3. Barriers to taking up new products and technologies have been overcome. 4. There is increased use of non-ruminant animals. 5. New industries are established for zero-CH_4 foods (market research, etc.). 6. Improved supply chain management creates closer connection with consumers. 7. Capital is mobilised to change land uses, e.g. capital syndication. 8. Business models are developed for indigenous plantations. 9. NZ exports expertise in low-emission products and technologies.	1. Networks and communications channels are fully utilised to share accurate information and debunk myths and misperceptions. 2. Sector conversations are held on new products. 3. Trust is established between government (central and regional) and farming community. 4. Consumer demand for low-emission food products (recognition of nutrient density or other measure of nutrition) makes them profitable. 5. Industry training and universities have transitioned out of training young farmers for ruminant agriculture and into alternatives. 6. Capability to shift New Zealand's economy from primary production toward clean tech is developed. 7. Consumer diet has changed (e.g. franchised insect bars; children prefer non-CH_4 food options).

Sector characteristic 2: New Zealand produces zero-CH_4, low-N_2O nutrition.			
A Technology milestones	**B Policy and regulatory milestones**	**C Business milestones**	**D Behavioural milestones**
	into council/local government planning, 8. Regional councils and the Resource Management Act facilitate the transition to low-emission food. 9. New structures (e.g. producer boards) are set up to support new industries (e.g. legumes, nuts, insects). 10. A National Policy Statement is implemented around biodiverse plantation forests. 11. An effective rural extension programme is implemented to train farmers in alternative food production.		8. Animal rights issues associated with new types of food production are addressed.

Wollenberg et al (2016) suggest that globally, improvements in the emissions intensity of agriculture will not be sufficient to achieve reductions consistent with two degrees of climate change. Reisinger and Clark (2015) confirm that within New Zealand even optimistic projections of technically feasible mitigation of emission intensity within livestock agriculture will leave high levels of absolute emissions. Changes in the type of food we produce and consume, and, in some places afforestation, are an additional part of the solution.

Large areas of New Zealand land that are currently pasture are very well suited for forestry and carbon storage (Todd, Zhang, and Kerr 2009). These are areas that can sequester large volumes of carbon, can produce fibre that is more valuable than food, and/or where forests would bring valuable co-benefits. New Zealand has policies to promote afforestation (though they could be strengthened). The ETS would offer a clear incentive for afforestation if the price were higher and expected to stay high. When the ETS price was around $20 foresters began to respond both by afforesting and considering avoiding deforestation (Karpas and Kerr, 2011; Carver et al, 2016). The Afforestation Grant Scheme offers a similar level of encouragement for small areas of replanting through grants of $1300 per hectare.[10] While new forests do displace some food production, this is unlikely to be a large issue if forestry is a more efficient land use – overall the world will have a more efficient land-use outcome if land-use flexibility and economic signals are able to prevail – as long as the effects on food security are not greater than the emissions gains. In New Zealand we know that afforestation on marginal land will lead to relatively small losses in food production because of the low quality of the land involved.

We have been less active in exploring alternative crops that could be profitably grown on land currently used for pastoral farming[11] and as a result New Zealand still has a relatively undiversified agricultural sector. Despite New Zealand's high-quality land, very small areas are in horticulture. One area of diversification that is emerging currently is goats for milk products – unfortunately goats are also ruminants. More systematic research effort into a diverse range of low-emission products including basic research to identify promising products and learn how to grow them in New Zealand conditions; on-farm experiments; and development of value chains to process and market products would be likely to pay off, according to Anders Crofoot. It is easier for farmers to produce something with existing support and guaranteed buyers, and coordination is required to develop these networks and systems for new products. Developing new food industries would lower emissions through reduced ruminant production. We could then focus the ruminant production we retain on very high-quality products that can achieve a

[10] https://mpi.govt.nz/funding-and-programmes/forestry/afforestation-grant-scheme/
[11] This may be a focus of the 'Our Land and Water - Toitū te Whenua, Toiora te Wai' National Science Challenge, launched January 2016.

market premium (based on being grass-fed, natural) while replacing the nutrition that was previously produced.

Historically, land-use change in response to shifts in profitability even among existing, well understood land-use options, has been slow. Rapid change is likely to be costly. This suggests that actively promoting the first stages of that transition now could significantly reduce long-term costs.

4.1.5 Reduce demand for high-emission products; move demand to low-emission products

Table 3: Ideas from the Low-Emission Future Dialogue on milestones on reducing food waste

Sector characteristic 3: NZ reduces food waste across the chain of food production and consumption			
A Technology milestones	**B Policy and regulatory milestones**	**C Business milestones**	**D Behavioural milestones**
1. New technologies improve effectiveness of food preservation/ refrigeration/storage. 2. New, less-perishable food products are developed. 3. Research into more accurate, context-specific, food expiry dates is done. 4. Food waste can be converted into cost-effective biofuels.	1. An accord with supermarket chains is negotiated to reduce food waste. 2. Supermarkets publicly report food waste.	1. Businesses collaborate to transform food supply chains to improve efficiency, match supply to demand and reduce waste. 2. Supermarkets develop programmes to reduce food waste and distribute surplus food to communities in need. 3. Businesses, schools and institutions match food supply to demand and distribute surplus food to communities in need. 4. On-farm milk waste is reduced. 5. Food waste is collected for biofuel production. 6. Food retailers are disincentivised from offering 'supersize' promotions.	1. Consumers value food more and make an effort not to waste it. 2. Consumers don't expect supermarkets to stock large amounts of perishable foods. 3. Consumers become more willing to substitute canned/refrigerated food for fresh food. 4. Consumers eat more seasonal food which reduces need for storage. 5. Consumers are well informed about the emission impact of wasting food.

Table 4: Ideas from the Low-Emission Future Dialogue on milestones on changing consumer demand for low-emission food

Sector characteristic 4: Consumers demand low-emission food			
A Technology milestones	**B Policy and regulatory milestones**	**C Business milestones**	**D Behavioural milestones**
1. New technologies for food production and distribution make low-emission food readily available to consumers.	1. Emission pricing is extended to biological emissions from food production. 2. Free allocation for the agricultural ETS is based only on exports, not domestic consumption, (so price flows through to domestic consumers). 3. Standard food nutrition index is agreed and certified values provided for all products. 4. Government policies support the testing, production and distribution of low-emission food. 5. Government introduces mandatory food emission labelling. 6. Government incorporates low-emission foods into government dietary guidelines. 7. Government introduces low-emission foods into school food services.	1. Businesses support food emission labelling. 2. Food is labelled (electronically) with nutrition and emissions information so apps can provide information to consumers on their shopping basket. 3. Businesses respond to domestic and international consumer demand by investing in development and production of low-emission foods. 4. Businesses secure a market premium in NZ and overseas for low-emission foods. 5. Businesses actively promote low-emission foods (e.g. marketing campaigns, low-emission cookbooks and training courses, low-emission recipe competitions). 6. Low-emission foods are affordable to consumers.	1. Consumers are educated about the value of low-emission food and the choices available to them. 2. Consumers become more willing to choose lower-emission food alternatives. 3. Consumers respond to emission price incentives applied to food. 4. Delicious low-emission meals are well known, profiled by chefs and taught in schools.

Reducing food waste at all points in the chain and educating consumers to begin the slow process of behavioural change both around food waste and the composition of their diets could lead to short-run gains and contribute to the adjustment toward long-run low-emission food systems. Emissions pricing that did not protect New Zealand consumers would provide extra encouragement to shift New Zealand diets away from high-emission foods. Some LEF participants suggested that although this would have little impact on our emissions profile it would be consistent with playing our part in an efficient global transition to low-emission food. Conversations with industry stakeholders suggest that to a small extent we can also influence international diets; for example by not actively promoting red meat or dairy products to new markets abroad, by producing less and hence raising global prices slightly; and by producing more alternative low-emission food products and then actively promoting them. While New Zealand is unlikely to provide active leadership on reducing demand for livestock products, given our comparative advantage, many industry stakeholders have suggested that we could focus on high-quality niche uses for ruminant products.[12]

4.1.6 Help improve the emissions efficiency of international food producers

New Zealand has very high-emissions efficiency relative to many producers who could use similar farming systems – for example parts of Brazil, Chile and Colombia – (Gerber et al. 2010). The Global Research Alliance and New Zealand farmers (e.g. Leite Verde in Brazil) are providing leadership in lowering on-farm livestock emissions through active international engagement. Anders Crofoot points out that New Zealand also has excellent systems for getting product out of the field and to the market without much waste. Companies such as Fonterra are already active researchers and investors in the region and several New Zealand leaders (e.g. Prime Minister John Key) have visited Latin America recently, but both Crofoot and Megan Owen believe that New Zealand could do more and would benefit from a coordinated, sustained effort to build capability, encourage more exchanges (between students, farmers, and business people) and facilitate joint ventures. This could lead to larger global emission reductions than could ever be achieved within New Zealand, and would reduce any perverse effects of leakage if production within New Zealand is limited.

[12] See for instance ideas in the 'Red Meat Sector Strategy Report' compiled in 2011 by Deloitte for Meat and Lamb New Zealand Limited and the Meat Industry Association of New Zealand. (Deloitte 2011)

4.2 What are likely to be the greatest challenges to achieving agricultural emission reductions over the next several decades?

Key challenges identified by the Low-Emission Future Dialogue
Lack of user-friendly tools to accurately measure GHG emissions at farm level.
Lack of technology to reduce ruminant emissions.
Even if low-emission technology (e.g. vaccine or inhibitor) is developed, will consumers accept its use?
Farmers are disengaged with climate change – we need to improve communication and reframe the message – e.g. as productivity benefit and price premium.
No current driver for farmers to adopt practices to reduce emissions unless there are additional benefits (e.g. productivity).
Farmers may have a lack of trust in authority (government, councils etc.), and other parties.
Consumers may not be willing to pay for low-emission food.
It is difficult to predict demand and supply for food in a low-emission world. That makes it hard to know what types of food will be most valued and hence what unit of nutrition we should use (kilogram of milk solid, kilogram of protein, kilo-calories) to compare emission intensity of food products.
Population growth – challenges to reduce absolute emissions globally

Here I highlight challenges that relate to the ease of transition to low emissions agriculture without significant economic impact in the rural sector. Each of these challenges may be able to be eased through policy interventions.

Poor capability of some farmers and especially a shortage of skills for marketing new high-value products. While New Zealand has some very innovative farmers, we also have a tail of farmers who have low productivity currently (Anastasiadis and Kerr 2013); these may struggle to respond to emissions pricing by implementing mitigation options or land-use change. They may also struggle with use of OVERSEER to estimate emissions. This can be done by a consultant but if farmers are entirely dependent on a consultant they cannot easily use OVERSEER as a management tool to help reduce emissions. Training at all levels and provision of tools will allow farmers to implement existing practices that could lower emissions and raise productivity. This is particularly critical for the new generation of farmers who will be managing farms around 2050, by which time the need to make significant changes to reduce CH_4 emissions will likely become urgent. If these new farmers are familiar with production of new non-ruminant products or technologies that allow extremely low-CH_4 farming, achieving low-emission agriculture will be an opportunity, not a cost.

Uncertainty about the practical applicability of new technologies and practices in complex real systems that need to work in conditions with high variability in weather and economic conditions. The future acceptability of specific technologies in international markets, e.g. vaccines, DCDs, animal health concerns with very high-productivity animals, genetic modification is unknown.

Limited experience with alternative crops and the value/supply chains needed to make them profitable. For instance, the existence of large food exporting companies such as Fonterra or Zespri who can handle the export of certain products lowers entry costs and risks for farmers who change land use. For many potential food products, these exporters do not yet exist. New Zealand does not yet have a vision for a prosperous agricultural sector that is not tied to increasing ruminant livestock production.

Lack of trust by farmers around issues related to climate change. Many farmers still have poor access to high-quality trusted information, particularly on climate mitigation. Mike Barton (beef farmer and founder of Taupo Beef) emphasises that it is also hard to gain the trust of farmers in the value and low risk of new technologies, practices and alternative crops. As with any sector, to get significant investment activity, farmers (and their bankers) will need to expect stable regulation and emissions pricing to make low-emission investments economically viable. Lack of trust among a wide group of farmers will make it harder to penalise even a small group of non-compliant farmers.

Access to capital for farmers to make rapid transitions once the appropriate actions are clear. This is particularly an issue for new farmers who are heavily indebted. If farms are individually owned, capital access can be limited by the farmer's own equity. New Zealand may need to continue to develop alternative financing instruments for the rural sector.

International environment. Lack of pressure to reduce agricultural emissions within competitor countries and lack of recognition by consumers (retailers) of the value of our (relatively) low emissions make emission reductions less economically attractive. Evidence suggests that few consumers are willing to pay more for climate-friendly products though being able to show that products have low emissions may help with market access.

Value of agriculture to the New Zealand economy. Agriculture is an important sector in the New Zealand economy, particularly in terms of exports. Reducing agricultural emissions need not be a threat to the role of agriculture. If the transition to low-emission agriculture is done in such a way that farmers are supported, international consumers recognise the value of New Zealand efforts, and new products emerge to replace livestock-based agriculture, the total value of production may not change, and could even grow. A more diverse economy is likely to be more resilient, which will be especially valuable as climate change progresses. The risks from an economy focused on livestock has been seen in the impacts of drought on gross domestic product (Tait, Renwick, and Stroombergen 2005), ripples flowing from the current depression in dairy prices, or instant falls in the New Zealand exchange rate following the botulism scare which affected dairy exports to China.[13] If we simultaneously reduce our demand for fossil fuels, any reduction in the value of exports of livestock products might be matched with a reduction in imports of oil.

In the short term, as discussed above, livestock production is unlikely to change rapidly – the initial impact of emissions pricing is likely to be largely on profits and land values. Farmers could suffer if not protected, but unless very poorly managed so that many farmers go bankrupt or face severe credit constraints, the economy as whole would not suffer. If we do not reduce agricultural emissions, and New Zealand is expected to reduce its emissions similarly to other developed countries, the economy will face the cost of meeting international targets in other ways – this would be more costly for the economy as a whole.

Distributional impacts within rural communities. The impact on farmers depends on international action (Reisinger and Stroombergen 2012; Dorner and Kerr 2015). If the international community acts effectively on deforestation and afforestation, New Zealand farmers will benefit. If all countries act on agricultural emissions, New Zealand farmers will not be strongly affected – the liability they face domestically will be more or less offset by higher commodity prices. If, however, the international community does not act on agricultural emissions but New Zealand acts strongly, its farmers will lose.

The average impact of the ETS with a cost of $25 per tonne and no output-based free allocation in 2012 would have been around 11% loss of profit for dairy farmers and 17% for sheep/beef (Timar 2016). Some other findings from Timar are summarised here.

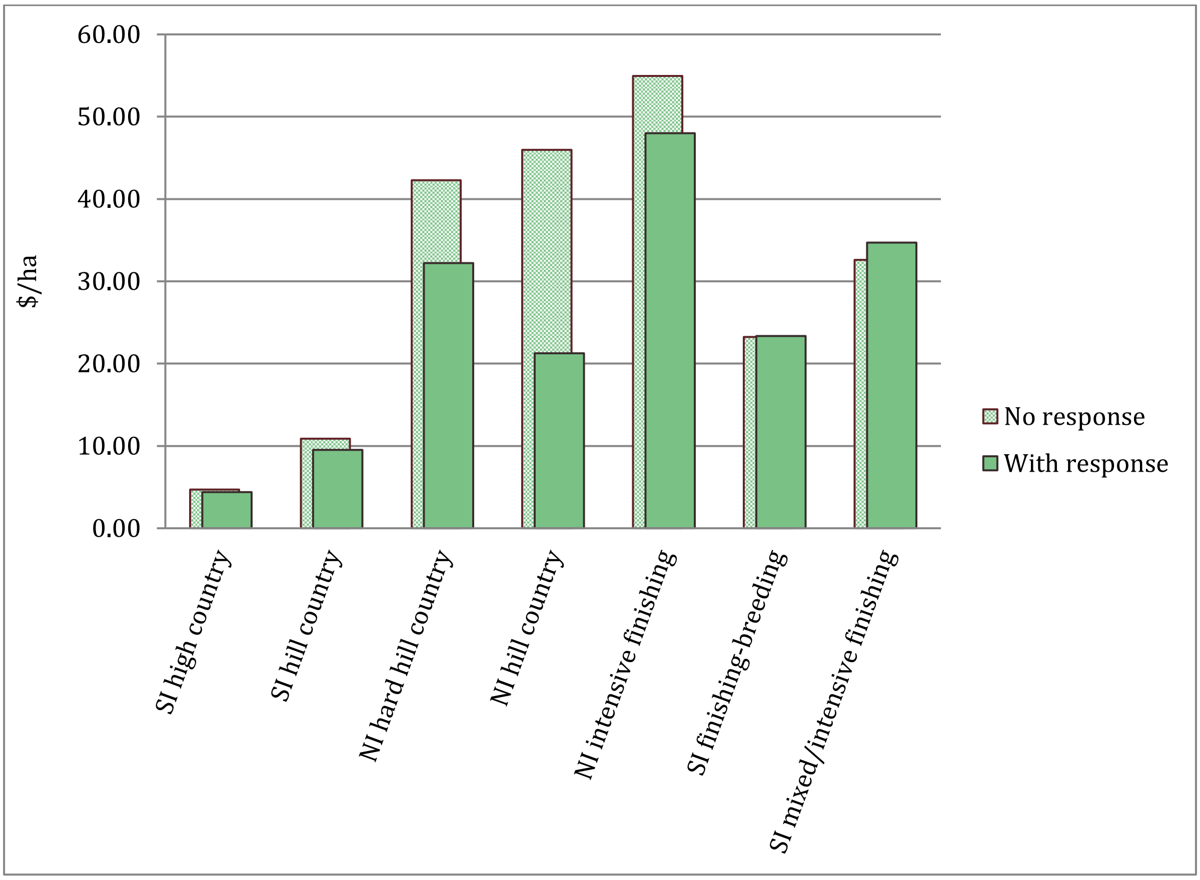
Table 5: Sector-level average profits and emission liabilities ($) under a hypothetical 2012 policy ($25 emission price with no output-based free allocation)

Land use	Profit/ha	Liability/ha	% impact
Dairy	2033.67	223.24	-10.98
Sheep/beef	194.00	33.47	-17.25

These averages hide a wide range across farm types, particularly in the sheep/beef sector.[14] Different farmers will tend to respond differently: some will find it profitable to convert part or all of their farm to plantation forest (possibly by selling the farm to foresters) or to allow native forest regeneration. This response is likely to occur mostly in extensive North Island sheep/beef farms, and the reward from this would offset some losses.

[13] Safety tests in 2013 by Fonterra found what appeared to be botulism-causing bacteria in dairy products. This led to a wide-scale product recall and China temporarily banned imports of affected products from New Zealand. Later tests showed that the bacteria were not botulism-causing.
[14] The dairy emissions liability per ha are consistent with those found with a different methodology in (Kerr and Zhang 2009); the sheep/beef emissions per hectare are much lower because of differences in the land that is counted as pasture.

Figure 1: Sheep/beef farms: Simulated net emission liabilities per hectare in 2030 (without and with a afforestation response) – Emission price: $25



For each farm class, the light green bar in the chart represents average liability per hectare under the baseline scenario in 2030.[15] The bright green bar represents net liabilities in 2030 when land use is allowed to respond to the policy. Net liabilities include emissions associated with meat production (Timar and Kerr 2014), as well as any rewards earned for the afforestation of land that was previously used for sheep/beef farming or left to scrub.[16]

As seen in figure 1 (from Timar 2016), for most farm classes, the land-use response reduces liabilities. This is due to a combination of lower pastoral emissions (abandoned or afforested sheep/beef land) and rewards earned for carbon sequestration (for new forests planted on sheep/beef or scrub land). The reward component dominates on North Island hill

[15] 2030 is used to allow time for gradual land use response. Profits within the sheep-beef sector are assumed to stay constant.

[16] It is assumed that scrub land belongs to sheep/beef farmers, so they are able to earn rewards for planting forests on this land. To express emission liabilities and rewards for carbon sequestration in comparable terms, rewards are converted to an annuity. The annuity is based on the discounted present value of rewards earned during the first ten years of a newly planted forest. A landowner would be able to sell all credits earned during this period without taking a carbon price risk because if a forest is replanted immediately after harvest, its carbon stock never decreases below this level. Therefore, the stock of carbon in a ten-year-old forest represents the amount of sequestration a risk-averse owner would be able to receive reward for with certainty. Although it does not relate to physical abatement, the annuity is relevant for considering the ability to mitigate as it captures the minimum extent to which a risk-averse farmer can offset emission liabilities through planting trees.

country farms, where a large fraction of simulated afforestation happens, leading to a particularly effective mitigation response there.[17]

Timar also shows that because emission liabilities are related to stocking rates, liabilities are in general higher on more intensive farm types. However, relative to profits, the impact of the policy tends to be larger for less intensive sheep/beef farms. Average profitability and the proportional impact is shown in Table 6.

Table 6: Average profits and the relative impact of the hypothetical policy ($25 emission price with no output-based free allocation) in 2030 (without and with a land-use response) by sheep/beef farm class

Farm class	**Profit/ha $**	**% change in profit**	
		No response	**Response**
SI high country	20	-24	-21
SI hill country	76	-14	-12
NI hard hill country	168	-25	-16
NI hill country	255	-18	-3
NI intensive finishing	335	-16	-13
SI finishing-breedings	275	-8	-8
SI mixed/intensive finishing	582	-6	-6

Losses of profit from production are likely to translate to reductions in rural land values (Allan and Kerr 2016a and b). The percentage losses will depend partly on the extent to which current land values depend on the attractiveness of the land as a place to live (amenity values) and the potential for it to be converted to a non-rural use – e.g. residential development. These amenity and option values will not be affected by emission liabilities. Land values for rural land close to cities are likely to fall by a smaller percentage. Grimes and Hyland (2013) show also that some of the impact of lost profit is likely to be passed into economic impacts on nearby urban communities. This is reflected in residential house prices within affected territorial authorities – changes in house prices reflect changes in the value of living in an area, such as local economic opportunities. The actual impact of any agricultural emission policy would depend heavily on whether and how free allocation is provided and also on any complementary policies to assist with community transition.

[17] For lack of data, Timar ignores conversion costs and any changes in profitability associated with the land-use response. For marginal price changes, the overall impact of these components would be expected to be close to zero. For two South Island farm classes, the land-use response increases net liabilities because of additional dairy conversions simulated under the policy. The ETS accelerates the slow movement of land out of low-intensity sheep/beef production.

5 Questions relating to domestic actions

5.1 What actions could the government take to deal with agricultural emissions other than, or in addition to, the Emissions Trading Scheme?

Here the report examines production-related opportunities: reducing emissions per unit of output; and shifting production to low-emission products. Many actions are possible, and below are ideas for some actions, not a comprehensive list. Most of the ideas are mutually complementary. The ideas are not listed in order of preference, and all would need further assessment and development before they are seriously considered. Some are already being pursued in various forms by government at different levels. Actions to reduce food waste are beyond the scope of this report. These ideas have emerged from AgDialogue and Low Emissions Future discussions, and are presented in four major groups: engage positively, research, build capability and regulate.

5.1.1 Engage positively with farmers and the rural community on climate change mitigation.

Emphasise the positive and the opportunities to make a difference, with no blame for past behaviour. This could include:

Involving the rural community effectively in climate policy governance and the process of developing a broad consensus around New Zealand's transition to low emissions would also facilitate efforts to directly reduce agricultural emissions.

This would need to be a well-informed process to avoid misdirected effort in the face of the complexity involved. It could involve a combination of within- and cross-sectoral dialogues.

A sector accord, similar to the 2003 Dairying and Clean Streams Accord could be negotiated with the key sectors.

This would probably be complementary to other instruments rather than a replacement, given a lack of local co-benefits from GHG mitigation, and hence lack of local pressure to comply. It could be linked to a more active effort to brand New Zealand livestock products as (relatively) climate friendly.

Continue active support for afforestation

This is relevant for marginal land, particularly North Island hill country. New Zealand already has the regulatory structures to do this – the ETS and the Afforestation Grant Scheme. The former would induce significant levels of afforestation if the GHG price were higher (some, including Chris Insley on the Iwi Leaders' Forum[18], have suggested that $15 per tonne is a

[18] Quoted by Brian Fallow in the New Zealand Herald on 18 October 2012 http://m.nzherald.co.nz/carbon-trading/news/article.cfm?c_id=1501831&objectid=10841199

critical level for forestry) and expected to stay high. In the first years of the programme, 2008–2011, afforestation was beginning, but the price then fell, afforestation plans were abandoned, and some people lost their investments. The Afforestation Grant Scheme (now in its second incarnation) provides more investment certainty but is available on a limited basis and only to small land owners. A higher and more stable price through ETS reform, and a widely available financial instrument that allows foresters to sell future carbon units at the time they plant, would make afforestation an attractive option in many areas and bring benefits to many of the farmers who could otherwise see climate change policy as a serious risk (those who face potentially high losses from high GHG liabilities on land with low profits). This would particularly bring benefits on marginal land, e.g. North Island hill and hard hill country. Much of the land suitable for afforestation is Māori land so Māori are particularly affected by this issue.

Facilitate renewable energy and lower emissions transport in rural areas.

While this may not be the highest priority for low-emission transport, rural people are highly dependent on private transport and will experience high cost from higher carbon prices. Rural areas also offer strong opportunities for renewable energy because of the availability of land and lack of grid access, and pose specific challenges – e.g. tractors and farm bikes.

Table 7: Opportunities, challenges and potential domestic actions

<table>
<tr><th>Opportunities</th><th>Challenges</th><th>Some Domestic Actions Government Could Take</th></tr>
<tr><td>Emissions per unit output
Increased productivity
New technologies</td><td>Lack of farmer trust and engagement
Uncertainty about new technologies, products and practices
Poor education of some farmers
Access to capital
International environment – lack of reward/driver</td><td rowspan="2">Engage positively with rural sector on climate change: Involve the rural community in climate policy governance; develop ‘clean climate accord’ with rural sector; facilitate renewable electricity and low-emission transport in rural areas; strengthen ETS and Afforestation Grant Scheme for forestry; celebrate current low-emissions-intensity; focus primary sector development on profitability not volume.
Research: continue work on low-emission livestock; robust user-friendly tools for farmers; spatial modelling of land use, climate and co-benefits – National Science Challenge on climate-smart land use.
Undertake more research on: alternative low-emission products and their supply chains; on-farm and supply-chain experiments.

Increase capability for high-value, low-emission agriculture: educate and retrain at universities, AgITO, extension services to help farmers; farmer support groups; demonstration farms; business schools, designers and IT with rural focus.

Regulate: capital gains tax on rural land; moratoria on conversion to ruminants; require ‘best practice’ or performance benchmark; continue to implement freshwater reforms; ETS.</td></tr>
<tr><td>Shifting production to low-emission alternatives</td><td>Limited experience with alternative crops and their supply chains
Macroeconomic value of agriculture
Distributional impacts within rural communities</td></tr>
</table>

Emphasise the role that the best New Zealand farmers can play in helping others lower their emissions – both within their communities and internationally.

This could involve greater use of farmer support groups – actively expanding them to include less-capable farmers, further developing demonstration farms, and encouraging farmer-to-farmer conversations around new options.

Celebrate New Zealand's current low-emissions-intensity.

Globally, New Zealand produces livestock products with a low GHG footprint (Saunders, Barber, and Taylor (2006); Gerber et al. (2010)). Farmers, including Megan Owen and Mike Barton, stress that as we begin to actively reduce our GHG intensity (rather than achieving it primarily through high productivity for good economic reasons alone), New Zealand could more actively promote this with a national 'clean climate' brand. This could be built upon at a farm level with a voluntary certification programme for farms to recognise good practice on GHG emissions. It is difficult to be quantitatively precise about the emissions performance of an individual farmer, because the emissions are partly due to environmental factors out of the farmer's control (except when choosing land to convert) and because animals move between farms. However, credible indicators of good practice and improving performance could be created. Government certification and a role in monitoring of these would provide extra credibility – even if the system were designed by the sector.

Simplified gold standard. AgDialogue has developed a prototype for a set of graduated environmental standards for on-farm management practices. These standards would go from bronze to platinum, and would need to be qualitative rather than numerical – not an explicit farm-level GHG footprinting or life-cycle analysis of products. They would be at the farm scale and would recognise actions that farmers could control. Furthermore, farmers, or those marketing their products, could use their certification to improve the value of their product if they wish.

Clean green food branding. As New Zealand farmers improve their environmental practices, AgDialogue participants see it as important to have a national brand to promote the environmental performance of New Zealand food producers.

Refocus discussion about primary sector development on profitability per hectare through optimised land-use choices and high-value products rather than aggregate growth in volume of product.

Some New Zealand work (Anderson and Ridler 2010) has suggested that some New Zealand farmers overstock their farms beyond the point of maximum profitability. Others challenge this, suggesting that these heavily stocked farms are easier to manage. This issue needs to be better understood.

5.1.2 Research

This is an active area already and stakeholders, government and researchers broadly agree that it should continue. Current funding tends to be focused on reducing N_2O and CH_4 in pastoral agriculture. This is valuable globally because New Zealand has developed internationally recognised research capability in this area and some of the potential solutions will be internationally transferrable. However, it is only part of the solution. The Low Emissions Future dialogue group has suggested that increased research emphasis, through additional funding, be placed on:

Alternative low-emission crops and animals.

Some of these alternatives have been tried previously or are currently done on a small scale, but more exploration may identify solutions to problems or discover opportunities not previously recognised. Nothing will be suitable everywhere, and more diversity provides resilience. The Low Emissions Future dialogue group noted that alternative food production to explore could include: more oats and barley (partly for non-ruminant animal feed), which may be possible on rolling hill country; chickens; pigs; rabbits; ostriches; land-based aquaculture; insects; wax-worms; fungi (e.g. quorn); hazelnuts; walnuts.

Predicting which crops and products are likely to be profitable in a future low-emissions world.

Global demand for nutrition will rise but nutrition is not uni-dimensional. Some aspects of nutrition will become more valuable – and hence profitable to produce. New Zealand should produce high-nutrition, low-emission food that makes the best use of the type of land and climate we have in New Zealand, says Megan Owen. We have tools to estimate the emissions content of different foods, but less attention has been paid to comparisons of nutrition content, and less still to relative nutrition per unit of emissions. One of New Zealand's greatest challenges is to justify the agricultural sector's high emissions (which make our global targets look unambitious). If New Zealand can show that it is increasing production of nutrition and in a globally low-emissions way, it could avoid a focus on reducing absolute emissions from agriculture. This would require a way to credibly compare 'nutrition' across food products.

More on-farm experiments, including exploring the implications of new products, practices and technologies for profitability, skill needs, and risk.

New Zealand's farms experience diverse conditions and use diverse management practice. This makes experimentation difficult but products and practices are unlikely to be attractive to farmers unless they can see that they work in the field, and with farmers similar to them, who they can trust. Understanding how new ideas will operate in the real, complex and highly variable world (in weather and price) is critical as new options get close to potential implementation. Field research must be structured to estimate implications for profitability and risk (i.e. studies over a number of years and complemented by carefully calibrated farm system modelling) as well as agronomic performance.

Experimentation with entire supply chains not just before the farm gate. Effective supply chains will consider processing, logistics, market research and effective marketing.

One of the greatest challenges for new products, and for getting greater value from existing products, in New Zealand is the need to coordinate a large number of small farmers to effectively identify attractive products for consumers in different cultures, produce them reliably and at sufficient scale, and market them to distant culturally distinct markets. This research needs to involve researchers with logistics, marketing, design, and other business skills, as well as people with specific cultural knowledge.

Actively develop alternative long-term land-use scenarios that facilitate consideration of non-ruminant land-uses, their profitability, wider environmental consequences, and implications for social and economic development of rural communities and remote regions.

To put this all together and understand the implications for rural communities, and for other environmental issues, New Zealand could develop a robust spatial information and modelling system that integrates GHG emissions, water quality, water demand, biodiversity, and economic viability including resilience to price and fluctuations and climate change. This could be done through a National Science Challenge on climate-smart land-use. Various pieces of this modelling framework already exist (e.g. NZFARM, the Climate Change Impacts and Implications project, LURNZ), but nothing that combines all issues, and the models we do have could be considerably strengthened, in part through systematic, sustained, active use for a range of applications.

Develop robust, user-friendly on-farm emissions monitoring and reporting tools that reflect mitigation outcomes of individual farmer practice changes.

To make all this research useful to change behaviour, it needs to be effectively communicated to farmers. Part of this could be through clever IT. Making research results and accepted algorithms easily available to software designers could facilitate production of cheap, user-friendly tools. This is beginning to happen (e.g. FarmIQ[19]) but these tools are not widely used yet.

Expanding research in all these areas is likely to require strategic research capability building as well as redirection of or additional funding. As research develops new ideas and tools for mitigation, they need to be picked up by those who can use them. That requires specific capability in the farming sector. Support from industry or government during the learning phase of adoption (when early adopters provide 'learning externalities' for other farmers who learn from their experience) could accelerate the diffusion of new ideas and tools.

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[19] http://www.farmiq.co.nz/

5.1.3 Increase capability

Participants in the AgDialogue emphasised that careful attention must be paid to the rural community transition, so that climate mitigation is not seen as a cost but as part of a transition to a different but equally or more attractive system. If the rural community has time to make a gradual transition and has the human, knowledge and financial resources required, the transition could be relatively painless and positive. These resources could involve active retraining, transitional assistance to vulnerable groups, and support for local initiatives.

Current and future farmers need to be trained so they understand the drivers of emissions and how they can change practices, adopt technologies or choose to engage in a different type of production.

This can be done through rural high schools (and even primary schools), Agricultural Industry Training Organisations, and through university agricultural programmes. Warwick Murray, General Manager Natural Resource Operations at Bay of Plenty Regional Council, emphasises that high-quality, credible information provided through channels that farmers understand and trust is essential. Industry leadership will be key to helping lead farmers where they need to go.

It is not only capability on farms that counts

Anders Crofoot and Megan Owen (who is a management consultant as well as a sharemilker) point out that it is critical to engage current and future business people to create the marketing, supply chain and other infrastructure to improve the value gained from low-emission meat and dairy and to facilitate the development of new crops. This could be done through business schools and agri-business programmes.

Educate the public so they better understand what a low-emission diet is, enabling them to gradually change habits.

Globally, demand must match supply, so low-emission production must be matched with low-emission demand. If our farmers are to produce low-emission food, consumers who recognise and reward those efforts and actively demand the food they produce will help. Certification of low-emission production practices can allow consumers choice, and more general understanding of the types of food that are low emission is also useful.

Improve access to capital for land-use change and implementing low-emission technology and practices.

Many New Zealand farmers are heavily indebted, meaning that banks have a key role in land-use decision making. Exploring new forms of capital syndication focused on low-emission production was an idea proposed by the Low Emissions Future dialogue group.

Poor capital access makes low-emission investments that may be risky and long-term harder to justify. Broadening the range of investors and spreading the risk may allow a faster transition.

5.1.4 Regulate

Regulation can help create an environment conducive to transition and can also act as a backstop to bring up the tail when the majority of farmers have already made a transition. A backstop can be efficient, by forcing action where there are insuperable capability or behavioural barriers, and equitable, by avoiding the possibility that some farmers benefit from continued poor practice.

Introduce a capital gains tax on rural land.

This may seem counter-intuitive but was suggested by several farmers in the AgDialogue group. If designed well it could help farmers, particularly new purchasers of land with limited access to capital. It would reduce some perverse incentives that may reduce farming profitability and increase emissions.

> Some AgDialogue participants consider that a capital gains tax on rural land would remove a perverse incentive to invest in intensification to avoid tax. Over-intensification likely leads to inefficient increases in absolute GHG emissions. The tax would be levied only on changes in value relative to a base year so would have no retrospective cost and it could be paid on sale to avoid cash flow implications. A capital gains tax would reduce pressure on land values, particularly near expanding urban areas. Land values that significantly exceed the underlying productive value of the land make it difficult for new farmers to purchase land and lead to high debt.

Continue to promote the freshwater agenda and recognise the gains that farmers are achieving for climate change through their efforts against this local problem.

In some catchments this could have considerable impacts on agricultural GHG emissions.[20] Recognise the other ecosystem services provided by well-managed farm land – e.g. biodiversity.

> **Benefits of freshwater reform**
>
> The GHG benefits from the Lake Taupo Nitrogen Cap could be estimated and celebrated. The increases in carbon sequestration are already rewarded through the Emissions Trading System, and were purchased for 15 years by Mighty River Power.

[20] The positive and negative interactions between water quality mitigation and GHG mitigation are the subject of two current research projects.

Two seemingly attractive options that are sometimes put forward may be hard to implement.

Direct regulation of specific practices.

Because of the complexity of biological systems, few specific solutions are efficient or even effective in all systems. This makes direct regulation difficult. For a while nitrate inhibitors seemed a very attractive mitigation option. If they had been required, however, it would have raised the cost for all farmers with offsetting productivity improvements for only a few. It also would have had limited impact in many areas where the temperature was higher, and when traces of DCD were found in milk and the problems with consumer acceptance of DCD arose, we would have had a much larger problem with the 'clean green' brand for New Zealand food. If a CH_4 vaccine was created and proven to be both cost effective on most farms and acceptable to consumers, it could be a candidate for regulation.

Stocking rates could be limited, with positive benefits for water quality and reductions in absolute levels of GHG emissions. However, even if some New Zealand farmers overstock their farms beyond the optimal level for profitability, limits on stocking rates would likely be a very inefficient policy. Optimal stocking rates vary dramatically across New Zealand depending on local conditions and farming systems. It is also not clear whether lower stocking rates imply lower GHG emissions intensity.

Farm emissions-intensity benchmarks.

Warwick Murray suggests that a better alternative, used by some regional councils to address water quality issues, would be to set a benchmark level of emissions intensity for each farm. This could be set high to focus attention on the inefficient tail of farms where improvements can clearly be made. This could be associated with guidance on best practice drawing on similar local farms with low-emissions-intensity.

Land use planning.

For the same reasons that mandatory regulation is difficult, it is not possible to prescribe the best land use. Land, existing infrastructure, and farmers are too heterogeneous and opportunities are too difficult to assess. However, regional councils could provide a forum for discussion, some guidance, and in some circumstances, could limit particular types of land use. If New Zealand believed that from a national risk perspective, we have enough dairy farming, we could consider a moratorium on new dairy farms (potentially with the ability to swap an existing one for a new one in a better location). This would be similar to the freeze on nutrient loss in the Rotorua catchment ('Rule 11') that has been used to provide a breathing space while long-term policy is put in place.

5.2 What are the pros and cons of including agricultural emissions in the Emissions Trading Scheme?

Here I focus on the pros and cons of the current 'processor-based' ETS design relative to no pricing of agricultural emissions.

Pros of processor-based ETS:

1. It would make it clear that dairy and red meat do have GHG impacts and that change is needed.
2. It would provide a targeted incentive to reduce long-lived N_2O emissions from fertiliser use (small in aggregate in New Zealand but a key focus elsewhere) and a weak incentive to reduce production of dairy and red meat products and to improve their emissions intensity.[21] The gain from mitigation through land-use change could be around $13 million per year at an emissions price of $25.[22]
3. It would have a small (because of high levels of free allocation) impact on land values which would start a gradual (and hence manageable) adjustment in the rural land market.
4. It would hopefully get past the first conversation with farmers – whether we do anything (beyond research and voluntary efforts) – to move on to discuss how much we need to do and how.
5. It would reduce the burden on taxpayers and other sectors to meet New Zealand's international targets. The total cost of agricultural emissions over the 2020s could be around $13 billion.[23] If agricultural emissions were included in the ETS, around $130 million per year of this cost would be borne by farmers.
6. Whatever payments are made by farmers could be used to fund emission-reducing investments in the agricultural sector or elsewhere in the economy – for example new infrastructure – or to fund mitigation abroad if New Zealand cannot cost-effectively meet those targets domestically. Some potential activities within the agricultural sector that could be funded are discussed above under question 5.

Cons of processor-based ETS:

1. The potential for high costs and loss of equity (when levels of free allocation diminish) could focus farmers' attention on costs to them and not on the opportunities to mitigate and find solutions. The negative emotions associated with this could make future

[21] It would be important to check that substitution of N fertiliser with other supplementary feed did not lead to an increase in emissions.
[22] This is a rough and possibly optimistic estimate. Kerr et al (2012) estimate around a 1 megatonne reduction in net emissions in 2024 from land-use change in response to a constant $25 carbon price applied to agriculture (on top of the existing forestry component of the ETS) with no output-based allocation from 2008. If roughly half of this is mitigation cost, the gain is around $12.5 million.
[23] This assumes a price of $25 per tonne for every tonne of emissions and some continued growth in agricultural emissions. "If agriculture is not included in the ETS, the fiscal cost from purchasing international offsets to cover increasing agricultural emissions could be around $13 billion over the 2020s," February 2015 briefing by the New Zealand Treasury to the Ministers of Climate Change and Transport cited by *Carbon News*, 21 September 2015.

conversations about mitigation more difficult and perversely even reduce mitigation in the longer term.

2. Implementation costs, though the administration costs of the currently proposed processor-based system are not high.
3. If the cost imposed was too high it would have large impacts on farmers and rural communities who would be unable to effectively or rapidly respond.

Methane reductions may not be as valuable at present as their current metric suggests if the dominant focus is to limit global peak warming. This limitation would apply to any policy aimed at CH_4 reductions. With the currently proposed high levels of output-based free allocation and low prices, agriculture could be immediately included in the ETS.[24] The system could then evolve. Alternatively, implementation could be delayed to start with a more focused farm-scale system. We discuss some of these options below.

5.3 If included, what are the pros and cons of different approaches to dealing with agricultural emissions within the Emissions Trading Scheme?

There are three basic forms of incorporation into the ETS, and three basic choices around the way that any free allocation is handled.[25]

5.3.1 Incorporation: Processor-based ETS

This approach is the one for which legislation and regulations have already been developed. Essentially it identifies 'pinch points' in the supply chains through which all agricultural production passes – both N fertiliser manufacturers at the start of the chain, and dairy and meat processors further on. This is a relatively small group of actors. Fertiliser and products are assigned emissions factors and liabilities are collected at these points. The key arguments in favour are that it is administratively relatively straightforward, the details have already been resolved and that it would have broad coverage. It could be implemented quickly, and would put a reasonably accurate price on emissions from N fertiliser and a cost on high-emission products. That would encourage farmers to more actively explore alternative low-emission products. If farmers could pass this price on, at least to domestic consumers, that, combined with education and labelling would begin to encourage diet change. Allan, Kerr, and Will (2015) show the high level of emissions in New Zealander's current diets.

The main limitation is that it provides limited incentives to farmers to reduce emissions within their current production systems. The emission factors are averages for the industry – they must be based on data available at the pinch point. This means that they do not vary with

[24] The current price could rise rapidly if the government signals stronger ambition. It is not clear on what basis New Zealand's units are currently priced. All modelling suggests much higher prices are needed to meet New Zealand's INDC, particularly if we continue to be unable to purchase international units.
[25] Different options are discussed in detail in Agriculture Technical Advisory Group (2009).

each farmer's on-farm decisions. While farmers are unable to pass on costs internationally (until either consumers value low-emission food or our competitors also price agricultural emissions), most of the cost would be absorbed in profits and hence land values.

5.3.2 Incorporation: Full farm-scale ETS

This involves treating each farm (above a size threshold) as a point of obligation. This options was recommended by the Emissions Trading Review Panel in 2011. The farm would be required to monitor the emissions arising from activities on their farm and surrender allowances to match those emissions. A similar approach, at farm scale, using OVERSEER and with defined thresholds to exclude non-commercial land blocks, has already been used in the Taupo catchment to manage N leaching that could have caused water-quality issues (Duhon, McDonald, and Kerr 2015).

The argument in favour is that it can provide much more efficient incentives to reduce emissions intensity within farms as well as (potentially) providing an efficient incentive to start the transition to different land uses and forms of food production. The degree of efficiency in signal depends on the quality of the model used to monitor emissions and the ability to audit the data required to model them. OVERSEER can already model a wide range of mitigation actions (mostly around physical productivity) and others can be added.

Given, however, that economic drivers already push towards increased productivity per animal, it is not clear to what extent an additional price signal would significantly shift productivity further along. Similarly, technology and practice adoption decisions are driven by a range of factors of which price is just one. Overcoming other barriers may be necessary to generate significant responses to price signals and will certainly increase price responsiveness. Newly emerging technologies such as inhibitors or vaccines that would be costly but relatively easy to adopt may be more price responsive.

Many stakeholders agree that the key difficulty is the cost of monitoring, verifying, and enforcing compliance by a large number of relatively small agents. Warwick Murray says that Bay of Plenty Regional Council experience is that OVERSEER needs considerable work to make it stable and easy to use and to generate more confidence among farmers – making this a research and outreach priority would help lay a strong basis for any mitigation action. Acceptability of the system would need to be higher to achieve the levels of voluntary compliance that will make the complex monitoring system manageable.

Many of farmers' and rural communities' concerns can in theory be addressed through carefully targeted free allocation and support but in practice, resolving complex distributional issues like this are difficult if the costs are high – just as regional councils and communities are finding as they set limits for freshwater management. Emissions intensity levels vary significantly across regions and land class and from farm to farm, particularly for the meat sector. A farm-level point of obligation may create windfall gains for some farmers and impose high costs on others. [26]

Costs vary significantly across farmers and there is no one valid approach to equity. Introducing the system with very low initial costs or accepting windfall gains to some farmers (as we have for forestry) may be the only feasible approach. Thresholds below which farms are not included can also be used to protect very small farmers and avoid the need to monitor and enforce compliance for very small sources.

To avoid many small farmers needing to learn how to manage liabilities and understand emissions pricing, farmers could be offered a fixed price for compliance that would adjust annually with some measure of the market price. The government could then manage the inter-annual price variation on their behalf. This would make the ETS very similar to a tax from an economic point of view.

5.3.3 Incorporation: 'Offsets' for particular activities

An option that is being implemented abroad (e.g. Australian Carbon Farming Initiative and Californian ETS offsets protocol[27]) is 'offsets' or specific subsidies for adoption of specific technologies or implementation of specific practices. These require estimation of a baseline level of emissions that would have occurred without an active project. Then actual emissions are measured and allowances are given for the difference. Standardised protocols are developed to assess eligibility, define baseline emissions and monitor actual emissions. The costs of creating offsets, particularly in agriculture, can be high relative to the potential gains.

The potential advantages of these offsets are that they do not require the complexity associated with dealing with all farmers or complete farm systems. They could be used to help the sector learn about new technologies. If used for this purpose, the programme would need to be structured with an emphasis on learning and sharing information rather than on the reductions they could generate.

This might more easily be done outside the ETS with cash grants. This would reduce the emphasis on measuring 'additional' emission reductions (reductions that would not have happened without the payment) and focus on the learning benefits. Certain activities or new technologies could be chosen as ones where faster adoption would help others learn. A level of support could be calculated to be sufficient to induce an adoption response and to be proportional to the expected social benefit. One requirement of the grant could be that the farmer shares their experience with others and provides data on environmental and financial

[26] There are also a lot of questions in regards to how value may flow through the farming economy. Often emissions do not occur where the allocation will occur. For example, a finishing beef farm may receive all the allocations for the beef produced, but only be responsible for small proportion of the emissions from cattle, resulting in allocations exceeding emissions for that farm. In theory, the finishing farm will pay more for raising stock, so the benefits will be passed up the supply chain – however there may be some transition difficulties as such policy is introduced. This is true in all sectors.

[27] http://www.climateactionreserve.org/how/california-compliance-projects/

and other outcomes. Unlike a traditional offset programme, the government could accept that they cannot determine whether a specific farm would have adopted a practice or technology but choose options that are not yet widely adopted throughout the sector – this is the approach taken for offsets in California's system. As adoption rates rise, the learning benefits would decrease and the grants could be discontinued. The California Solar Initiative, which aims to increase uptake of solar photovoltaics on residential housing, operates on this principle and automatically phases out subsidies as adoption reaches certain thresholds.

The key disadvantage of offsets as an approach to rewarding mitigation is that they can address only a tiny set of mitigation options. The options must be unlikely to be adopted otherwise, clearly defined and have measurable impacts. Internationally offsets tend to be focused on specific technologies such as CH_4 digesters which are not a significant current option in New Zealand (however new technologies such as methanogen inhibitors may offer possibilities). The impossibility of predicting a business-as-usual level of emissions for heterogeneous farm systems and avoiding leakage to other farms makes whole farm-scale offsets infeasible. Offsets also require funding (either through purchase of units or cash). If the offsets increase the profitability of the operations they could have the perverse effect of encouraging increased production of high-emissions food.

Low Emissions Future: Market mechanisms and emissions pricing
Pricing mechanisms established to reward efficiency and discourage inefficiencies – poorly performing farmers have an incentive to become more efficient.
Long-run achievement: efficiency of performance across the curve increases, New Zealand maintains competitive advantage and improves productivity and profitability.

A hybrid of the processor-point of obligation and an offset scheme may be possible and would provide a pathway to create an emissions price incentive while also passing emissions costs from the taxpayer to the farmer. This option was considered by the Agricultural Technical Advisory Group in 2008 and rejected because of the complexity of assigning emissions to specific farms in a way that cannot be manipulated, but recent developments in technology and thinking may make it worth revisiting. Potential options could include processor-level as the default but farm-scale for the dairy sector (for farms above a given size threshold), including a default emissions factor for animals that are grazed off, or farm-scale for all large farms. Larger farms that are more emissions efficient than the average may benefit from this approach rather than a processor-level system, but some may lose. Making the farm-scale component mandatory rather than optional would reduce problems of selection that could lead to significant bias. Farms that are regulated at the farm scale would receive a rebate for their processor-level payments.

5.3.4 Support during transition: Output-based allocation.

The currently developed processor-level ETS uses a form of output-based allocation to reduce the impact on farmers. The 'pro' of this approach is that it is easy to implement; it is based on data collected in the compliance process – it simply reduces the net liability.

The 'con' is that output-based allocation essentially provides an output subsidy to high-emission production. This could be appropriate in the short-term if the sector might suffer international leakage or a costly rapid transition. However land-use change is very slow so the major impacts are likely to be on land values and rural communities. Slow land-use change also means that New Zealand is unlikely to lose a significant part of its agricultural sector through emissions pricing before its competitors (unless it imposes very high prices) and later regret it (Kerr and Coleman 2008). This had been a concern with sectors such as steel where production could rapidly shift to competitors. In the long term it may make sense for steel to be produced in New Zealand because of our low-emission electricity. We might regret the loss of steel plants if they are costly to rebuild – though even there, the cost of protecting them through a long transition is likely to be too high to be efficient. In the long term it would be prudent for New Zealand to move out of livestock agriculture where we can find profitable alternatives. In the short term, land use is sticky – it does not change fast (Kerr and Olssen 2012). As Warwick Murray and Anders Crofoot stress, farmers, for good reasons, are conservative and make changes slowly.

Output subsidies through output-based allocation will reduce the impacts on land values and rural communities but at a cost. Ideally these impacts would be addressed directly.

5.3.5 Support during transition: Grandparenting or land-based allocation.

The second broad option is to allocate in a lump-sum way – where allocation does not change with future behaviour, so has no incentive effects. One option is to allocate on the basis of past production (with a benchmark for emissions intensity to avoid perverse benefits to those with poor historical performance); another is on the basis of the land's potential to produce. While the latter may seem most fair – matching compensation to the amount of land value lost and protecting low-current emitters such as Māori and foresters – it may be hard to agree on a measure for 'potential to produce'. If allocation is given in this lump-sum fashion it could be gradually allocated in the form of allowances to landowners. Gradual allocation would reduce price risk, which affects the level of both loss and compensation, and manage fiscal cost.

5.3.6 Support during transition: No free allocation but use of auction revenue to support adjustment.

Revenue could be used to fund the complementary programmes as discussed or more directly to support farming families and rural communities during the transition. This may be a more effective way to support change and protect the vulnerable than allocation to landowners.

5.3.7 What different time frames should be considered?

Short term – next 2-5 years

A low price could be introduced immediately through the existing processor-based system. This would provide a signal that pastoral agriculture does create emissions – with particular focus on N_2O. It would create a precedent that farms will bear some cost although the immediate impact on farm values would be small given the high level of protection in the current system. Expectations of more stringent regulation over time would ease the transition in rural land values and provide some impetus to efforts to prepare to make stronger emission-reducing investments.

Some revenue collected from the ETS could be used to fund activities that help New Zealand learn how to effectively reduce agricultural emissions: e.g. research, trials – both on farm and within supply chains, and to develop the capabilities needed for low-emission agriculture through all levels of education and training: school, university and agricultural ITOs, and extension services to farmers. It could also subsidise some specific on-farm activities that would ultimately be included in a farm-scale monitoring tool – as a way to instigate learning about the use of these activities that will lower their costs, reduce uncertainty and increase acceptability among farmers.

We need to continue to develop on-farm monitoring tools that will allow us to more easily take the ETS down to a farm scale. Because of the lower short-term concern about CH_4, the emission factors included within the ETS, and the mitigation methods modelled in the monitoring tool used for farm scale enforcement, we could focus more on factors that affect N_2O.

Medium term – between 5-10 years from now

As some farmers begin to mitigate and provide leadership, the tools to monitor farm-scale emissions robustly develop and are more widely implemented, and acceptance grows in the rural community, we could transition to a farm-scale ETS.

As a transition measure, a farm-scale ETS could be considered for the dairy sector first, and for large sheep/beef operations. Their products could then be exempted from the processor-level requirements. This would lead to some cross-farm leakage (e.g. to dairy support systems) so the thresholds would need to be gradually lowered to cover all commercial production. As farms transition to a farm-scale point of obligation, we could also transition to lump-sum free allocation to avoid a perverse incentive to stay in pastoral agriculture in the long term.

5.4 If not (never) included, what are the pros and cons of different approaches to dealing with agricultural emissions outside of the Emissions Trading Scheme?

If agricultural emissions are never included in the ETS, all the policies discussed above in 5 would still be relevant and more emphasis might be put on these to compensate for the lack of a price. Because an emissions price would complement these policies however, they would be less effective without it. More funding would be needed for freshwater reforms which would have to bear a higher burden for the reductions. This would leave a considerable funding gap – meaning the complementary policies that could raise revenue might be employed more heavily. It would also mean that on the margin, dairy, sheep/beef and other emissions-intensive agriculture would be, from society's point of view, artificially profitable. Without an emissions price, the complementary policies that reduce the profitability of livestock agriculture are likely to bring greater social benefits than those that could implicitly subsidise it by lowering cost.

To correct for the lack of ETS pricing two broad options (or a combination of them) would be possible:

Increased levies on the key industries (red meat, dairy and fertiliser) to fund mitigation programmes. These could be applied on the same basis as existing levies to support industry associations rather than on the basis of emissions factors and production as proposed in the ETS. If a tax or levy were applied on the same basis as the processor-based ETS it would essentially be the same as an ETS – just a fixed price rather than a market-generated price.

Most ETSs now have some form of price management and financial instruments can be designed to offer price certainty to specific groups (the Afforestation Grants Scheme is an example of this). Similarly, a tax and dividend programme can be made to be identical to an ETS where the units are auctioned and the revenue from the auction given back to taxpayers as a 'dividend'. The challenges with implementing these – for example monitoring a large number of farms and managing distributional impacts – are identical.

Subsidy programmes for specific practices in order to achieve reductions (not focused on learning as in 5) (the cost of subsidies aimed at achieving reductions could be offset with sector levies). The 'pro' of these would be that some on-farm mitigation would be encouraged and there would be some additional learning within the rural community. The main 'con' is that, as discussed above under 'offsets', these are expensive. They are also costly to monitor, though voluntary participation by a subset of farms is easier to manage than full farm-scale ETS. Practices to subsidise could include high-genetic-merit animals, grazing off poorly drained soils in winter, high replacement rates or other measures of productivity, or low-emission irrigation practices. The total emission-reducing impacts of these policies is likely to be quite small, particularly if the subsidies are not large. There could be an argument for slightly reducing the bias toward sheep/beef farming relative to forestry by making afforestation more attractive to foresters – possibly by reducing the price risk to foresters through an extension of the Afforestation Grant Scheme or something similar.

6 Questions relating to New Zealand's international contribution

6.1 What role should New Zealand have internationally with respect to addressing agricultural emissions?

This is addressed first from the point of view of New Zealand's direct interests and then from a global perspective. It is assumed that New Zealand is contributing its 'fair-share' and that this is determined by politicians.

6.1.1 For a given level of effort, what would bring the most benefit to New Zealand?

Reisinger and Stroombergen (2012) show that New Zealand is likely to be better off if all countries address agricultural emissions than if none (including New Zealand) do. This is partly because New Zealand is an efficient producer of high-emission agricultural products but also because CO_2 prices would be lower if agricultural emissions are priced; New Zealand would benefit from that. This suggests it is in our interests to push for the inclusion of agricultural emissions as part of the package – without reducing efforts to reduce CO_2.

However Reisinger and Stroombergen also show that if others do not address agricultural emissions, New Zealand bears the costs of emission reductions and covering agricultural emissions in our target without the benefits of higher global livestock prices or lower CO_2 prices. Even after the Paris Agreement in December 2015 it seems that while many countries are including agricultural emissions within their intended Nationally Determined Contributions, none has a strong domestic policy to address them. Their planned mitigation actions are largely in other sectors. It is in our national interest to work out how to price and effectively mitigate agricultural emissions, and to encourage and help others do likewise.

Encouraging global efforts to halt deforestation and encourage afforestation and afforestation are not only directly valuable to the climate but also will reduce the damaging effects on carbon storage in forests of excessive food production while agricultural emissions are not effectively controlled. Reisinger and Stroombergen also suggest that international efforts to protect and enhance global forests will have more value for our agricultural sector by raising food prices, than efforts on agricultural emissions themselves.

The picture is slightly different from a farmer's point of view. Farmers do not benefit strongly from low CO_2 prices and they do benefit from low agricultural emission prices. If farmers face only 10% liability for their emissions, they prefer a scenario where all countries price agricultural emissions, but if they face 100% liability they may slightly prefer that agriculture is excluded from the international agreement (Dorner and Kerr 2015). What is clear is that at 100% liability, they will be strongly affected by the extent to which other countries price emissions. This would argue for some protection for farmers (either through lower prices or free allocation) during the possibly long phase where we price emissions and others do not.

In summary, both New Zealand and its farmers will benefit if other countries are assisted to reduce deforestation, increase afforestation and reduce their agricultural emissions – particularly if those efforts lead to higher costs of production that are passed into international livestock prices. To the extent that others' efforts on agricultural emissions are slow to develop, we need to manage the pressure we place on our own farmers, supporting an efficient transition but avoiding excessive adjustment costs.

6.1.2 For a given level of effort, how can New Zealand provide the most effective global contribution?

New Zealand's emission reductions are as valuable per unit to the climate system as those from any other country, so first and foremost we can reduce emissions where it is globally efficient for us to do so. Beyond this, we have choices in how we do that and where we focus our limited resources.

Effective cooperation to solve an environmental issue like climate change involves 3 Cs: it requires that we increase and sincerely express concern, build capacity to respond, and contract through regulation and law to make low-emission actions and investments work economically and to bring the laggards along with those who support cooperation. New Zealand can support each of these at an international level through our local actions.

To build cooperation it is critical that New Zealand is, and is seen to be, sincere in its efforts to reduce global emissions. New Zealand can choose any level of ambition independent of the form of international policy. Although INDCs have been pledged by most countries through 2025 or 2030, they will continue to be reviewed and updated for future periods. Two agricultural issues are likely to remain live in international discussion: whether countries should separate their targets for agricultural emissions from targets for other GHGs; and how short-lived gases such as CH_4 should be treated relative to long-lived gases. New Zealand can engage constructively on both issues.

First, New Zealand can discuss the best solution to these issues for all countries, not just for New Zealand. Second, when defining its ongoing Nationally Determined Contribution (NDC) New Zealand can make it conditional on a given treatment of the agriculture sector and short-lived gases and demonstrate its fairness and ambition on that basis. If we subsequently change how we treat agricultural gases (e.g. in response to changes in international convention), we can alter our NDC to achieve an equivalent or greater level of ambition. Separating these two discussions allows us to engage in an open discussion of how we treat agriculture without any perception that we are trying to choose an approach that is best for New Zealand rather than an approach that makes most sense for all countries.

If we set our NDC with a transparent model that allows the implications of different approaches to be easily compared, others may be more accepting of our need to adjust our NDC as approaches change and we may avoid any perception that our adjustment constitutes 'backsliding'. Our reputation for sincere and reasonably selfless collaboration and cooperation is critical both for New Zealand's interests and for our ability to influence global thinking on treatment of agriculture and beyond (e.g. internationally transferrable mitigation outcomes and land-sector accounting – both of which are critical issues for the cost-effectiveness of New Zealand's effort).

Under the bottom-up approach for NDCs under the Paris Agreement, we have the flexibility to optimise our domestic agricultural emissions policy without top-down constraints by focusing on N2O reductions with less pressure for immediate reductions in CH4 and by focusing efforts on our and others' ability to respond more strongly over a longer time frame. However, depending on how our future NDCs are structured, this may have implications for the mitigation responsibility expected of other sectors or covered by purchasing international units.

To reduce and ultimately eliminate net emissions of long-lived GHGs and significantly reduce shorter-lived gases, we need local research that allows us to apply international learning in our local context. Other countries won't do this. We may also have some specific areas of comparative research advantage that can help build global capacity.

New Zealand has already been a leader in thinking about how to address agricultural emissions and setting up research efforts such as the Global Research Alliance on Agricultural Greenhouse Gases to find solutions. Our unusual emissions profile (within the OECD), the research and policy capacity we have built up around this issue, our relatively unregulated and unsubsidised agricultural sector, and the innovative nature of our best farmers give us a strong base for further leadership. Others within the OECD are beginning to strengthen their research and policies on agricultural emissions but only a small amount of their work is transferrable to New Zealand because of differences in our agricultural systems and geophysical conditions. In some ways, our agriculture is more similar to that in regions like Latin America than to other OECD countries. They may be unlikely to generate strong lessons that we can benefit from in the short run, but they can learn from us.

Our most important contribution will be how we can set an example and help others to follow – others, especially in developing countries, have enormous potential for emission reductions within the agriculture sector. We can continue to drive research into new solutions that could be of significant global value. Developing new technologies, exploring different actions and policies within New Zealand and then evaluating them and sharing our experience with others could have an influence far greater than their direct effect on our local emissions.

What might this imply beyond developing effective mitigation actions and policies within New Zealand? Evaluating those efforts in credible ways and sharing the tangible and intangible knowledge we develop is one key aspect. Consistent sustained relationships with key countries to build trust and capability in individuals and institutions will effectively transfer knowledge.

Upscaling their capacity to reduce agricultural emissions alongside increasing productivity in their agricultural sectors can avoid any constraint on their development and even enhance it.

If New Zealand wanted to go beyond this and help to finance and possibly gain more explicit international credit for reducing agricultural emissions elsewhere we could develop bilateral or multilateral results-based contracts with one or more developing countries where we provide investment funding and technical support and have the opportunity to purchase emission reductions beyond an agreed baseline. As developing countries begin to implement their INDCs, they may have greater ability to commit to sectoral targets beyond which reductions are credibly additional. This type of agreement could both encourage and enable the countries to take real action and lead to a flow of environmentally credible units that could help New Zealand manage its own commitment. It would also help the global process of developing institutional arrangements to effectively accelerate the transition to low emissions in developing countries.

Effectively mitigating domestic agricultural GHG emissions will help New Zealand to achieve net emission reduction targets and produce economic benefits as well as environmental co-benefits. If, in addition, we can leverage our domestic knowledge and resources to help others reduce agricultural emissions, we would benefit as a nation from lower global emission prices. Helping others through some form of results-based agreement that generates credible emission reduction units which we can count toward our NDC would be a further advantage. Farmers might face lower livestock (and other food) prices if we help others produce with lower emissions, but society as a whole benefits. If we can accelerate progress on protecting forests and promoting reforestation we will benefit not only through lower emission prices but also through higher livestock and other food prices.

If New Zealand can be seen to be making a genuine effort to address the global challenges around agricultural emissions rather than serving only our local interests, we will get international recognition (for example our existing efforts may have contributed to our 2015–16 seat on the United Nations Security Council and an invitation to address the G20), greater international understanding of our domestic mitigation potential and ambition, and possibly even improved market access for our increasingly low-emission products.

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Appendix one: Notes and further ideas from the Low Emissions Future dialogue group

Research need: the ability to identify efficiency of food production at a global level

Develop a methodology to achieve international agreement on GHG measurement on farms and a tool to compare GHG efficiency across countries and farm systems (comparing apples with apples – and cows with chickens).

Consumer education

Supermarket receipts could tell consumers the emissions and the nutritional content of their food basket. This would require a standardised measures of average (too much detail on emissions foot prints of specific product varieties has proven to be excessively complex and expensive to produce and keep updated) emissions per product, and a standard measure of nutrition content for each product. These could be provided by government for each product code. The register would then simply match purchases to the information and print the result. A similar initiative is already being run by the Wellington Public Library, which tells readers how much money they are saving by borrowing the book from the library rather than purchasing it.

Appendix two: Notes and further ideas from the Agricultural Dialogue discussion group

Participants in the AgDialogue group stressed that it is important to remember that global climate change is everyone's problem to solve, and everyone has a part in the solution. We need to avoid falling into the trap of assuming that agricultural emissions are a problem only for government to regulate. We need to recognise this is a problem about multiple actors, and multiple types of action, coordinating to meet shared goals. (Dorner and Kerr, 2013, based on AgDialogue)

Improved interface for OVERSEER. AgDialogue discussion groups note that an important tool for farm management in New Zealand is the computer programme OVERSEER, which has been developed by government-funded institutions to model nutrient flows and GHG emissions of farms (www.overseer.org.nz). By improving OVERSEER's interface, farmers could be encouraged to use it more frequently when making decisions about their farm. It can also be used to test different farm management plans when farmers are deciding what approach to take next. If OVERSEER was made open source, then the interface could be developed by anyone with the appropriate skills. OVERSEER could be further improved by allowing farmers to easily download information about their own farm kept by other organisations, such as fertiliser companies, spreading companies and the national animal register (NAIT). This would avoid a farmer having to enter this data themselves. Furthermore, some of the outputs of OVERSEER (such as GHG emissions) could be uploaded to a central database if farmers wish, allowing each farmer to compare their GHG emissions to national and local averages, with the aim of encouraging farmers to make GHG efficiency improvements. The increased data would help farmers discuss amongst their peers, in formal or informal ways, practices that work for them to improve outcomes such as GHG intensity.

Farmer awards. The AgDialogue discussion group noted that awards such as the Ballance Farm Environment Awards could explicitly highlight the lower GHG levels or emissions intensity on the excellent New Zealand farms they recognise.

Incorporate climate change into the farming (and other) curricula: AgDialogue participants suggest there are many ways to introduce units on climate change mitigation within agricultural qualifications. It is also important to insert climate change mitigation into the general curriculum much earlier, at secondary or even primary level.

Sustainable cooking TV competition: In popular culture, cooking good food is becoming increasingly popular as a recreational activity, as evidenced by the large amount of cooking shows on television. This prototype would tap into the desire of many to get back in touch with where food comes from, and its environmental impact. The prototype proposes the use of the competition format of cooking shows to educate consumers about the environmental aspect of their food consumption. This could include on-farm segments and an environmental component to the judging of dishes.

Proactive banking. Given that there are tens of billions of dollars worth of loans to farms in New Zealand, banks play an important role in how farms operate around New Zealand. This prototype was discussed at length during AgDialogue. Although on the whole banks have brought at least some aspect of sustainability into their businesses, the discussion group believed much more could be done. This is important for banks, given the increasing level of environmental regulation affecting farms and therefore affecting banks' investments. An example of this is ensuring basic environmental good practice on a farm before approving a loan. An even more proactive approach could see banks lending increasingly for on-farm capital investments which lessen a farm's environmental impact, and perhaps even discounted interest rates for that type of investment.

Kapa Haka competition: Kapa Haka is a type of traditional Maori performing art. The idea behind this prototype is to make climate change the theme of an annual Kapa Haka competition, to help inspire and deepen the knowledge of young Maori, and to encourage them to think creatively about the problem in a culturally relevant way.

Educational farming game: Inspired by computer games such as the popular Facebook game Farmville, and educational websites like Mathletics (www.mathletics.co.nz), this prototype aims to create a fun and educational resource for primary and secondary students. A particular issue that came out of the AgDialogue was the perceived urban/rural divide in New Zealand (the rural point of view being that urban people do not know much about the realities of farming). By having an innovative programme to help urban kids learn more about farming and the challenges of mitigating environmental issues in agriculture, knowledge would be built within the important group of urban consumers.

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