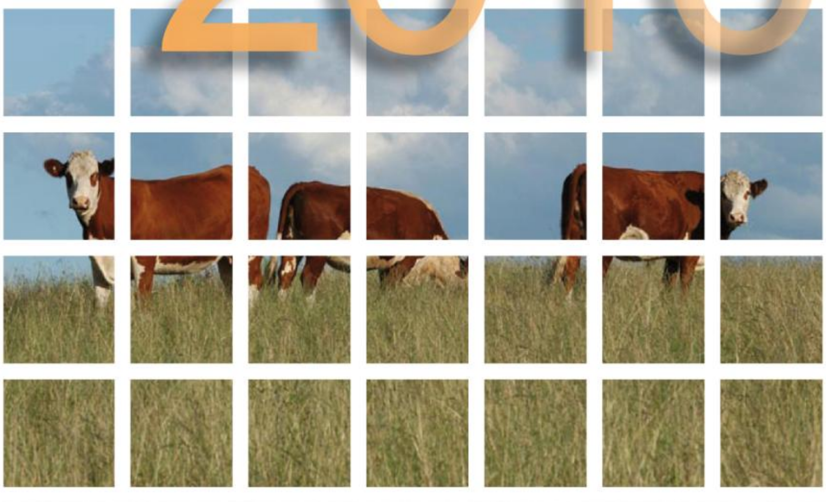
Australian Government

Department of Climate Change and Energy Efficiency

Agriculture

emissions projections

2010



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Executive Summary

Key Points

- In 2009 agriculture emissions represented 15 per cent of Australia's total greenhouse gas emissions, and at 86 Mt CO_2-e were 0.7 per cent below 1990 emissions of 87 Mt CO_2-e.
- Average emissions during the Kyoto period are projected to be 86 Mt CO_2-e, 0.4 per cent below the 1990 level. By 2020 emissions are projected to have grown to 94 Mt CO_2-e. Although this represents a net increase over the 1990 level of emissions, when compared with the agriculture emissions in 2000 it represents a drop of 0.2 Mt CO_2-e.
- Prolonged drought over extensive areas of Australia over the past decade led to a decline in animal populations and diminished crop yields, especially over the period 2006-2009. The breaking of the drought in southern and eastern Australia in 2010 means the projection for the next decade is for strong growth in agricultural emissions, with re-stocking of the Australian livestock herd and recovery of cropping activities.
- Livestock emissions account for 70 per cent of agriculture emissions, with a projected Kyoto period average of 61 Mt CO_2-e. By 2020 livestock emissions are projected to reach 67 Mt CO_2-e.
- By 2030 indicative projections suggest agriculture emissions will reach 104 Mt CO_2-e.

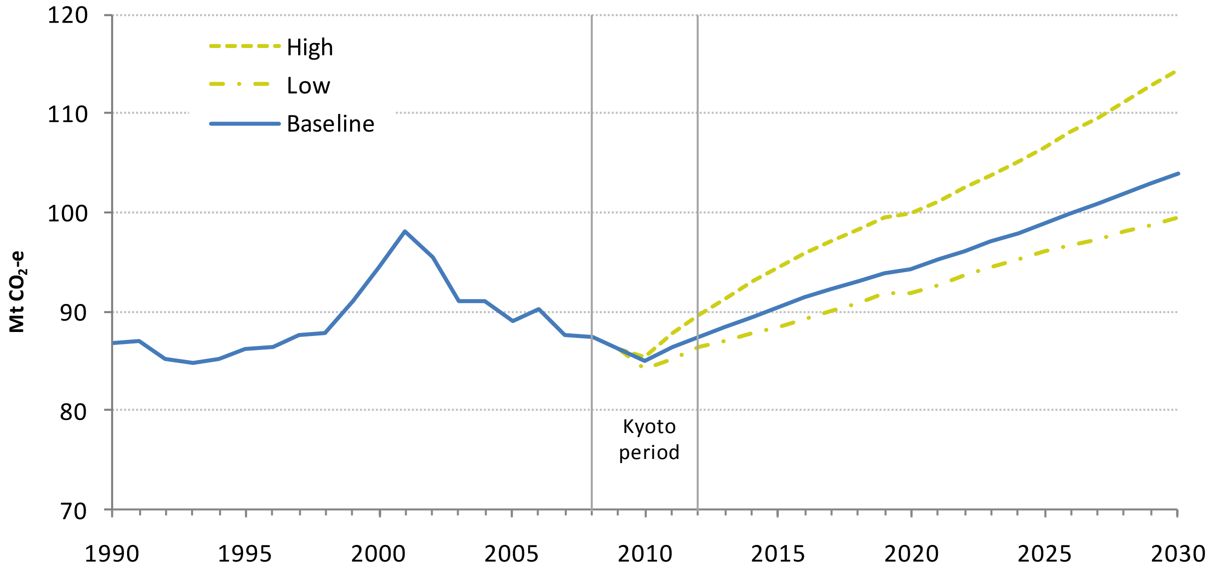
Baseline projection

- The agriculture baseline projection is based on modelling Australian agricultural commodities, including export markets, competition by rivals and the global economy. This is translated into Australian agricultural activity and consequent emissions.
- Average emissions during the Kyoto period are projected to be 86 Mt CO_2-e, 0.4 per cent below the 1990 level. By 2020 emissions are projected to have grown to 94 Mt CO_2-e. Although this represents a net increase over the 1990 level of emissions, when compared with the agriculture emissions in 2000 it represents a drop of 0.2 Mt CO_2-e.
- The dominant source of emissions from the agriculture sector is enteric fermentation from livestock, representing 64 per cent of all agriculture emissions. As well as being the largest subsector, it is also projected to contribute the most to emissions growth. In 2020 emissions from enteric fermentation are estimated to reach 61 Mt CO_2-e, up from

55 Mt CO_2-e in 2009.[1] This growth in emissions is due to post-drought recovery in livestock herds and flock sizes, mainly from grazing beef.

- Emissions from agricultural soils are projected to grow 1.9 Mt CO_2-e from 2009, reaching 16 Mt CO_2-e in 2020. These emissions are linked to the recovery in livestock numbers and to growth in cropping activities.
- Agriculture emissions are projected to reach 104 Mt CO_2-e in 2030.

Figure 1 Baseline agriculture emissions, 1990 to 2030



Source: CIE (2010), ABARES (2010), DCCEE analysis.

Table 1 Baseline agriculture emissions, Kyoto period average and 2020

	1990	2000	Kyoto period average 2008-12		2020	
	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Increase on 1990 (%)	Mt CO_2-e	Increase on 2000 (%)
Enteric fermentation	64	60	56	-13	61	1.3
Manure management	2	3	3	60	4	13
Rice cultivation	0.5	0.7	0.2	-62	0.4	-42
Agricultural soils	13	16	15	9	16	-0.5
Prescribed burning of savannahs	7	13	12	88	12	-8
Field burning of agricultural residues	0.3	0.4	0.3	17	0.5	14
Total	**87**	**94**	**86**	**-0.4**	**94**	**-0.2**

Source: CIE (2010), ABARES (2010), DCCEE analysis. Numbers may not add due to rounding.

[1] All years in this publication are Australian financial years, ending on the 30 June of the year quoted.

Impact of measures

- There are currently no significant abatement measures in the agriculture sector.
- The Government has committed to implement the Carbon Farming Initiative (CFI), which provides a mechanism for crediting abatement that occurs in the land sector. It is expected to provide incentives for activities to reduce emissions from agriculture.
- The Government has announced that methodologies for some agriculture sources could be developed, assessed and approved by December 2011, with methodologies for other sources to follow. Future projections updates for agriculture will take into account progress in development of methodologies and project activity in response to the Carbon Farming Initiative.
- The Carbon Farming Initiative allows proponents to export credits to international markets. If proponents choose to do this, the abatement achieved would not be counted towards Australia's emissions reduction targets.
- Previous projections included abatement measures such as reduction in fertiliser application, reduced burning of crop residues, and improved manure management systems in pig feedlots. These actions have led to some small reductions in emissions from the agriculture sector. These actions are now regarded as within business-as-usual (BAU) practices.

Changes from 2009 projection

- Previous projections released in 2009, in Australia's Fifth National Communication on Climate Change to the UNFCCC, assumed a return to normal conditions and positive growth in emissions from 2009.

Table 2 Changes to 2010 projection from the 2009 projection

	Kyoto period average 2008-12	**2020**
	Mt CO_2-e	Mt CO_2-e
Enteric fermentation	-1.5	-2.4
Manure management	-0.1	0.1
Rice cultivation	-0.0	-0.0
Agricultural soils	-0.3	-0.2
Prescribed burning of savannahs	-1.1	-0.3
Field burning of agricultural residues	-0.0	0.1
Total	**-3.0**	**-2.8**

Source: CIE (2010), ABARES (2010), DCCEE analysis. Numbers may not add due to rounding.

- As a result of the extended drought, herd and flock populations are now lower than anticipated in the previous projection, which means that restocking begins from a lower base.
- Herd restocking is also estimated to be slower than in the previous projection, due to reduced global demand due to the Global Financial Crisis (GFC). This is projected to lead to reduced livestock enteric fermentation emissions for both the Kyoto period and 2020. Reduced livestock numbers also lead to reduced agricultural soils emissions, due to reduced animal waste fertiliser use.
- Some livestock populations are also expected to be diminished post-recovery for other reasons: the sheep flock is expected to be 21 per cent smaller in 2020 than predicted by the 2009 forecast, due to a stronger emphasis on meat commodities such as lamb instead of wool.

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Introduction

To produce the agriculture emission projections, the Department of Climate Change and Energy Efficiency (DCCEE) commissioned two sets of independent activity and emissions forecasts: one from a private-sector organisation, the Centre for International Economics (CIE), and the other from the Australian Government's commodity forecaster, ABARES. The forecasts were calibrated to the June Quarter 2010 National Greenhouse Gas Inventory (NGGI) data. These forecasts were used by DCCEE to derive a composite projection for Australian agricultural activity and emissions for the period 2009-2030.

Multiple scenarios were projected, enabling the sensitivity of projections to key assumptions to be examined. As outlined in Table 3, the scenarios examined were business-as-usual (BAU), baseline, and multiple high and low sensitivity scenarios to examine the impact of variations on assumptions such as an extended drought, different slaughtering weights, changes in productivity and shifts in global demand and pricing.

Table 3 Projections scenarios

Scenario	Description
Business-as-usual (BAU)	Emissions in the absence of Government abatement policies and measures
Baseline	Emissions given current policy settings
High/ low	Sensitivity scenarios around the baseline – determined by modifying key assumptions such as economic growth rates

Base level emissions for 2009 have been taken from the NGGI. As not all the NGGI methodologies for estimating agriculture emissions are suitable for projection into future years, emissions from some agriculture subsectors are projected using simplified methodologies calibrated to the NGGI data.

The basic methodology for calculating projections of emissions from the agriculture sector involves multiplying estimates of agricultural activity levels (such as livestock numbers and area of crops sown) by emission factors. Agricultural models are used to project estimates of activity levels and the emission factors are drawn from the latest NGGI.

Savannah burning is the exception to this. Projections for savannah burning are not formally modelled but are calculated by taking a long term average of past emissions, due to the inherent lack of predictability of future rainfall patterns.

In accordance with the IPCC (1997, vol.1) guidelines, emissions are reported as three-year averages where possible (i.e. the reported emissions for 1990 are the average for those for 1989, 1990 and 1991). Annual livestock emissions are calculated before determining a three-year moving average, whereas annual cropping activities (e.g. hectares of crops grown) have their moving average calculated over three years before emissions are determined.

Throughout this report the composite projection is shown and contrasted with the 2009 agriculture projection, to examine changes in prevailing national and international conditions and their impacts on emissions in this sector.

These projections have been developed on the basis of current policies in place regarding carbon pricing both in Australia and internationally. They illustrate expectations of Australia's agriculture emissions in the absence of a carbon price.

The Australian Government has reiterated its intention to introduce a carbon price in Australia to reduce emissions and meet its 2020 targets. These projections assume current levels of global policy action on climate change. Consistent with the domestic policy assumptions, they do not include additional global action, such as actions to implement all of the Copenhagen Accord pledges.

Coverage of the sector

In 2009 agriculture sector emissions represented 15 per cent of Australia's total greenhouse gas emissions, and at 86 Mt CO_2-e were 0.7 per cent below 1990 emissions of 87 Mt CO_2-e.

The agriculture sector comprises emissions from livestock and cropping, plus savannah burning. Livestock emissions arise from enteric fermentation (anaerobic digestion of plant matter), manure management and feedlot animal waste as fertiliser in agricultural soil. In 2009 livestock emissions amounted to 59 Mt CO_2-e, or 70 per cent of total agriculture emissions. The largest component of livestock emissions was cattle, at 78 per cent, while sheep accounted for a further 19 per cent, with the remainder divided among swine, poultry and other livestock. Cropping accounted for 16 per cent of agriculture emissions, and included rice cultivation, field burning of agricultural residues and nitrogen emissions from synthetic fertilisers applied to fields.

Recent trends – National Greenhouse Gas Inventory

The recent drought is the dominant factor in recent agriculture emission trends, causing a substantial fall in emissions. All subsector emissions fell throughout the drought. Within these subsectors a range of other factors have contributed to trends since 1990, including changes in the global economy. From 2002 to 2009, prolonged drought conditions over extensive areas of southern and eastern Australia led to a decline in animal populations, causing a decline in enteric fermentation, dropping 5 Mt CO_2-e (9 per cent) from its 2001 peak of 61 Mt CO_2-e.

The effects of the drought can be seen by examining agriculture sector emissions without savannah burning. Excluding savannah burning, emissions from agriculture increased by 3 per cent (2 Mt CO_2-e) between 1990 and 2001 but declined by 11 per cent (9 Mt CO_2-e) between 2001 and 2009.

Livestock enteric fermentation emissions declined by 13 per cent (9 Mt CO_2-e) between 1990 and 2009. In the early 1990s emissions declined due to a fall in sheep numbers. However, by the late 1990s enteric fermentation emissions began to rise as numbers of beef cattle increased, reflecting shifts in commercial returns in these industries.

Manure management emissions increased from 1990 to 2007, by 69 per cent (1.4 Mt CO_2-e), due to strong growth in the intensive feedlot cattle industry. Between 2007 and 2009 a decline in emissions of 5 per cent (0.2 Mt CO_2-e) occurred, reflecting a decline in populations of dairy and feedlot cattle and pigs.

As all rice cultivation in Australia is flood-irrigated, this industry was severely affected by the recent drought. Emissions from rice cultivation in 2009 were 0.4 Mt CO_2-e lower (90 per cent) than in 1990 and 0.1 Mt CO_2-e lower (76 per cent) than in 2007.

Agricultural soils emissions increased by 10 per cent (1.4 Mt CO_2-e) between 1990 and 2007, but have declined between 2007 and 2009 by 3 per cent (0.4 Mt CO_2-e). The increases had been driven by shifts in agricultural activity: there had been a significant increase in the use of synthetic fertilisers, while the sugar cane industry's shift towards green cane harvesting had led to increased retention of crop residues. At the same time the amount of animal wastes applied to soils as fertiliser had increased due to the growth in intensive livestock industries. However as crop production, animal populations and fertiliser use all fell during the recent drought, emissions have declined since 2007.

Emissions from field burning of agricultural residues declined by 7 per cent (0.02 Mt CO_2-e) between 1990 and 2009.

Savannah burning increased by 92 per cent (6 Mt CO_2-e) between 1990 and 2009.

Projections results

Emissions from the agriculture sector are projected to average 86 Mt CO_2-e per year over the Kyoto period, which is a 0.4 per cent decrease on the 1990 level (Tables 4 and 5 and Figure 2).

Table 4 Baseline agriculture emissions, Kyoto period average and 2020

	1990	2000	Kyoto period average 2008-12		2020	
	Mt CO_2-e	Mt CO_2-e	Mt CO_2-e	Increase on 1990 (%)	Mt CO_2-e	Increase on 2000 (%)
Enteric fermentation	64	60	56	-13	61	1.3
Manure management	2.1	3.3	3.3	60	3.7	13
Rice cultivation	0.5	0.7	0.2	-62	0.4	-42
Agricultural soils	13	16	15	8.9	16	-0.5
Prescribed burning of savannahs	6.6	13	12	88	12	-8
Field burning of agricultural residues	0.3	0.4	0.3	17	0.5	14
Total	**87**	**94**	**86**	**-0.4**	**94**	**-0.2**

Source: CIE (2010), ABARES (2010), DCCEE analysis. Numbers may not add due to rounding.

By 2020 emissions are projected to have grown to 94 Mt CO_2-e. Although this represents a net increase over the 1990 level of emissions, when compared with the agriculture emissions in 2000 it represents a drop of 0.2 Mt CO_2-e.

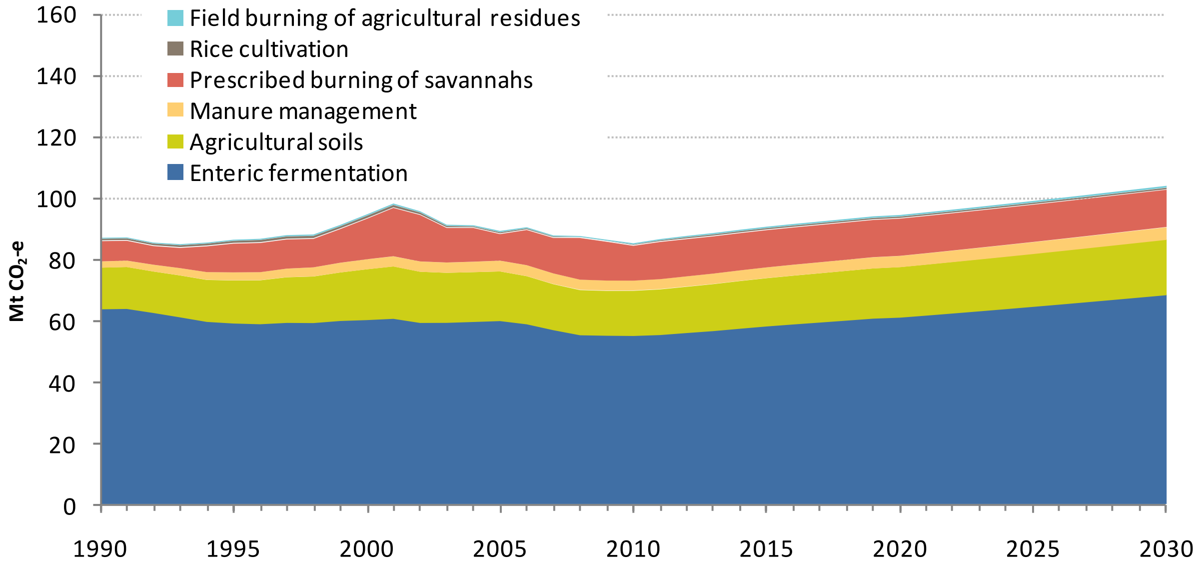
By 2030 indicative projections suggest agriculture emissions will reach 104 Mt CO_2-e.

Table 5 Agriculture emissions, 1990 to 2030, Mt CO_2-e

	1990	2009	KPA	2020	2030
Enteric fermentation	64	55	56	61	68
Manure management	2.1	3.3	3.3	3.7	4.1
Rice cultivation	0.5	0.0	0.2	0.4	0.5
Agricultural soils	13	14	15	16	18
Prescribed burning of savannahs	6.6	13	12	12	12
Field burning of agricultural residues	0.3	0.3	0.3	0.5	0.6
Total	**87**	**86**	**86**	**94**	**104**

Source: CIE (2010), ABARES (2010), DCCEE analysis. Numbers may not add due to rounding.

Figure 2 Baseline agriculture emissions trends, 1990 to 2030



Source: CIE (2010), ABARES (2010), DCCEE analysis.

Trends in the agriculture projections

Water availability and global demand for Australian livestock commodities are the key elements in projecting agriculture activity and emissions in Australia. Following the breaking of the drought in 2010 in eastern Australia, animal flocks and herds are expected to halt their decline, with Australia's sheep flocks and cattle herds projected to grow gradually in subsequent years, rebuilding after recent lows. Analogous growth is projected in cropping activities, leading to a growth in emissions from 2010 to 2020 across all subsectors other than savannah burning.

In the 2010 projection, this post-drought restocking of livestock numbers and growth in cropping activity are now expected to follow a path lower and slower than that envisaged in the previous projection.

The main reasons for this are reduced livestock numbers, and reduced global demand for Australian agricultural products as a result of the global financial crisis (GFC), which has caused the International Monetary Fund (IMF) to predict lower income growth internationally.

Although climate change is expected to cause future changes in rainfall and climate patterns, with consequences for agricultural productivity, these agriculture projections do not address such changes and instead extrapolate future agricultural activity and emissions based on long-run historical rainfall and climate patterns.

Main drivers of agriculture emissions

The populations of livestock herds and flocks are the key drivers of agricultural emissions. As can be seen in Figure 2, direct emissions from livestock (enteric fermentation and manure management) dominate the sector. Some indirect emissions also arise from livestock; for example, animal waste is a form of fertiliser leading to emissions from agricultural soils.

Assuming adequate carrying capacity on the land, i.e. adequate supplies of water and feed, future livestock populations are projected based on forecasts of commodity prices, as a result of domestic and export markets. Commodity production from livestock is a combination of the number of head of livestock and productivity per beast: for example, global demand for Australian dairy products in 2020 is combined with expected milk productivity per beast of the Australian dairy herd in 2020 to generate a likely estimate of the size of the herd at that time. Productivity trends per beast are extrapolated from historical data and an assessment made whether these trends might saturate to a maximum value: for example, whether historical trends upwards in slaughtering weights of beef and veal reach a foreseeable final value.

Measures estimates

There are currently no significant abatement measures in the agriculture sector, so the baseline represents business-as-usual practices.

The Government has recently committed to implement the Carbon Farming Initiative (CFI) which will provide incentives for activities to reduce emissions from agriculture, by crediting land sector offsets.

The Government expects that methodologies for some agriculture sources could be developed, assessed and approved by December 2011, with further development and approval of methodologies for other sources to follow. Future projections updates for agriculture will take into account progress in development of methodologies and any initial indications of project activity in response to the Carbon Farming Initiative.

The Carbon Farming Initiative allows proponents to export credits to international markets. If proponents choose to do this, the abatement achieved would not be counted towards Australia's emissions reduction targets.

In previous projections, abatement measures, such as reductions in fertiliser application, reduced burning of crop residues and improved manure management systems in pig feedlots, were included. These activities have led to some small reductions in emissions in the agriculture sector. However, following review these are now regarded as within business-as-usual practices.

Changes from the previous projection

The current projection forecasts emissions in the Kyoto period to be 86 Mt CO_2-e, which is 3 Mt CO_2-e below the 2009 projection. In 2020 the current projection is for emissions to be 94 Mt CO_2-e, again 3 Mt CO_2-e below the 2009 projection. These reductions are due to structural differences in assumptions, as the agriculture sector recovers from drought: a lower population base for livestock and reduced growth in global demand. This is discussed in more detail in Appendix A.

Table 6 shows the sectoral decomposition of the differences between the two projections.

Table 6 Changes between the 2009 and 2010 projections

	Kyoto period average 2008-12	**2020**
	Mt CO_2-e	Mt CO_2-e
Enteric fermentation	-1.5	-2.4
Manure management	-0.1	0.1
Rice cultivation	-0.0	-0.0
Agricultural soils	-0.3	-0.2
Prescribed burning of savannahs	-1.1	-0.3
Field burning of agricultural residues	-0.0	0.1
Total	**-3.0**	**-2.8**

Source: CIE (2010), ABARES (2010), DCCEE analysis. Numbers may not add due to rounding.

Livestock: enteric fermentation and manure management

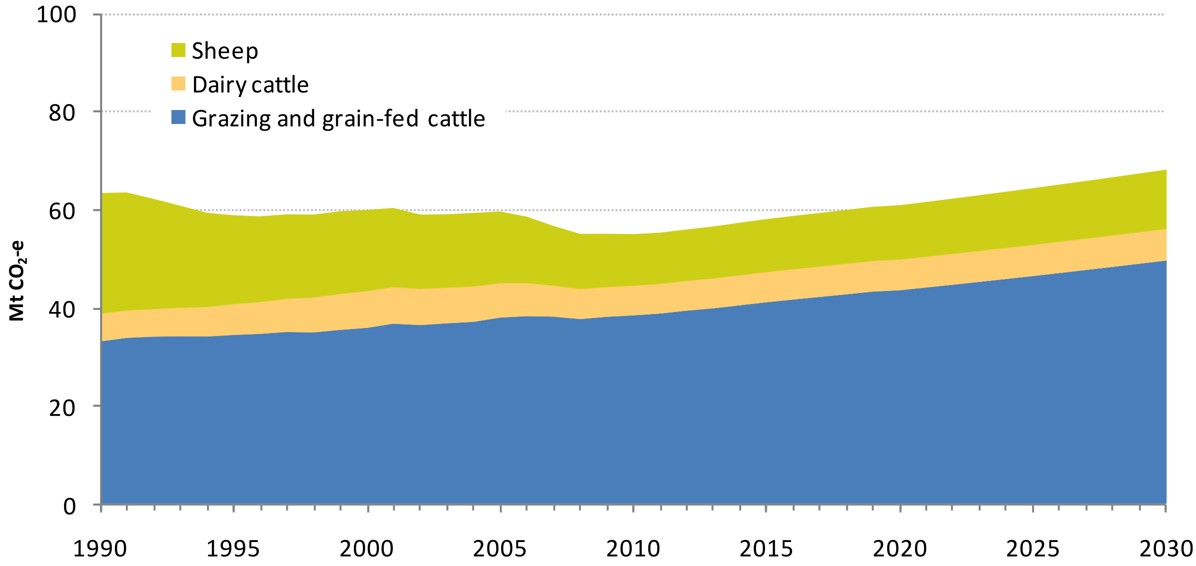
Enteric fermentation (Figure 3) and manure management emissions (Figure 4) are driven by the meat and dairy industries. Emissions in both of these subsectors are proportional to populations of livestock, and so are projected to increase as herds are restocked.

Enteric fermentation emissions arise from the digestive process in livestock, in which plant material consumed by an animal is broken down by bacteria in the gut under anaerobic conditions. A portion of the plant material is fermented in the rumen to simple fatty acids, CO_2 and CH_4. The fatty acids are absorbed into the bloodstream and the gases are vented by eructation and exhalation by the animal. Emissions from enteric fermentation vary by season and depend on the type, age and sex of the animal, and the type and amount of feed.

Figure 3 shows that in 2009 sheep provided 20 per cent of enteric fermentation emissions, with the remaining 80 per cent almost entirely from cattle (66 per cent grazing beef, 11 per cent dairy, 3 per cent grain-fed beef). A tiny proportion, 0.1 per cent, came from swine.

Similar proportions are expected in 2020, with sheep providing just over 18 per cent of enteric fermentation emissions and cattle almost 82 per cent, with the almost 2 per cent shift taken up by grazing beef cattle.

Figure 3 Enteric fermentation emissions by livestock, 1990 to 2030

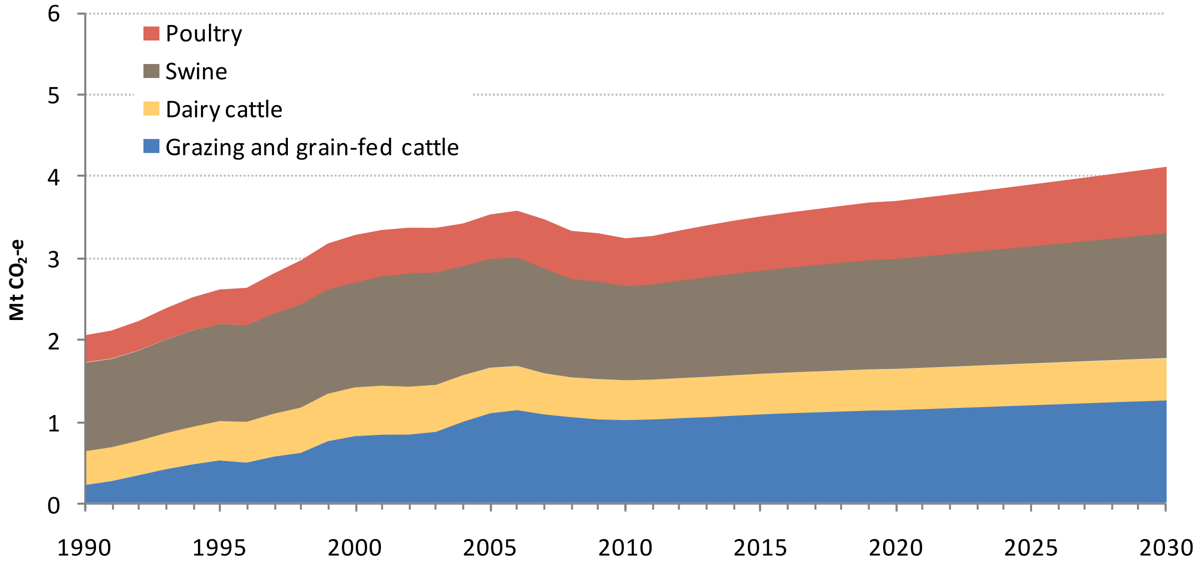


Source: CIE (2010), ABARES (2010), DCCEE analysis.

Manure management refers to emissions arising from the manure of dairy cattle, feedlot cattle, pigs and poultry. When large numbers of animals are managed in a confined space, manure is typically stored in large piles or lagoons. Methane is produced from the decomposition of organic matter remaining in the manure under anaerobic conditions. Nitrogen contained in the wastes can undergo a chemical process leading to nitrous oxide emissions. Range-kept livestock (e.g. grazing beef cattle, sheep, goats etc.) generate negligible manure-associated methane, due to the generally high temperatures, high solar radiation and low humidity environments of Australia, combined with the prevalence of scarab (dung) beetles.

Figure 4 shows that in 2009 swine contributed 36 per cent to manure management emissions, poultry 18 per cent, while cattle contributed 46 per cent (grain-fed beef 30 per cent, dairy 15 per cent and grazing beef 1 per cent).

Figure 4 Manure management emissions, 1990 to 2030



Source: CIE (2010), ABARES (2010), DCCEE analysis.

Similar proportions are expected in 2020, with cattle down almost 2 per cent due to a reduction in dairy manure, this amount being taken up by increases from poultry and swine.

Table 7 Livestock-related emissions by category, Mt CO_2-e

	1990	2009	KPA	2020	2030
Enteric fermentation	63.9	55.4	55.6	61.2	68.5
Manure management	2.1	3.3	3.3	3.7	4.1
Total	**66.0**	**58.7**	**58.9**	**64.9**	**72.6**

CIE and ABARES forecasts calibrated to NGGI. Composites are average of the two modellers. Numbers may not add due to rounding.

Projected livestock numbers

Table 8 shows the projected trends in national flock and herd sizes from 1990 to 2030 (Figures 5 to 10). Livestock numbers are important because they determine emissions from enteric fermentation, manure management and contribute to agricultural soil emissions.

For the meat industry, assuming rainfall or available feed enable adequate carrying capacity, trends in flock or herd size are determined by

- the growth in demand for meat products, and
- the average weight of the animal concerned.

For a specified growth in demand, the number of animals required to fulfil demand depends on the projected growth in the weight of the animals.

Table 8 Projected livestock activity (million head), 1990 to 2030

Animal	1990	2010	2020	2030
Sheep	173.7	70.7	74.9	81.8
Dairy cattle	2.6	2.5	2.6	2.7
Grazing beef cattle	22.1	23.6	27.2	31.0
Grain-fed cattle	0.2	1.1	1.2	1.4
Swine	2.7	2.2	2.6	3.0
Poultry	59.0	89.5	111.0	127.3

Source: CIE (2010), ABARES (2010), DCCEE analysis. Numbers may not add due to rounding.

Demand for Australian meat products is determined by:

- supply conditions and productivity growth in Australia, which determine how the Australian industry can respond to increases in demand and/or competitively displace other rival sources of supply;
- supply conditions and productivity growth in countries competing with Australia in the export markets; and
- growth in incomes and population in consuming countries. For a fixed level of per capita consumption, population growth translates into an increase in total consumption, whereas income growth (i.e. increasing affluence) tends to translate into increases in per capita consumption.

Similar assumptions are made regarding dairy and wool commodities, where trends in flock or herd size are determined by

- the growth in demand for products, and
- the average productivity per animal (e.g. volume of milk per cow per year).

The 2010 agriculture projection makes two key assessments that underpin its forecast of projected growth in livestock emissions:

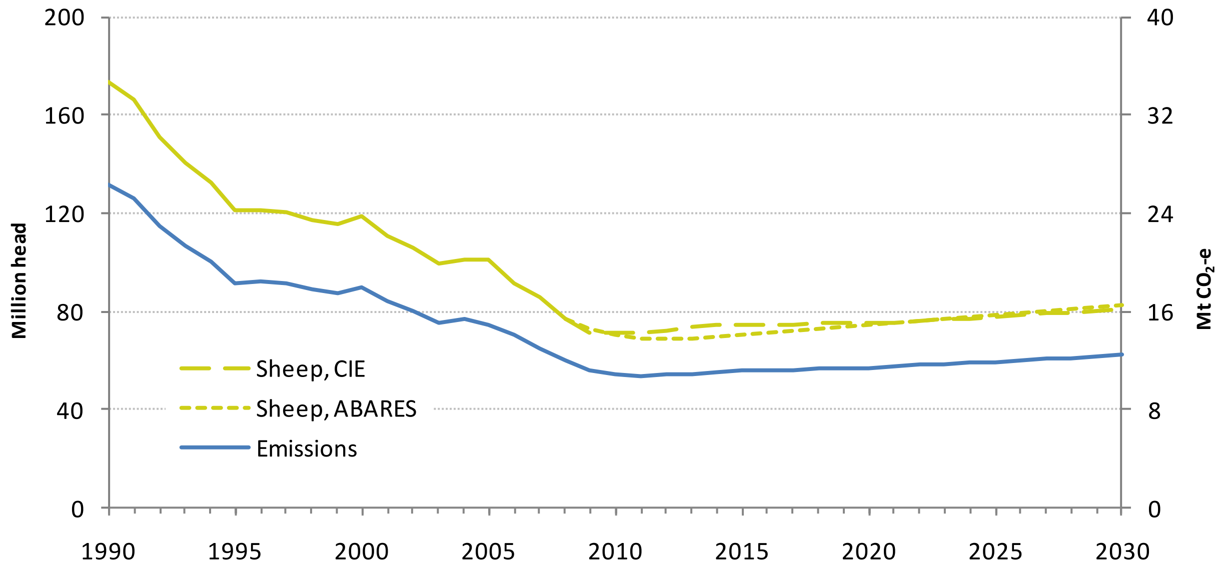
1. Income and population growth in Australia's key current and emerging export markets are assumed to be quite strong, leading to increasing demand for a range of Australia's livestock products, and

2. The scope for ongoing productivity growth in Australia is assumed to be positive, compared with key competitors.

Sheep

As shown in Figure 5, the size of Australia's sheep flock is expected to stabilise post-drought and grow gradually, although remaining well below historical levels. The outlook for the short-term growth rate and size of the flock is more pessimistic than in the previous forecast, due to the shift in value among sheep-related commodities and hence slaughtering decisions within the flock (e.g. wool versus lamb meat). In 2020 the national flock is expected to be at 79 per cent of the population envisaged in the 2009 projection.

Figure 5 Sheep projected activity and emissions



Source: CIE (2010), ABARES (2010), DCCEE analysis.

CIE models the stock of ewes as depending on supply elasticities and the relative prices of the commodities of lamb, mutton, wool and live sheep. For a given stock of ewes, producers then choose between four outputs on the basis of relative prices. Consequently CIE projects lamb meat and live sheep exports as increasing in scale 2009-2030, while mutton is projected to decline. Including the reduced profitability of wool compared with sheep meat (remarked on by both sets of modellers), this indicates a much more modestly-sized national flock than in 1990.

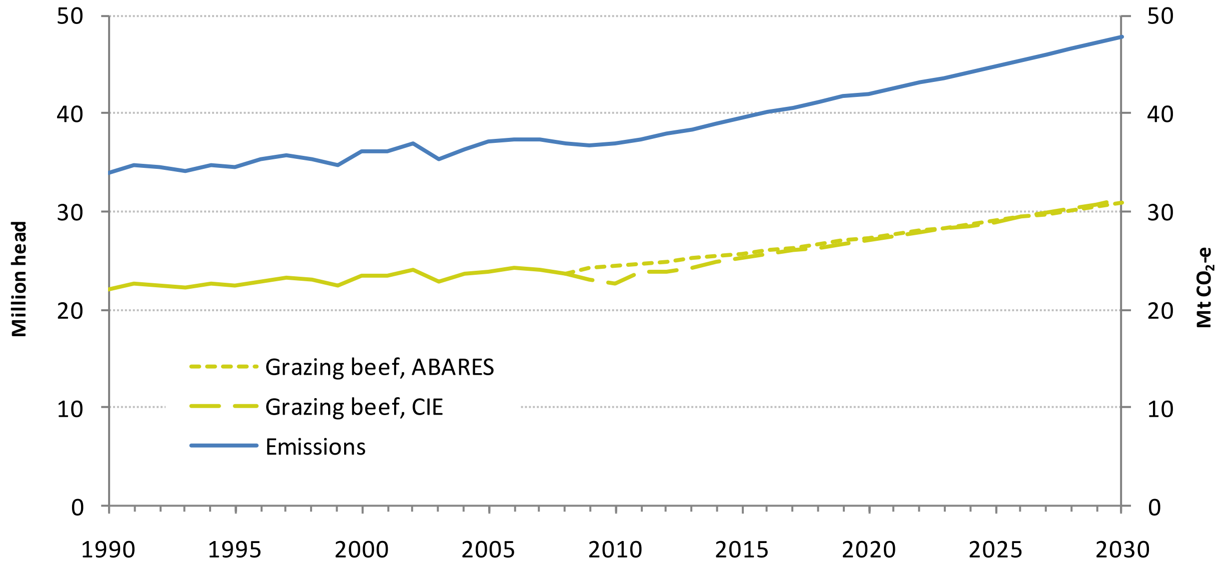
ABARES uses a difference balance between livestock retention for breeding for flock growth and slaughter rates for sheep and lamb meat commodities, forecasting more sluggish short-term growth in the national flock and a slightly higher long-term growth rate than CIE.

Grazing beef

The recent decline in herd size for grazing beef is expected to cease, with the national herd stabilising post-drought and restocking relatively rapidly.

As shown in Figure 6, CIE suggests a longer drought-related slide in Australia's grazing beef herd numbers than does ABARES, although both modelling forecasts remain positive regarding longer growth trends. Both modellers flagged significant structural changes to export markets, with long-term declines in the proportion of grass-fed beef exported to US and Japanese markets and increased market demand from other Asian countries and Europe.

Figure 6 Grazing beef projected activity and emissions

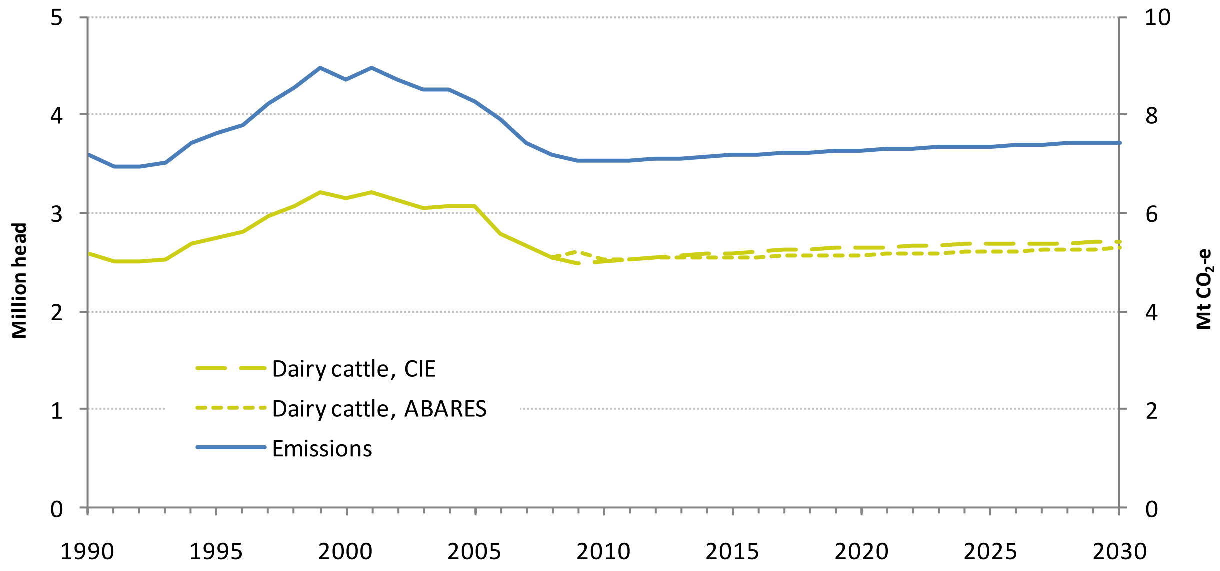


Source: CIE (2010), ABARES (2010), DCCEE analysis.

Dairy cattle

Although recent declines in the national dairy herd are expected to level out (as shown in Figure 7), herd growth estimates are more conservative than in the previous projection.

Figure 7 Dairy cattle projected herd growth and emissions



Source: CIE (2010), ABARES (2010), DCCEE analysis.

Estimating post-drought herd growth relies on productivity assumptions: determining the maximum milk production achievable under favourable conditions per cow dictates the extent the dairy herd needs to increase to fulfil demand. Trends of milk production per cow from 1961 and ratios of cows to dairy cattle numbers since 1988 were used to inform these assumptions.

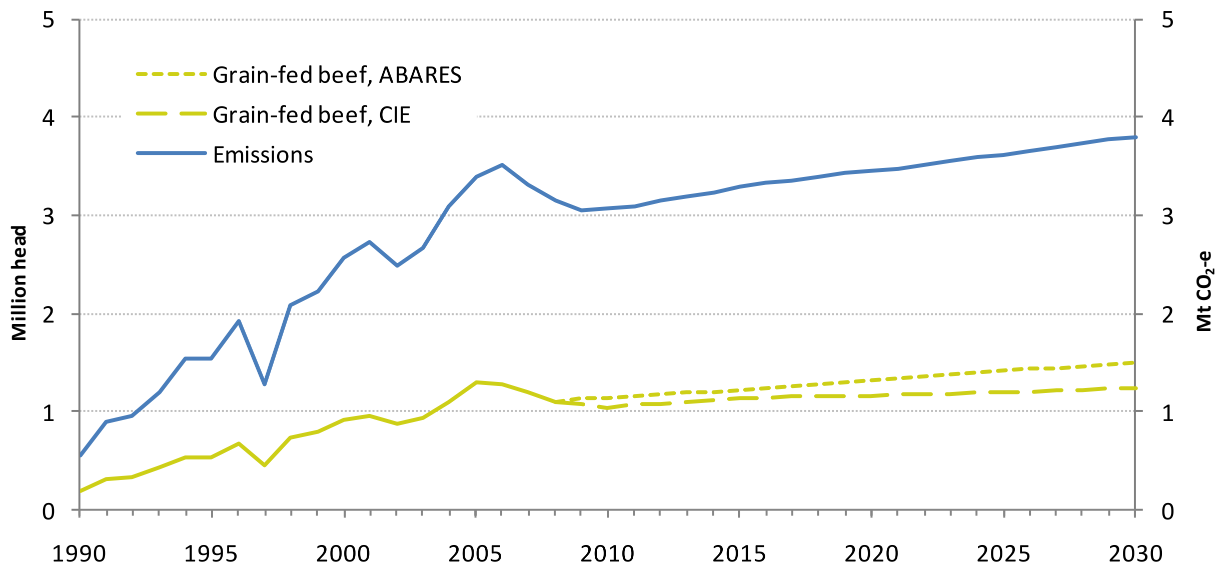
In CIE's forecast, milk production per cow is expected to undergo post-drought recovery, returning to the trend of milk productivity growth per cow that has been prevalent in Australia for the last fifty years. ABARES similarly projects growth in milk yield per cow and expects it to outweigh herd growth when responding to market demand.

By 2020 the dairy population is expected to be 87 per cent of the previous projection's predicted value.

Grain-fed beef

The recent decline in grain-fed beef numbers is again expected to cease, with the herd gradually re-stocking. As in the other cattle projections, an important question is how longer-term commodity response to market demand will be managed, balancing an increase in livestock numbers with improvements per beast. In this case the balance is between improved slaughtering weight per carcass and the number of carcasses required to fill demand.

Figure 8 Grain-fed beef projected herd growth and emissions



Source: CIE (2010), ABARES (2010), DCCEE analysis.

A growth in slaughtering weight is expected to cause beef cattle numbers to grow more slowly than beef production growth, while changes in export markets are anticipated, due to demographic shifts in Japan, rising prosperity in other parts of Asia and increasing competition from other countries.

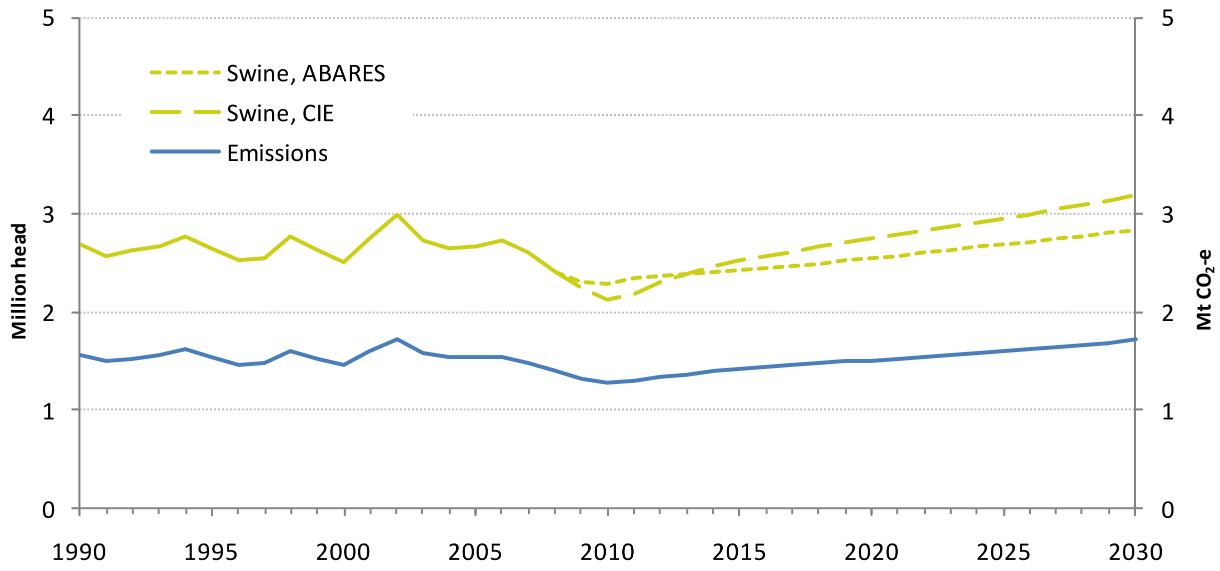
By 2020 the grain-fed beef population is expected to be at 91 per cent of the previous projection's predicted value.

Swine

The swine population is significantly lower than in the previous projection, although it is expected to grow due to expansion in domestic and export demand and low growth in slaughtering weight per carcass.

CIE and ABARES have markedly different forecasts for pig activity levels. ABARES points to the Australian market and pig meat imports from competing countries with access to cheaper, more energy-intensive feed grains; CIE suggests a more aggressive growth rate, reinforced by higher productivity growth compared with other meat products.

Figure 9 Swine activity and emissions

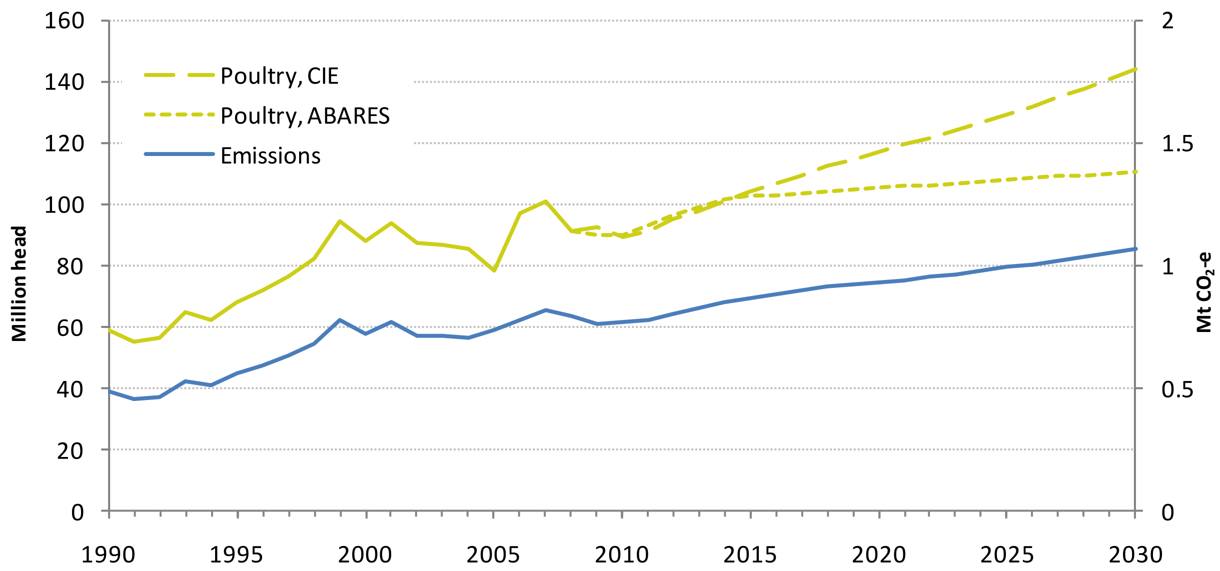


Source: CIE (2010), ABARES (2010), DCCEE analysis.

Poultry

Poultry growth rates between CIE and ABARES are very similar until 2014, where ABARES applies a lowered growth rate and CIE argues for continued strong growth.

Figure 10 Poultry activity and emissions

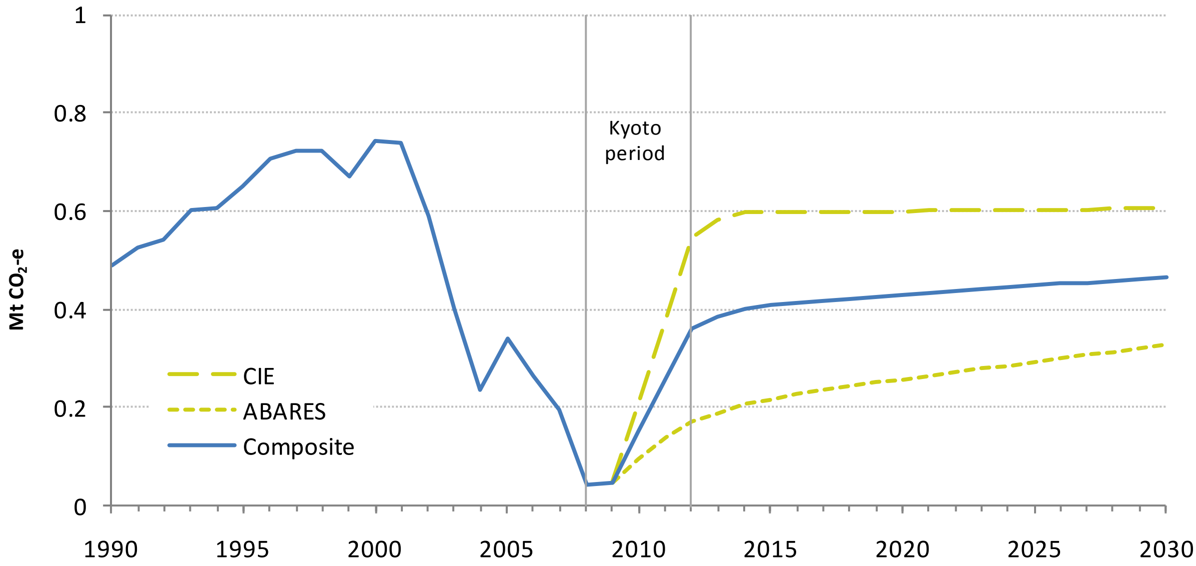


Source: CIE (2010), ABARES (2010), DCCEE analysis.

Rice cultivation

The projection of rice cultivation and associated emissions in Australia is predicated on the availability of water. The area of cultivation under rice fell sharply in 2002 due to drought, recovered in 2006, and then fell again to a low due to drought, with the emissions consequences shown in Figure 11 and Table 9. Post-drought recovery is expected, although limited by water allocations in the Murray-Darling Basin.

Figure 11 Rice cultivation emissions, 1990 to 2030



Source: CIE (2010), ABARES (2010), DCCEE analysis.

CIE and ABARES have modelled the consequent post-drought rice cultivation activity differently. CIE proposes a relatively rapid return to the average level of cultivation in the 1980s and 1990s, reflecting a reduction of 30 per cent from the peak cultivation level of 2001, and a reduction of almost 20 per cent from the average cultivation level between 1996 and 2001. ABARES, in contrast, postulates a much slower growth of cultivation area. The composite projection is a weighted mean of these views, calibrated using the subsequent NGGI data for 2009.

Table 9 Rice cultivation emissions, 1990 to 2030, Mt CO_2-e

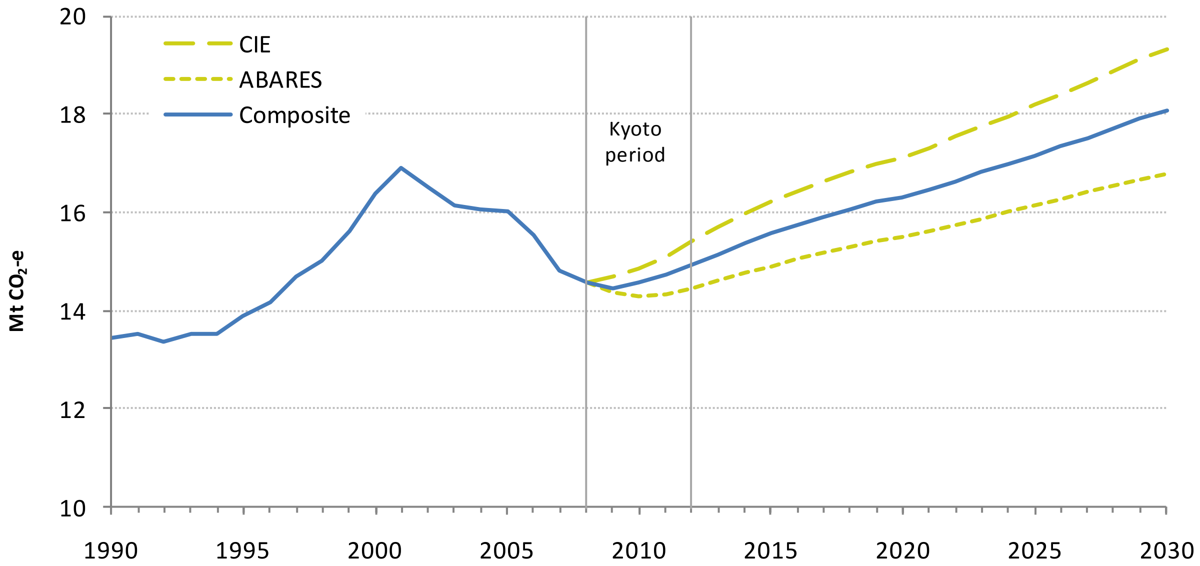
	1990	2009	2020	2030
Rice cultivation	0.49	0.05	0.43	0.47

Note: Composite is average of CIE and ABARES forecasts, calibrated to NGGI.

Agricultural soils

Emissions of nitrous oxide from soils arise from microbial and chemical transformations that produce and consume nitrous oxide within the soil. These transformations involve inorganic nitrogen compounds in the soil, namely ammonium, nitrite and nitrate. These nitrogen compounds can be added to the soil through the application of inorganic fertilisers, the application of animal wastes to pastures, biological nitrogen fixation, application of crop residues, mineralisation due to cultivation of organic soils, atmospheric nitrogen deposition or the leaching of inorganic nitrogen and subsequent denitrification in rivers and estuaries.

Figure 12 Agricultural soils emissions, 1990 to 2030



Source: CIE (2010), ABARES (2010), DCCEE analysis.

Agricultural soils emissions are projected as a result of livestock and cropping activities that have an impact on agricultural soils, and associated processes such as fertiliser application and nitrogen leaching and runoff.

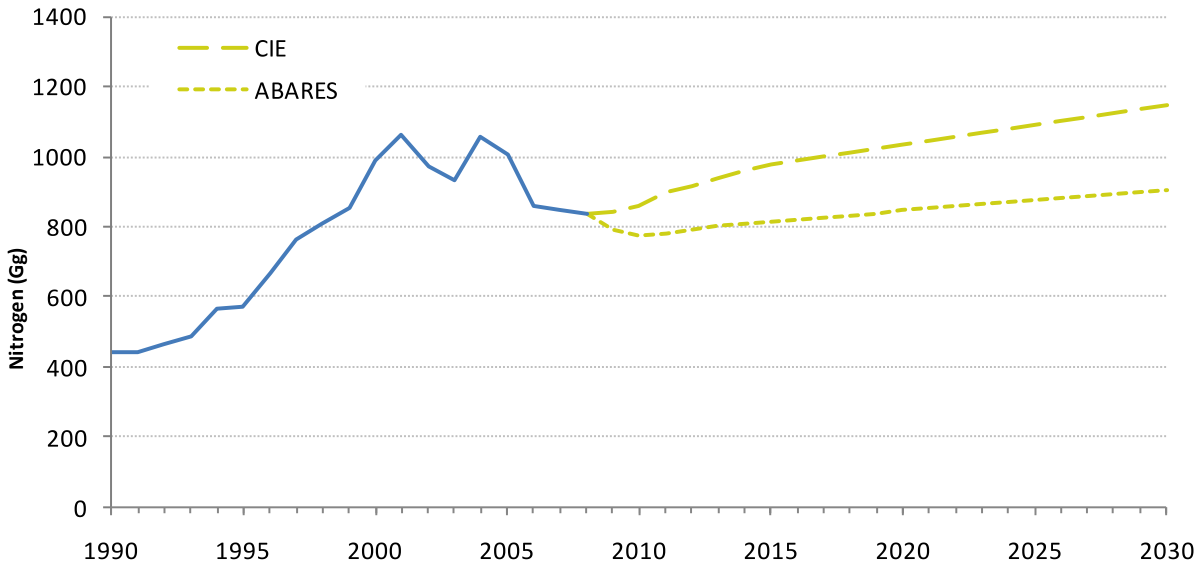
The livestock activity forecasts have already been presented in earlier pages of this sectoral report. Key cropping and fertiliser forecasts are depicted graphically in Figures 13 to 15, with the resulting emissions in Table 10.

Table 10 Agricultural soils emissions, 1990 to 2030, Mt CO_2-e

	1990	2009	2020	2030
Agricultural soils	13.4	14.5	16.3	18.1

Composite is average of CIE and ABARES forecasts, calibrated to NGGI.

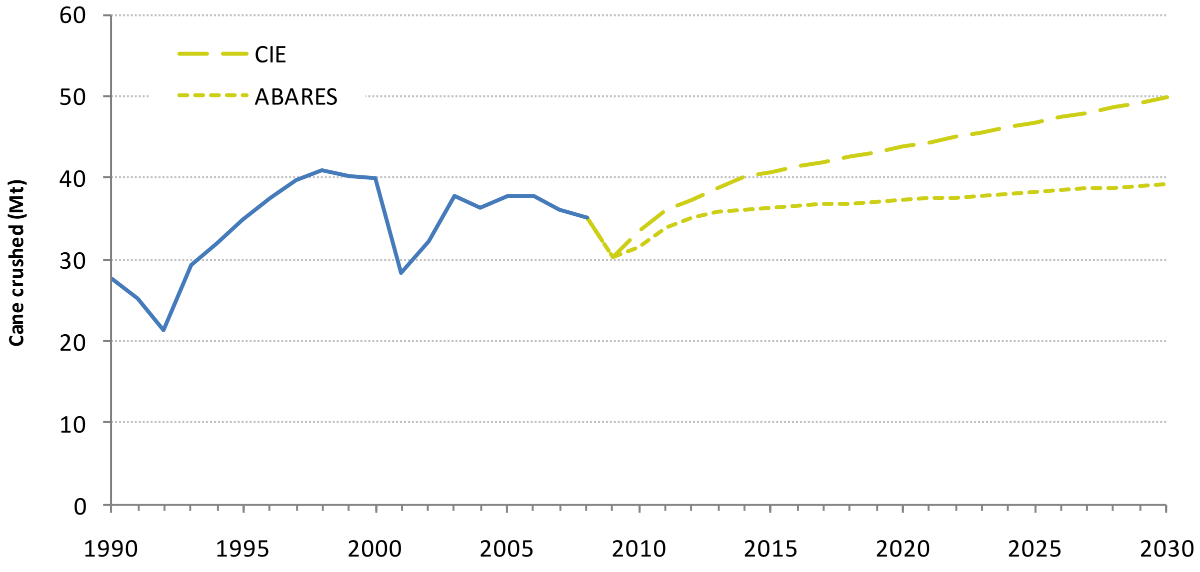
Figure 13 Total fertiliser applied, 1990 to 2030



Source: CIE (2010), ABARES (2010), DCCEE analysis.

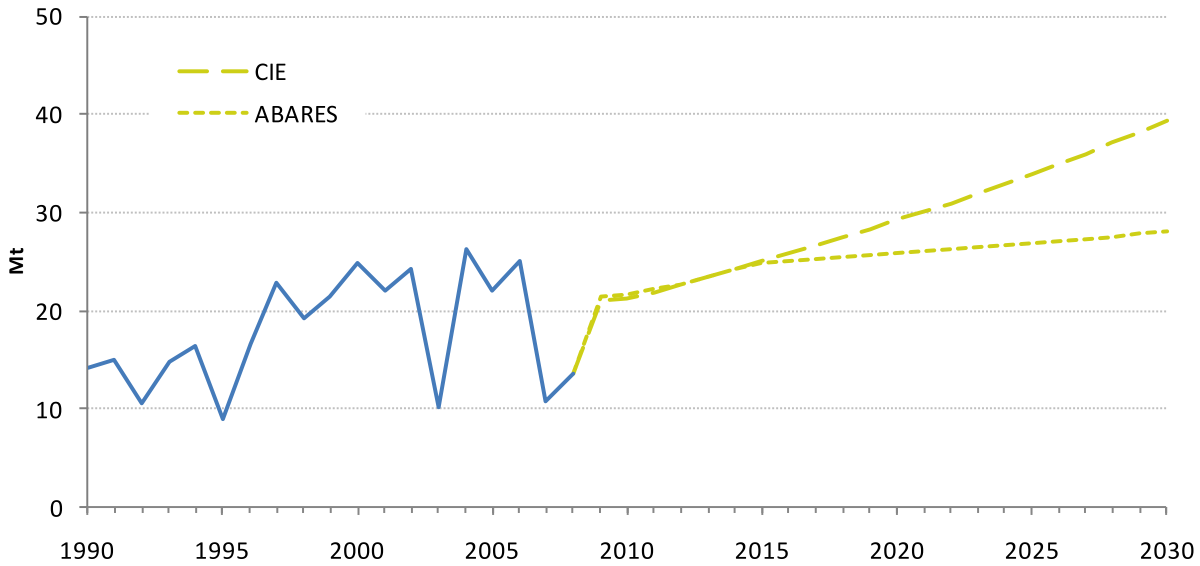
Compared with previous forecasts, production forecasts for wheat and barley are significantly reduced, while sugar cane exhibits growth despite coming from a lower base in 2009, partly driven by a higher global demand for biofuel.

Figure 14 Forecast of sugar cane production, 1990 to 2030



Source: CIE (2010), ABARES (2010), DCCEE analysis.

Figure 15 Forecast of wheat production, 1990 to 2030



Source: CIE (2010), ABARES (2010), DCCEE analysis.

Prescribed burning of savannahs

Savannah burning is a key source of CH_4 and N_2O and is an important source of CO, NO_x and non-methane volatile organic compounds (NMVOCs). Carbon dioxide emissions from savannah burning are estimated and reported as stock changes in the “grassland remaining grassland” category in the Land Use, Land Use Change and Forestry (LULUCF) sector.

The definition of savannah used by the IPCC is “tropical and sub-tropical formations with continuous grass cover, occasionally interrupted by trees and shrubs” (IPCC, 1997). This includes monsoonal through to semi-arid grasslands. In the Australian inventory this reporting category also includes burning of temperate grasslands in southern Australia and Tasmanian moorland.

Savannah and temperate grassland ecosystems in Australia are burnt either anthropogenically or as a result of wildfires (bushfires). The anthropogenic burning occurs for a variety of reasons, including pasture management, fuel reduction, prevention of uncontrollable wildfires (back burning) and traditional Aboriginal burning. These anthropogenic fires replace wildfires that would otherwise occur naturally, albeit later in the dry season or at other times of the year.

It should not be assumed that stopping anthropogenic fires would lead to a reduction in greenhouse gas emissions, because they would be replaced by natural wildfires. In many cases it is impossible to determine whether a fire has been deliberately lit or is the result of a natural ignition process such as a lightning strike. Consequently, as recommended by the IPCC (1997), all fires in Australian savannahs and temperate grasslands are included in the NGGI and projections.

NGGI data is obtained from a combination of high-resolution (AVHRR) satellite imaging, regional fire authority data based on local records and the expert judgement of district officers. Since 1998 satellite imaging has been the dominant source of data.

The area deliberately burnt is generally assumed to have been relatively steady year to year, but wildfires do occur and vary significantly from year to year. It is the frequency and severity of these wildfires, especially in central and northern Australia, that provide the source of much variability seen in the area burnt by savannah fires.

Emissions arising from savannah burning depend on a number of factors including the area under fire management, the mass of fuel available from the previous season’s growth, climatic conditions such as temperature and rainfall, and the timing of fires within the Dry season. Of these factors, the most important driver appears to arise from the relationship between rainfall and the accumulation of burnable vegetation (“fuel load”).

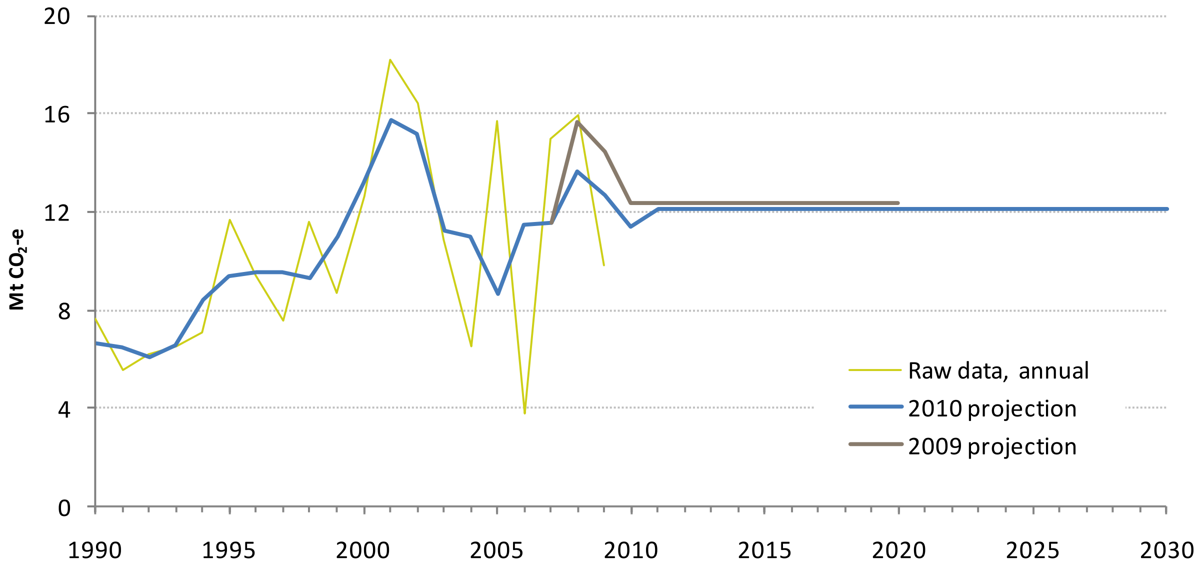
In general, plant growth occurs during the Wet season (December to March), with little activity in the subsequent Dry season during which the grass and litter fuel progressively dries out. In central Australia, where rainfall is infrequent and episodic, significant plant growth occurs only after major and sustained rainfall events. Studies of the relationship between rainfall and savannah fires show that extensive fires throughout central and northern Australia occur primarily in dry periods after sustained and widespread rainfall have caused vegetation to grow and accumulate into fuel load. Once burnt, fuel load is unlikely to burn again until subsequent rains have caused regeneration.

In northern Australia future rainfall is inherently difficult to forecast over a timescale of years, due to the presence of unpredictable meteorological drivers such as the El Niño Southern Oscillation. Given this difficulty, averages from past data are projected, as shown in Figure 16. This projection of savannah burning emissions is calculated by initially taking an average of actual emissions over the previous ten years. This projected annual data is then averaged over three years, consistent with the NGGI methodology. The ten-year long-term average is used to reflect the variability evident in savannah burning.

Modelling results

The updated results are shown in Figure 16, which shows both the raw emissions data and their moving average. The short-term reduction in projected emissions has led to a reduction in the total Kyoto period average of 1 Mt CO_2-e, while the forecast for 2020 is 12 Mt CO_2-e.

Figure 16 Savannah burning emissions, 1990 to 2030



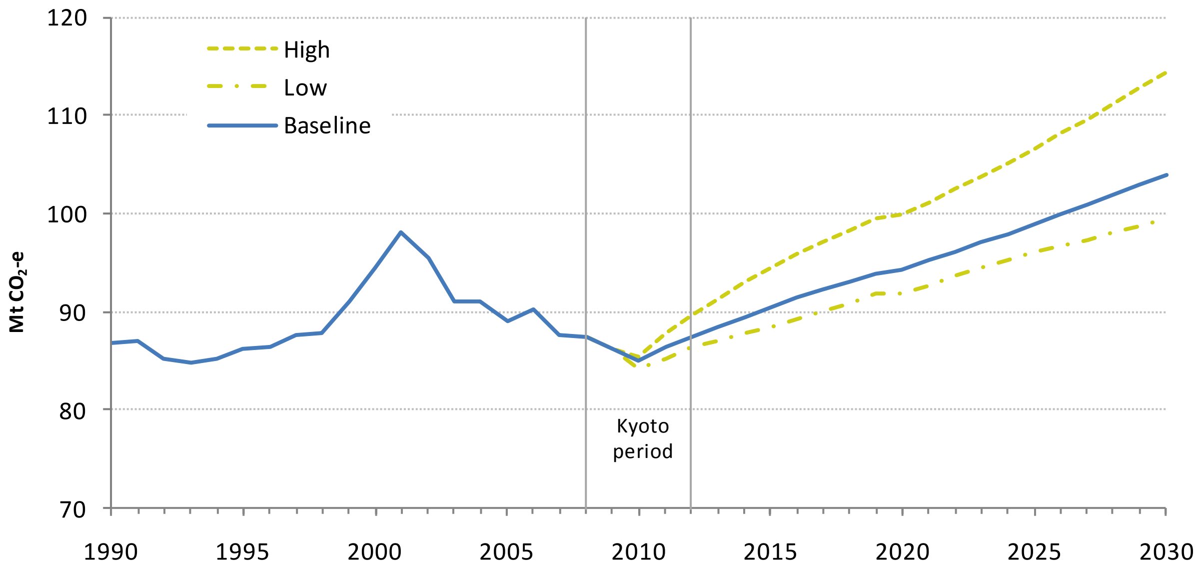
Source: DCCEE analysis.

Key uncertainties and sensitivity analysis

In order to explore the sensitivity of the baseline emissions projection to changes in future circumstances, sensitivity analysis was undertaken using multiple scenarios, where each scenario represented a variation in one or more assumptions. These 15 scenarios examined agriculture emissions without savannah burning, to concentrate on the impacts of different anthropogenic circumstances on emissions.

As shown in Figure 17, composite high and low emissions scenarios have been constructed from this modelling. As this work was commissioned prior to the drought breaking in 2010 in eastern and southern Australia, a possibility both modellers were asked to examine was where the drought continued across the continent for a significant further period. Their extended drought scenarios are shown in Figure 18 to inform the sensitivity analysis, although this risk has now been averted, so the actual composite low scenario excludes them.

Figure 17 Agriculture sensitivities, excluding savannah burning



Source: CIE (2010), ABARES (2010), DCCEE analysis.

Table 11 gives relevant results in key years, while Table 12 outlines the variations from the baseline for each component scenario.

Table 11 Agriculture emissions excluding savannah burning, 1990 to 2030, Mt CO_2-e

	1990	2009	KPA	2020	2030
High scenario			75	88	102
Baseline	80	74	74	82	92
Low scenario			74	80	87

Source: CIE (2010), ABARES (2010), DCCEE analysis.

Table 12 Sensitivity scenarios assumptions—changes from baseline

Scenario	Description of Scenario
Demand (CIE)	Higher and lower demand for Australian agricultural products (±10 per cent variation on assumptions of population and income growth in Australian and overseas markets).
Australian productivity (CIE)	Higher and lower productivity growth (±10 per cent variation in Australian productivity improvements).
Growth (CIE)	Higher and lower growth rate (±10 per cent) in slaughtering weight and milk yield in Australian cattle, per head.
Input Prices (CIE)	Higher and lower input prices for Australian agriculture.
Extended drought (CIE)	Drought in early 2010 extends to 2011 with similar severity, recovery in 2012.
High and Low (CIE)	High combines high demand, high Australian productivity, low growth rate and low input prices. Low combines low demand, low Australian productivity, high growth rate, high input prices and drought.
Productivity (ABARES)	By 2030 agriculture productivity is 10 per cent higher than in the reference case.
Export demand (ABARES)	Sensitivity of Australia's emissions to a livestock disease outbreak, depicting a 20 per cent drop in export demand of beef from 2010 to 2012.
Fertiliser (ABARES)	Increasing fertiliser prices increase farm input costs: permanent 20 per cent increase in real fertiliser price from 2010 to the end of the simulation period.
Extended drought (ABARES)	A severe five-year drought 2010 to 2015, characterised by a 20 per cent reduction in stocking rates (number of stock per hectare), a 20 per cent reduction in yields of dryland crops and perennial crops, and a 20 per cent reduction in the effective land supply of cotton and rice.

The CIE high-demand scenario is driven largely by increases in enteric fermentation (4 Mt CO_2-e), agricultural soils (1.6 Mt CO_2-e) and manure management (0.3 Mt CO_2-e) by grazing beef cattle and sheep, with crop residue and rice cultivation emissions making up the remaining 0.4 Mt CO_2-e. The enteric fermentation increase is predominantly due to grazing cattle (83 per cent), sheep (12 per cent) and the remainder mainly dairy cattle.

Table 13 gives the variations from baseline of important scenarios, exploring the influences of varied productivity, demand and input price assumptions.

The composite high scenario was constructed using the CIE high scenario, while the composite low scenario was constructed from a combination of the CIE low scenario and the ABARES fertiliser scenario. The emissions for all other scenarios lay within the interval defined by these composite high and low projections, apart from those of the two extended drought scenarios in Figure 18.

Table 13 Difference from baseline of scenarios, Mt CO_2-e

		KPA	2020	2030
Productivity	High Australian productivity (CIE)	+0.2	+2.2	+3.8
	Fertiliser (ABARES)	-0.4	-2.4	-3.2
Demand	High demand (CIE)	+0.3	+3.1	+6.1
	Low demand (CIE)	+0.1	-0.1	-1.5
Input prices	Low input prices (CIE)	+0.7	+2.6	+3.4
	High input prices (CIE)	-0.4	+0.3	+0.8
	Fertiliser (ABARES)	-0.4	-2.4	-3.2
Composite	High	+0.8	+5.5	+10.5
	Low	-0.6	-2.4	-4.4

Source: CIE (2010), ABARES (2010), DCCEE analysis. All scenarios recalibrated using NGGI data.

The CIE high scenario was constructed from component CIE scenarios. It modelled high demand for Australian agricultural products by adding 10 per cent to population and income growth assumptions in domestic and export markets. Larger population growth in all markets magnified the demand for commodities, while increased income growth in export markets translated into greater demand for commodities such as meat and dairy products. The high scenario also added 10 per cent to productivity growth by Australian farmers in responding to demand, but reduced the growth rate per beast in slaughtering weight and milk yield by 10 per cent, thus requiring more livestock to fulfil this demand for Australian commodities. Input prices (i.e. costs of farming) were dropped by 10 per cent, enabling agricultural activities to be performed more cheaply. The result was an increase in emissions from the baseline, by 6 Mt CO_2-e in 2020 and by 11 Mt CO_2-e in 2030.[2]

The CIE low scenario made opposite assumptions to those of the CIE high scenario. Demand for Australian agricultural products was reduced by removing 10 per cent from population and income growth assumptions in domestic and export markets. Productivity growth by Australian farmers in responding to demand was also reduced by 10 per cent, but the growth rate per beast in slaughtering weight and milk yield was increased by 10 per cent, thus requiring fewer livestock to fulfil this demand for Australian commodities. Input prices were increased by 10 per cent, making farming more expensive, while some residual drought effects were also included in 2010.

Given that fertiliser prices have more than doubled over the last decade, the ABARES fertiliser scenario modelled the case where the real fertiliser price increased by 20 per cent from 2010 onwards. This represented a significant additional input price for farming and hence lowered

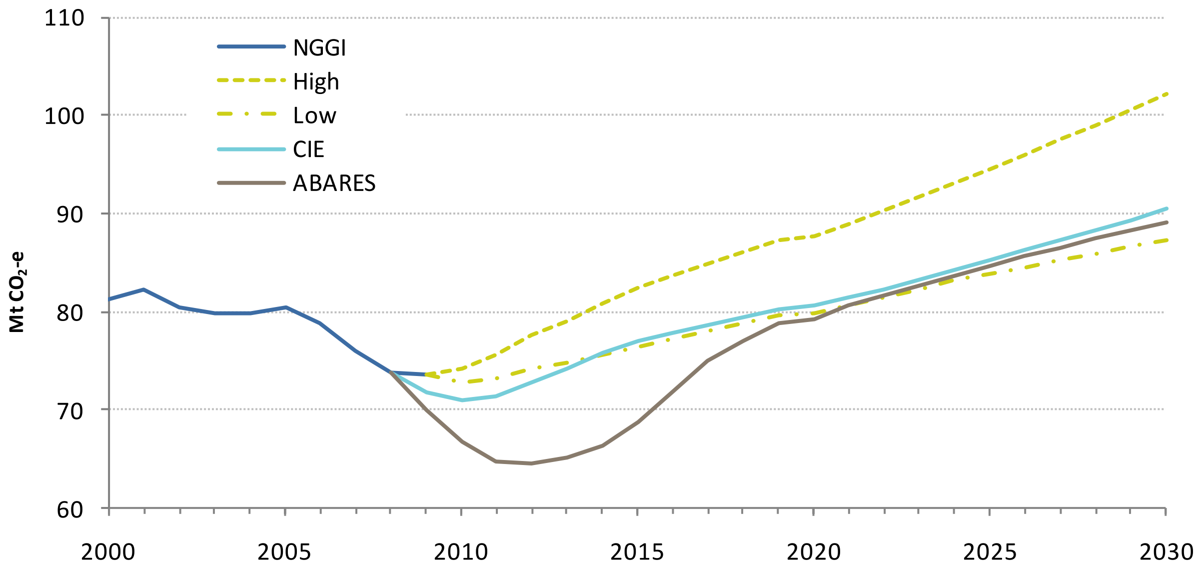
[2] Note that emissions from combining scenario assumptions were not perfectly additive: the increase in emissions over baseline from a high-demand low-cost agricultural scenario is not exactly equal to the sum of the changes in emissions of a high-demand scenario plus a low-cost scenario. Analysing the effects of varying individual economic drivers in isolation is useful, but combining changes in drivers can create internal payoffs affecting emissions.

the amount of fertiliser used. Consequently this reduced direct fertiliser emissions from soil and had a wider “knock-on” effect, reducing agricultural production and related emissions.

The resulting composite low scenario had a decrease in emissions from the baseline by 2 Mt CO_2-e in 2020 and by 4 Mt CO_2-e in 2030.

The extended drought scenarios in Figure 18 indicated the effects of further drought on emissions, had it not broken in eastern and southern Australia in 2010. The ABARES extended drought scenario indicated that a further five years of drought, with its associated reductions in cropping and livestock, would have lead to an additional drop of 9.7 Mt CO_2-e below the composite low scenario in 2012. The CIE drought scenario, although much milder in effect, still indicated a drop of 1.7 Mt CO_2-e below the composite low scenario in 2010.

Figure 18 Drought scenarios, excluding savannah burning



Source: CIE (2010), ABARES (2010), DCCEE analysis.

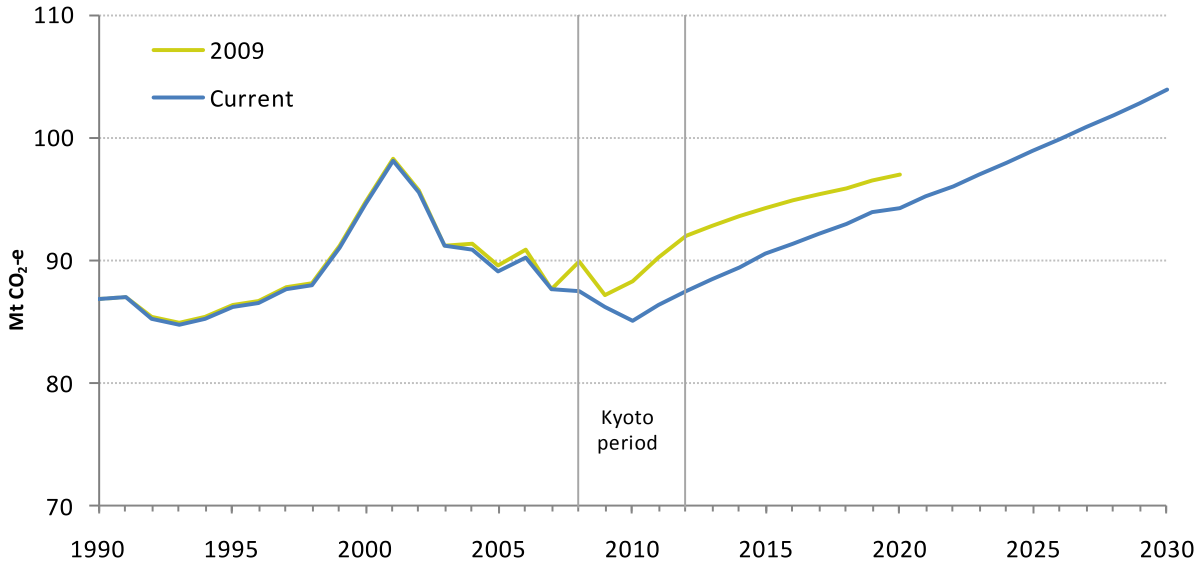
Appendix A – Changes from 2009 projection

The key differences between the 2009 and 2010 agriculture projections are the persistence of the drought, which finally broke in eastern and southern Australia in 2010, and the prevailing global economic conditions under which post-drought recovery and restocking will now occur.

The previous projection, released in Australia's Fifth National Communication on Climate Change to the UNFCCC, assumed a return to normal conditions and a return to positive growth in emissions from 2009. However, as a result of the prolonged drought, herd and flock numbers are now lower than anticipated in the previous projection, which means that restocking begins from a lower base.

Restocking in herds is also anticipated to be slower than in the previous projection, due to reduced demand from global markets due to the GFC. By 2020 dairy and grain-fed cattle populations are expected to reach 87 per cent and 91 per cent of the numbers expected in the previous forecast. Some qualitative differences also exist: the sheep flock is expected to be 21 per cent smaller in 2020 than predicted by the 2009 forecast, due to a stronger emphasis on sheep meats such as lamb as the relevant commodity instead of wool.

Figure 19 Baseline sector emissions trends, 1990 to 2030



Source: CIE (2010), ABARES (2010), DCCEE analysis.

These reduced numbers are predicted to lead to reduced livestock emissions (enteric fermentation and manure management) for the Kyoto period. Reduced livestock numbers also lead to reduced agricultural soils emissions, due to reduced animal waste fertiliser.

As shown in Table 14, the reduction in livestock numbers and the slowed restocking of herds and flocks has a clear effect on the enteric fermentation forecasts. The 2010 projection has much slower emissions growth post-drought and is 2.4 Mt CO_2-e lower in 2020 than the previous projection.

Manure management is also reduced during the Kyoto period, although the difference between the two projections also reflects the difference in growth rates in particular categories of livestock. Due to steeper growth now expected in swine population, manure management in 2020 is expected to be 0.1 Mt CO_2-e above the previous projection.

The 2010 composite projection for rice cultivation emissions is slightly lower than the 2009 projection due to less area under cultivation, although the difference is not visible on a scale comparable with other subsectors.

The reduced cropping areas and livestock numbers immediately post-drought have reduced agricultural soils emissions to 2020 when compared with the previous projection. In 2020 the current projection is 0.2 Mt CO_2-e lower than the previous projection, with the former measure of reduced fertiliser application now regarded as a BAU practice.

Field burning of agricultural residues is up by 0.1 Mt CO_2-e in 2020, due to steeper biofuel-induced growth in sugar cane cropping.

The updated time-series for savannah burning has led to a reduction in the projected average of emissions to 2020.

Table 14 Changes to the 2010 projection from the 2009 projection

	Kyoto period average 2008-12	**2020**
	Mt CO_2-e	Mt CO_2-e
Enteric fermentation	-1.5	-2.4
Manure management	-0.1	0.1
Rice cultivation	-0.0	-0.0
Agricultural soils	-0.3	-0.2
Prescribed burning of savannahs	-1.1	-0.3
Field burning of agricultural residues	-0.0	0.1
Total	**-3.0**	**-2.8**

Source: CIE (2010), ABARES (2010), DCCEE analysis. Numbers may not add due to rounding.

Appendix B – Methodology

The basic methodology for calculating projections of emissions from the agriculture sector involves multiplying estimates of agricultural activity levels (such as livestock numbers and area of crops sown) by emission factors. Agricultural models are used to project estimates of activity levels and the emission factors are drawn from the latest NGGI.

Savannah burning is the exception to this. Projections for savannah burning are not formally modelled but are calculated by taking a long term average of past emissions, due to the inherent lack of predictability of future rainfall patterns.

The projections of agricultural activity levels were developed by two sets of agricultural models, one set by the Australian Bureau for Agricultural and Resources Economics and Sciences (ABARES) and the other by the Centre for International Economics (the CIE). Composite projections of activity levels were then produced by averaging these two sets of projections.

The CIE undertook modelling of the Australian agriculture sector using three global models: the GMI model of global meat markets, the CIE Dairy model and the CIE Grain model. Each of these models is driven by a common set of macro-economic assumptions such as income growth by region, population growth and exchange rates, and they predominantly describe demand-side effects. This multi-model approach offered by CIE allows for the incorporation of considerable detail about policy and other influences to each commodity or region.

ABARES undertook modelling work using a hybrid approach, combining the TRANSPLANT model of the Australian agriculture sector with commodity analysts' expert judgement to 2015. TRANSPLANT is a multi-region and multi-commodity competitive equilibrium model of Australian agriculture, which enables modelling of competition for inputs, such as land, among agricultural activities. It is predominantly a supply-side model. TRANSPLANT also provides a link to global markets and provides price feedbacks due to the supply and demand of agricultural commodities on global markets.

Both the CIE and ABARES were given historical agricultural activity data from the 2008 NGGI to calibrate their forecasts to 2030. Subsequent re-calibration of the results to 2009 data has taken place as more recent NGGI data has become available.

Agricultural activity forecasts were expressed in terms of head of livestock, hectares of cultivation or tonnes of commodity. The DCCEE composite forecast for each form of activity was constructed from the average of the CIE and ABARES forecasts of that activity for each year in the interval 2010-2030. Associated yearly emissions were then calculated by multiplying the activity data for that year by relevant emissions factors. In many cases the one activity gave rise to multiple forms of emission: for example, grain-fed beef cattle engage in enteric fermentation, while their manure gives rise to both manure management and agricultural soils emissions.

In accordance with the IPCC (1997, vol.1) guidelines, the consequent emissions have been reported as three-year averages where possible (i.e. the reported emissions for 1990 were the average for those for 1989, 1990 and 1991). Annual livestock emissions were calculated before determining a three-year moving average, whereas annual cropping activities (e.g. hectares of crops grown) had their moving average calculated over three years before emissions were determined. For years in the Kyoto period (2008-2012), DCCEE has reported emissions projections as an average of emissions over these years (Kyoto period average).

Appendix C – Key assumptions

Three sets of assumptions are relevant to the agriculture projection: emissions factors and historical activity statistics used by the DCCEE and the modelling assumptions by the two external consultants.

The emissions factors and historical activity statistics were taken from the NGGI data:

- For a particular kind of livestock, different regions of Australia were assigned different emissions factors, to capture regional variations in conditions or farming practices affecting emissions.
- To be suitable for projection purposes, these emissions factors had to be simplified and converted from seasonal to annual numbers, so they could be multiplied by predicted annual livestock populations in each region of Australia to estimate future emissions.
- For projections purposes these emission factors, based on recent NGGI emissions data, were held constant over the projection period (2009-2030).

As regards the external modellers, the CIE modelling had the following underlying assumptions:

- Annual population growth figures in Australia and other countries or regions identified by the CIE GMI model were drawn mainly from the United Nations Population Division's (UNPD) latest population projection, as revised in 2008, using the medium variant series.
- Projections of real income growth for the 22 countries or regions identified by the GMI model were primarily sourced from the International Monetary Fund's latest World Economic Outlook for the period up to 2015. Beyond that point a gradual transformation path is assumed for each country or region, so it reaches its long-term growth rate, estimated from the 20-30 years' growth rate prior to 2008 (hence correcting for the perturbation of the GFC).
- Trends in the average weights of meat and volumes of milk production per beast 1961-2010 were used for the period beyond 2011. This data was taken from ABARES published material, including the Australian Commodity Statistics (2009), and CIE assessments.
- The long-term trends of technical progress in meat sectors across countries or regions were taken to be functions of both farm productivity and processing productivity. These rates were tabulated for various forms of livestock and derived commodities for each of the 22 regions.

- Due to inherent difficulties in modelling exchange rates, changes in exchange rate were modelled only for 2010 and assumed fixed beyond 2011. Effects analogous to changes in these assumed exchange rates were modelled in the sensitivity scenarios.
- Projected world food prices (and crude oil prices) in the Grain model were taken to be consistent with those of the United States Department of Agriculture (USDA) to 2019. The growth rate in 2019 was then assumed to continue to 2030.

The ABARES modelling made assumptions consistent with the Australian Government's 2010 Budget:

- Real GDP in Australia is projected to grow by 3 per cent in 2011 and 3.8 per cent in 2012, returning to 3 per cent in 2013 and beyond.
- Economic growth for the rest of the world is assumed to average 4 per cent in 2011, 4.8 per cent in 2012 and 4 per cent in 2013 and beyond.

Diversity in the assumptions underlying modellers' forecasts was welcomed by DCCEE, to provide multiple likely world views from which to construct the emissions projection. The robustness of these assumptions was then explored in the multi-scenario sensitivity analysis.

Appendix D – References

ABARE, *Reference Case Projections of Australian Agricultural Activity Levels and Greenhouse Gas Emissions: 2005-06 to 2019-20*, ABARE report to the Department of Climate Change, Canberra, November 2008.

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Thorpe S. and Klijn N., *Projections of Agricultural Activity and Associated Greenhouse Gas Emissions*, ABARE report to the Australian Greenhouse Office, Canberra, July 2002.

UNPD, *World Population Prospects: the 2008 Revision*, United Nations Population Division, New York, 2009.

USDA, *Long-Term Agricultural Projection Tables to 2019*, United States Department of Agriculture, Washington DC, 2010.

Appendix E – Glossary

Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
AVHRR	Advanced Very High Resolution Radiometer
BAU	Business as usual
CIE	The Centre for International Economics
DCC	Department of Climate Change
DCCEE	Department of Climate Change and Energy Efficiency
GFC	Global Financial Crisis
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
KPA	Kyoto period average
Mt CO_2-e	Megatonne (1 million tonnes) carbon dioxide equivalent
NGGI	National Greenhouse Gas Inventory
UNPD	United Nations Population Division
USDA	United States Department of Agriculture

Explanations

Baseline	Refers to the level of emissions expected to occur in the absence of an emissions trading scheme, but including the impact of all other measures.
Business as usual	Refers to a projection that incorporates changes in activity levels and greenhouse gas emission factors, but with the exclusion of any effects that are directly attributable to greenhouse policy measures.
Measures	Refers to past, current or committed Australian, State/Territory or local government policy actions that have an impact on greenhouse gas emissions, causing them to deviate from the BAU path after the base year of 1990.
High emissions	A 'high emissions' scenario adopts plausible high-emission assumptions.
Low emissions	A 'low emissions' scenario adopts plausible low-emission assumptions.
Kyoto period	Includes the years 2007-08 through to 2011-12, as specified by the Kyoto Protocol.