# Climate Goals for New Zealand in 2030:

***An Ambitious Domestic Emissions Target within an Appropriate Share of the Global Budget***

## ANNEX A

## SECTOR ANALYSES

A. New Zealand's Domestic Abatement Potential: 2015 to 2030

Sector analyses:

## (i) Energy

## 1. New Zealand's Energy Emissions Profile

New Zealand's energy emissions, 1990 to 2012 (actual) and baseline projections to 2030 (based on published Govt. projections under current policy settings) are shown in Table 1.

**Table 1**

**Energy Emissions (Mt $CO_2$–e)**

| | | Actual | | | Projected | | |
|---|---|---|---|---|---|---|---|
| | | 1990 | 2010 | 2012 | 2015 | 2020 | 2030 |
| **Energy** | **Sub-total** | **23.8** | **31.9** | **32.3** | **32.9** | **32.9** | **34.4** |
| | Electricity | 3.5 | 5.4 | 6.3 | 4.8 | 4.1 | 2.8 |
| | Transformation | 2.5 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| | Transport | 8.7 | 13.8 | 13.8 | 14.4 | 14.9 | 15.9 |
| | Manufacturing etc. | 7.6 | 8.3 | 8.6 | 10.3 | 10.7 | 12.4 |
| | Fugitive emissions | 1.5 | 2.9 | 2.4 | 2.0 | 2.0 | 2.0 |

*Sources: 6th National Communication, Ch. 5 Projection; 2014 Greenhouse Gas Inventory*

A more detailed breakdown of recent emissions is shown in Table 2.

**Table 2**

**Energy Emissions in 2012 (Mt $CO_2$-e)**

| Sub-sector | Category | | | | Total |
|---|---|---|---|---|---|
| **TOTAL** | | | | | 32.3 |
| **Fuel combustion** | | | | 29.9 | |
| Energy Industries | | | 7.6 | | |
| | Public electricity & heat | 6.3 | | | |
| | Petroleum refining | 0.9 | | | |
| | Solid fuels manufacturing | 0.4 | | | |
| Manufacturing | | | 5.3 | | |
| | Iron & steel | 0.1 | | | |
| | Non-ferrous metals | 0.1 | | | |
| | Chemicals | 1.0 | | | |
| | Pulp, paper & print | 0.5 | | | |
| | Food processing | 2.2 | | | |
| | Other | 1.4 | | | |
| Transport | | | 13.8 | | |
| | Civil aviation | 0.9 | | | |
| | Road transportation | 12.4 | | | |
| | Railways | 0.2 | | | |
| | Navigation | 0.3 | | | |
| Other Sectors | | | 3.3 | | |
| | Commercial / institutional | 0.9 | | | |
| | Residential | 0.6 | | | |
| | Agric., forestry, fisheries | 1.8 | | | |
| **Fugitive emissions** | | | | 2.4 | |
| Solid fuels | | | 0.4 | | |
| | Coal mining | 0.3 | | | |
| | Solid fuel transformation | 0.1 | | | |
| | Other | 0 | | | |
| Oil & natural gas | | | 1.2 | | |
| | Oil | 0 | | | |
| | Natural gas | 0.9 | | | |
| | Venting & flaring | 0.3 | | | |
| **Geothermal** | | | 0.8 | | |

*Source: 6th National Communication (April 2015); CRF Table 1.*

From Table 1 and 2[1] it is clear that, in the Energy sector, one sub-sector in particular, road transport (at 12.4 Mt), is the largest emission source that demands domestic abatement. Electricity emissions (at 6.3 Mt) no doubt can be reduced and perhaps food processing (2.2 Mt).

## 2. Ambitious Abatement Potential: Scenarios

*Summary*

We have constructed two alternative scenarios for energy and transport emissions based on several measures to reduce greenhouse gas emissions. We call these the 'Moderate ambition' and 'High ambition' scenarios. These are developed in reference to the baseline scenario described in the document 'Baseline scenario description'.[2]

Without access to full datasets, models and other resources used by government departments, we have adopted a simplified approach based on transparent assumptions. These are not comprehensive assessments of mitigation opportunities. Rather they are indicative scenarios showing the emissions reductions that would result from sets of measures in the energy and transport sectors.

*Main assumptions*

**Transport:**

| ***Moderate ambition*** | ***High ambition*** |
|---|---|
| Light vehicle km. *per capita*: declining at 1.5% p.a. from 2015. | Light vehicle km. *per capita*: declining at 2.0% p.a. from 2015. |
| Light vehicle fleet efficiency improves from 240 g$CO_2$ /km in 2015 to 150 g $CO_2$ /km in 2030. | Light vehicle fleet efficiency improves to 100 g$CO_2$ /km in 2030. |
| Other transport emissions (heavy road vehicles, aviation, marine and rail) do not change from 2015 to 2030. | Other transport emissions (heavy road vehicles, aviation, marine and rail) do not change from 2015 to 2030 except for a reduction due to the uptake of 40 PJ of biofuels. |

**Electricity:**

| ***Moderate ambition*** | ***High ambition*** |
|---|---|
| Coal-free by 2020 | Coal-free by 2020 and 100% renewable (i.e. gas-free) by 2030. |
| Emissions follow MBIE Electricity Insight ‘Global Low Carbon’ scenario to 2030. | Fossil emissions follow ‘Global Low Carbon’ scenario to 2025, then fall to zero by 2030. |
| | Fugitive emissions from geothermal as per ‘Global Low Carbon’ scenario. |

**Manufacturing and other:**

| ***Moderate ambition*** | ***High ambition*** |
|---|---|
| Zero thermal coal use by 2030 (linear phase out). | Coal and liquid fuel use reduced to 10% and 60% of 2015 values. |
| No change in liquid fuel and gas use from 2015 to 2030. | No change in gas use from 2015 to 2030. |

**Transformation:**

| ***Moderate ambition*** | ***High ambition*** |
|---|---|
| No change from 2012. | Reduced proportional to total consumption of oil products. |

[1] Note: In interpreting the different categories between two tables, Transformation (Table 1) is comprised (in Table 2) of ‘petroleum refining’ plus ‘solid fuels manufacturing’; and ‘Manufacturing etc.’ (Table 1) is comprised (in Table 2) of ‘manufacturing’ plus ‘other sectors’) .

2 Broadly speaking there are two ways we can seek to develop alternative future mitigation scenarios for a particular sector: (1) Calculate feasible emissions reductions and subtract from the baseline projection; (2) Calculate total emissions independent of the baseline projection. The former is preferable to achieve maximum consistency with the baseline scenario, but it relies on having detailed sectoral information for the baseline, which we do not have. We therefore opt for the latter approach of building our own emissions estimates in a bottom-up manner, aligning these with what we know about the baseline projection wherever possible.

**Fugitive emissions:**

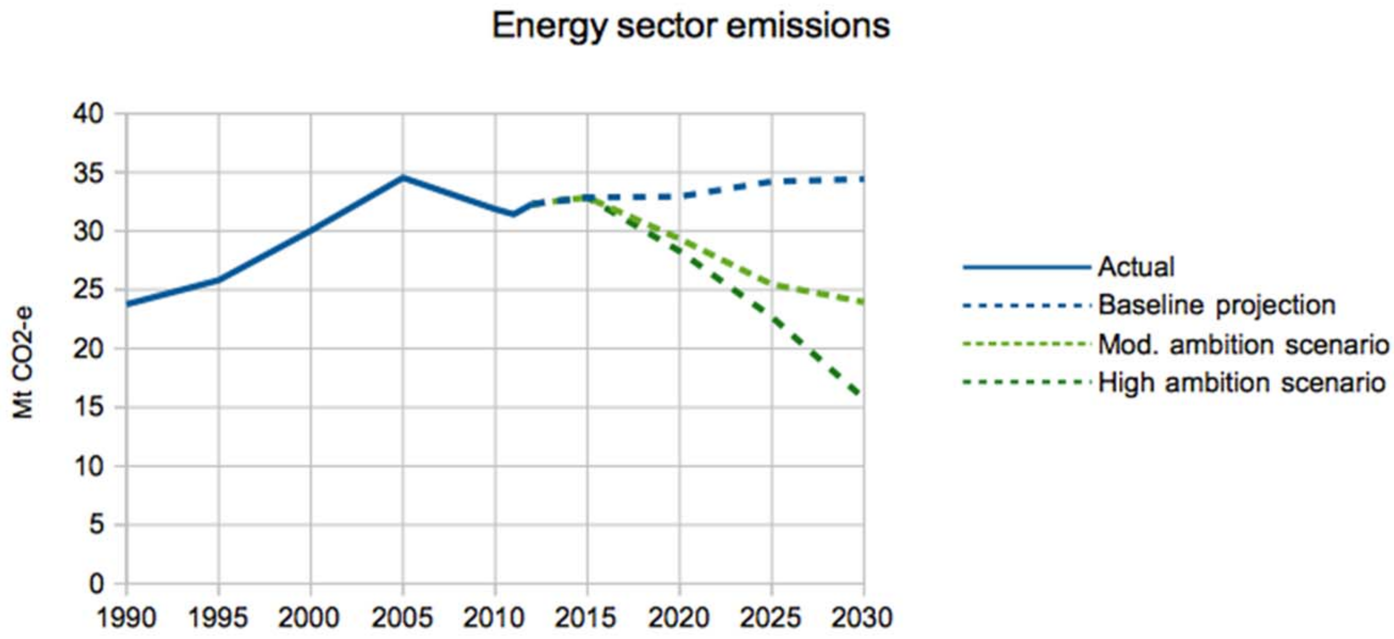
| ***Both scenarios*** |
|---|
| Geothermal emissions as per our electricity assumptions. |
| Other fugitive emissions equal to baseline projection. |

*Results*

Total emissions from energy and transport are reduced from 32.9 MtCO2-e in 2015 to 24.0 Mt CO2-e in 2030 under the moderate ambition scenario, and to 15.7 MtCO2-e under the high ambition scenario. These are 10.5 Mt lower and 18.7 Mt lower than the baseline projection in 2030, respectively. For comparison, energy and transport emissions in 1990 were 23.8 MtCO2-e.

## Energy sector emissions projections, MtCO2-e

| | | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|
| **Total** | *Baseline* | 32.9 | 32.9 | 34.2 | 34.4 |
| | *Moderate ambition* | 32.9 | 29.3 | 25.5 | 24.0 |
| | *High ambition* | 32.9 | 28.3 | 22.7 | 15.7 |
| **Electricity Production** | *Baseline* | 4.8 | 4.1 | 2.9 | 2.8 |
| | *Moderate ambition* | 4.8 | 3.6 | 2.0 | 2.0 |
| | *High ambition* | 4.8 | 3.6 | 2.0 | 0.0 |
| **Transformation** | *Baseline* | 1.3 | 1.3 | 1.3 | 1.3 |
| | *Moderate ambition* | 1.3 | 1.3 | 1.3 | 1.3 |
| | *High ambition* | 1.3 | 1.1 | 0.9 | 0.7 |
| **Transport** | *Baseline* | 14.4 | 14.9 | 15.5 | 15.9 |
| | *Moderate ambition* | 14.4 | 13.0 | 11.6 | 11.2 |
| | *High ambition* | 14.4 | 12.5 | 10.0 | 6.8 |
| **Manufacturing and other** | *Baseline* | 10.3 | 10.7 | 12.5 | 12.4 |
| | *Moderate ambition* | 10.3 | 9.5 | 8.6 | 7.7 |
| | *High ambition* | 10.3 | 9.1 | 7.9 | 6.6 |
| **Fugitive Emissions** | *Baseline* | 2.0 | 2.0 | 2.0 | 2.0 |
| | *Moderate ambition* | 2.0 | 2.0 | 1.9 | 1.7 |
| | *High ambition* | 2.0 | 2.0 | 1.9 | 1.7 |


Energy sector emissions
Mt CO2-e
40
35
30
25
20
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1990
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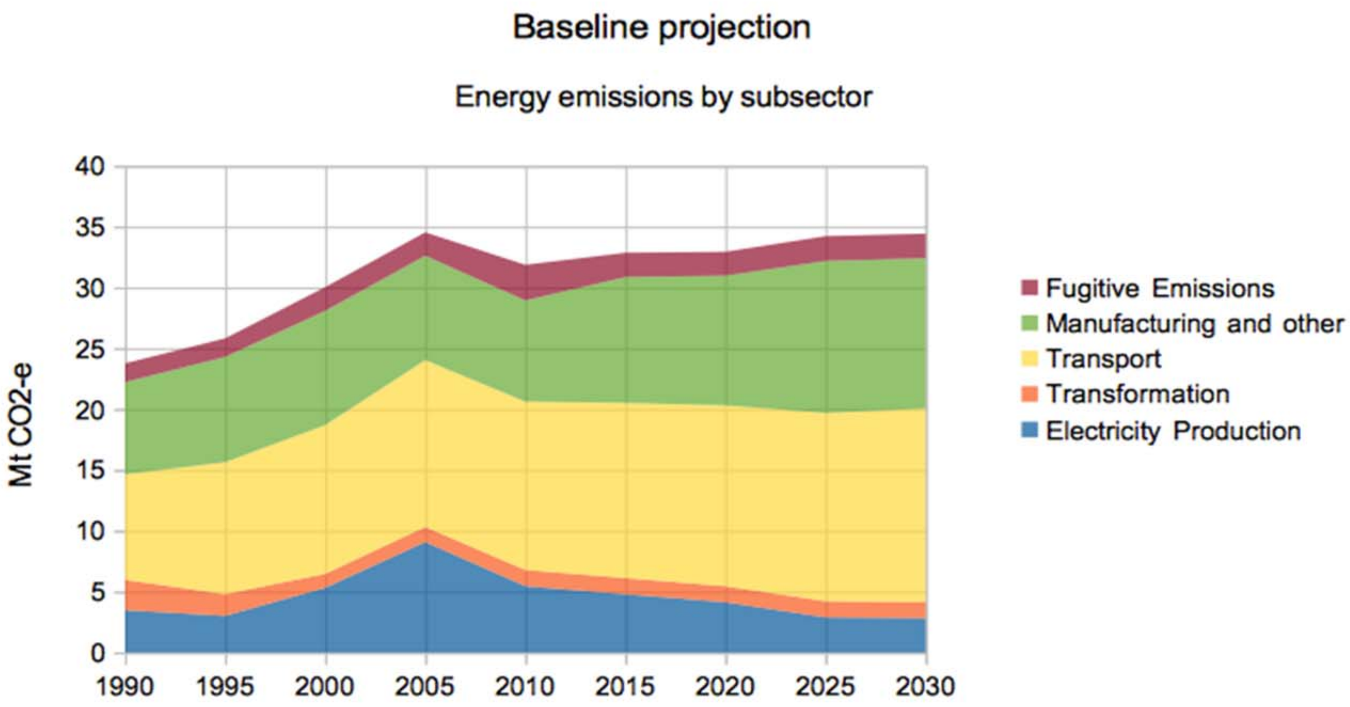
2025
2030
Actual
Baseline projection
Mod. ambition scenario
High ambition scenario


Baseline projection
Energy emissions by subsector
Mt CO2-e
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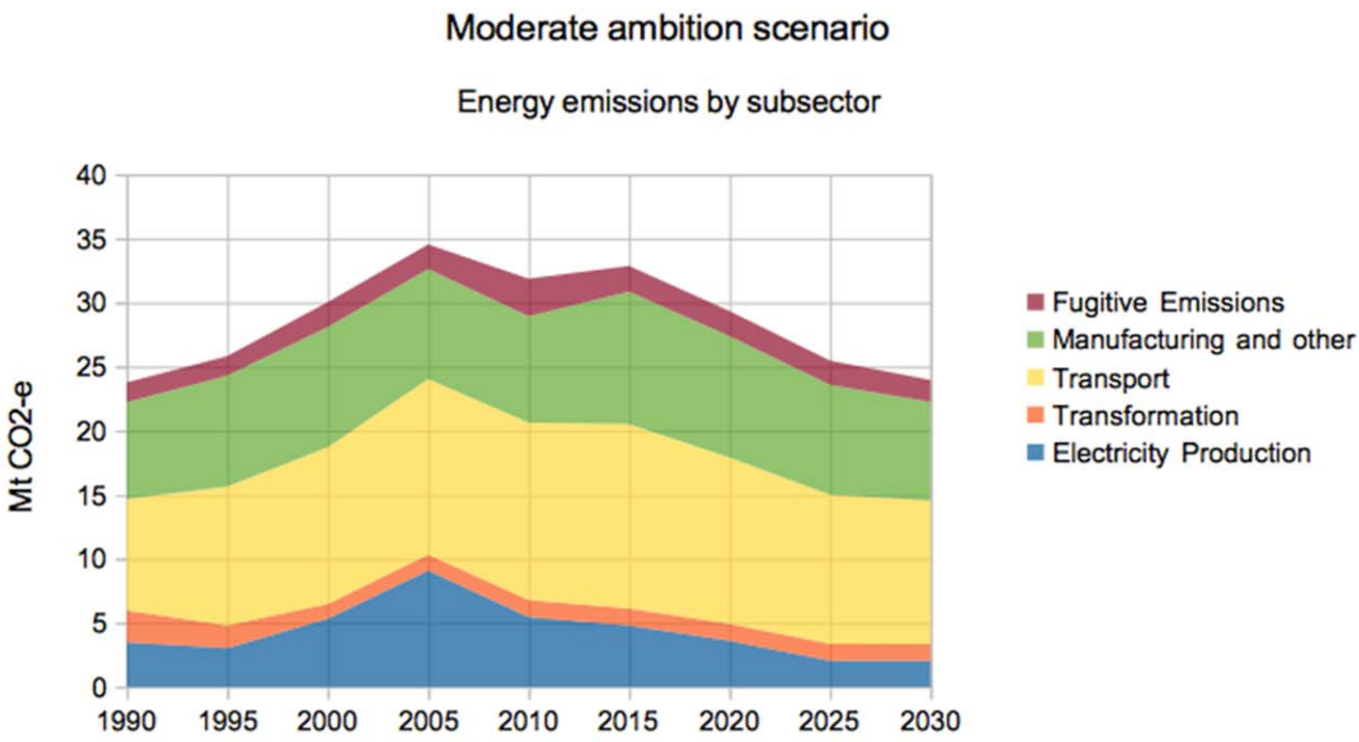
Fugitive Emissions
Manufacturing and other
Transport
Transformation
Electricity Production


Moderate ambition scenario
Energy emissions by subsector
Mt CO2-e
40
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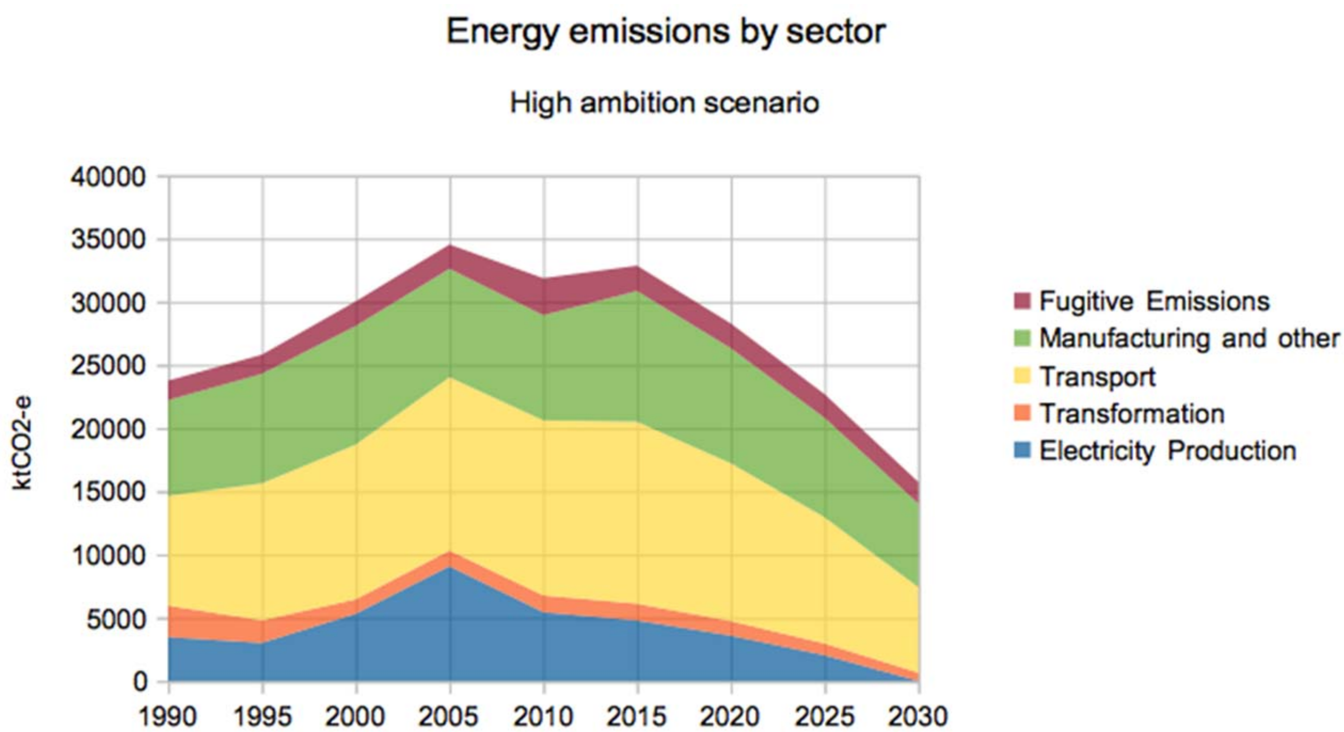
Fugitive Emissions
Manufacturing and other
Transport
Transformation
Electricity Production


Energy emissions by sector
High ambition scenario
ktCO2-e
40000
35000
30000
25000
20000
15000
10000
5000
0
1990
1995
2000
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2015
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2025
2030
Fugitive Emissions
Manufacturing and other
Transport
Transformation
Electricity Production

## 2.1 Transport

The Sixth National Communication ("6NC") provides data and projections for the transport sector. We have additional data in *Energy Greenhouse Gas Emissions 2013* (MBIE) and *Energy in New Zealand 2014* (MBIE) allowing this to be broken down by transport mode and vehicle type. Road transport accounts for approximately 90% of transport emissions: approximately 55% from light vehicles and 35% from heavy and commercial vehicles (predominantly freight).

Emissions from aviation (7%), marine (2%) and rail (1%) have been reasonably flat over recent years, with virtually all of the growth in transport emissions since 1990 being due to road transport. The 6NC states that "emissions from light vehicles are expected to remain fairly constant, with increases in vehicle kilometres due to population growth being offset by improvements in vehicle efficiency". Essentially all of the projected growth to 2030 is therefore from road freight.

For light vehicles, we assume:

| ***Moderate ambition*** | ***High ambition*** |
|---|---|
| Light vehicle per km./ per capita declines at 1.5% per annum from 2015. | Light vehicle km./ per capita declines at 2.0% per annum from 2015. |
| Light vehicle fleet efficiency improves from 240 $gCO_2$ /km in 2015 to 150 $gCO_2$ /km in 2030. | Light vehicle fleet efficiency improves to 100 gCO2e /km in 2030. |
| Other transport emissions (heavy road vehicles, aviation, marine and rail) do not change from 2015 to 2030. | Other transport emissions (heavy road vehicles, aviation, marine and rail) do not change from 2015 to 2030 except for a reduction due to the uptake of 40 PJ of biofuels. |
| The same population growth projections used in the 6NC. | |
| Vehicle-kilometres travelled (VKT) by light vehicles in 2015 the same as in 2013 (most recent figures). | |

Light passenger vehicle travel per capita declined at an average of approximately 1% per annum from 2003-2012. The two scenarios assumes this rate of reduction can be improved upon. It is envisaged this can be achieved through a focus on better public transport, walking and cycling, travel demand management and smart urban planning.[3] Under the moderate ambition scenario, VKT for light vehicles declines from 31.0 billion km in 2015 to 28.1 billion km in 2030 (a 9% reduction). Under the high ambition scenario, this declines further to 26.0 billion km (a 16% reduction). For comparison, the Ministry of Transport's recent *Future Demand* study gives five plausible future scenarios which range from a 30% reduction to a 20% increase in VKT by 2030.[4] Reductions occur through a combination of fewer journeys (due to higher travel costs and increased digital connectivity) and mode shift.

The light vehicle fleet efficiency goal in the moderate ambition scenario would roughly mean catching up to current fleet averages in the UK and other EU countries by 2030, while the high ambition scenario would go beyond this. These are achievable through a combination of more efficient petrol- and diesel-powered vehicles as well as uptake of electric vehicles.

We have tested the feasibility of the fuel-efficiency goals with a simple vehicle fleet model.

- 150 gCO2/km by 2030 is readily achievable with current vehicle purchase and scrapping rates maintained, and less stringent fuel efficiency standards for new vehicles than those planned for the EU, Japan and the US.[5]
- 100 gCO2/km by 2030 is achieved by meeting the EU's new vehicle standard of 95 gCO2/km in 2021, followed by a transition to nearly 100% electric vehicle purchases by 2030, and vehicle turnover increasing from 2020-2030. This is a believable scenario if battery costs continue to come down and new vehicle ownership models drive a faster transition to EVs.

Based on these assumptions, emissions from light vehicle travel would fall from roughly 7.5 MtCO2-e in 2015 to 4.2 MtCO2-e in 2030 under the moderate ambition scenario, and to 2.6 MtCO2-e under the high ambition scenario.

For other road travel (described here as 'road freight'), aviation, marine and rail we assume:

| ***Moderate ambition*** | ***High ambition*** |
|---|---|
| Road freight accounts for all transport emissions growth from 2012-2015. | |
| No change in emissions from 2015 to 2030. | No change in emissions from 2015 to 2030 except for a reduction due to the uptake of 40 PJ of biofuels. |

3 We have not considered an increase in public transport emissions so it is assumed efficiency improvements and electrification can offset the increase in services.
4 Our scenarios are both fairly close to the 'Digital Decadence' scenario in Future Demand.
5 The new vehicle efficiency standards are: EU, 95 gCO2/km by 2021; Japan 105 gCO2/km by 2020; US 93 gCO2/km by 2025. Our simple model uses NZ standards of 105 gCO2/km by 2020 and 70 gCO2/km by 2030.

Aviation, marine and rail have all maintained relatively flat emissions in recent years, so we assume this continues. All of them in fact had lower emissions in 2012 than in 2000, with increased more than offset by efficiency gains.

Road freight volume and emissions grew hugely since 1990, stalled in 2007 but have seemingly begun to increase again. The moderate ambition assumption of no increase in emissions from 2015 is therefore more challenging than for the other modes. The National Freight Demand Study projects an increase in freight tonne-km of approximately 40% from 2012-30. We assume this can be offset through a combination of mode shift to rail and marine freight,[6] efficiency gains and limited uptake of biofuels and electric vehicles.

Under the high ambition scenario we assume emissions can be further reduced primarily through uptake of biofuels in freight. We assume a supply of 40 petajoules (slightly less than other published ambitious scenarios)[7] and for simplicity we assume the biofuels are all used for road freight. We also assume that these biofuels all contribute zero net emissions. This would reduce road freight emissions from 5.5 MtCO2-e in 2015 to 2.7 MtCO2-e in 2030.

**Results**

| TRANSPORT (Mt CO2-e) | | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|
| | | | | | |
| **Baseline** | | **14.4** | **14.9** | **15.5** | **15.9** |
| | | | | | |
| **Green moderate ambition** | | **14.4** | **13.0** | **11.6** | **11.2** |
| | Difference from baseline | 0.0 | -1.9 | -3.9 | -4.7 |
| | | | | | |
| **Green high ambition** | | **14.4** | **12.5** | **10.0** | **6.8** |
| | Difference from baseline | 0.0 | -2.4 | -5.5 | -9.1 |

6 Rail and marine emissions are assumed to remain steady despite increased volumes.

7 The New Zealand Energy Revolution scenario modelled by the German Aerospace Centre for Greenpeace projects 44 PJ of biofuel supply by 2030. This is somewhat less than the New Zealand Bioenergy Strategy developed by the Bioenergy Association. We have adopted a more conservative figure given that both these pathways were developed several years ago and there has been little support from government to begin growing biofuel supply and capacity.

## 2.2 Electricity

The projection for electricity emissions in the 6NC is not provided but is “mainly based on assumptions in the ‘Mixed renewables’ scenario published in *New Zealand’s Energy Outlook: Electricity Insight* (2013), differing slightly on assumed carbon price and GDP growth. This should not have much effect on the results, so we assume we can use data from Electricity Insight.

*Assumptions:*
**Electricity:**

| *Both scenarios* | |
|---|---|
| ***Moderate ambition*** | ***High ambition*** |
| Coal-free by 2020 | Coal-free by 2020 and 100% renewable (i.e. gas-free) by 2030. |
| Emissions follow MBIE Electricity Insight ‘Global Low Carbon’ scenario to 2030. | Fossil emissions follow ‘Global Low Carbon’ scenario to 2025, then fall to zero by 2030. |
| | Fugitive emissions from geothermal as per ‘Global Low Carbon’ scenario. |

In the baseline scenario ('Mixed Renewables'), coal is in fact phased out by 2020 with the closure of both remaining Huntly units in 2019. However there is still significant generation from gas in 2030 causing emissions of 2.8 MtCO2e.

Our moderate ambition scenario simply follows another Electricity Insight scenario, 'Global Low Carbon', which has the Huntly units closed earlier and a greater reduction in gas generation, but emissions from gas plateau from about 2025 on at slightly above 2 MtCO2e. This scenario also has lower geothermal emissions than the 'Mixed Renewables' scenario as a higher carbon price leads to greater preference for wind.

In our high ambition scenario we follow the 'Global Low Carbon' scenario to 2025, and then assume emissions from gas generation can be phased to zero by 2030. This would rely on cost-effective energy storage, demand management and smart grid technologies to maintain security of supply. We also assume geothermal emissions are the same as in 'Global Low Carbon' in 2030, implying that the additional gas generation is replaced by generation (or efficiency) options other than geothermal.

We have not considered any use of carbon capture-and-storage (CCS).

Note that the convention is to account for geothermal fugitive emissions under the 'Fugitive emissions' category rather than the 'Electricity generation'. We have followed this in the summary table shown earlier.

*Results*

| ELECTRICITY GENERATION (Mt CO2-e) | | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|
| | | | | | |
| **Baseline** | | **4.8** | **4.1** | **2.9** | **2.8** |
| | *Geothermal fugitive* | *0.8* | *1.1* | *1.3* | *1.4* |
| | *Total incl. geothermal* | *5.6* | *5.2* | *4.1* | *4.2* |
| | | | | | |
| **Green moderate ambition** | | 4.8 | 3.6 | 2.0 | 2.0 |
| | Difference from baseline | 0.0 | -0.5 | -0.8 | -0.8 |
| | *Geothermal fugitive* | *0.8* | *1.1* | *1.1* | *1.1* |
| | *Total incl. geothermal* | *5.6* | *4.7* | *3.2* | *3.1* |
| | *Difference from baseline* | *0.0* | *-0.5* | *-1.0* | *-1.1* |
| | | | | | |
| **Green high ambition** | | **4.8** | **3.6** | **2.0** | **0.0** |
| | Difference from baseline | 0.0 | -0.5 | -0.8 | -2.8 |
| | *Geothermal fugitive* | *0.8* | *1.1* | *1.1* | *1.1* |
| | *Total incl. geothermal* | *5.6* | *4.7* | *3.2* | *1.1* |
| | *Difference from baseline* | *0.0* | *-0.5* | *-1.0* | *-3.1* |

# 3 Manufacturing and other (combustion)

This category is more complicated than transport and electricity due to its diversity. It essentially covers emissions from all fossil fuel combustion outside of electricity generation and transport, and its largest component is industrial heat. In *Energy Greenhouse Gas Emissions* this is s broken down as follows (with 2012 emissions estimates):

| | Subcategory | 2012 emissions (MtCO2-e) |
|---|---|---|
| **Manufacturing** | | **5.2** |
| | Chemicals | 0.9 |
| | Pulp, Paper & Print | 0.5 |
| | Food | 2.2 |
| | Mining & Construction | 0.6 |
| | Non-metallic Minerals | 0.4 |
| | Other | 0.5 |
| **'Other Sectors'** | | **3.3** |
| | Commercial | 0.9 |
| | Residential | 0.6 |
| | Primary Industries | 1.8 |

Some of the biggest single contributors are coal and gas combustion for heat for milk processing (in 'Food'), gas combustion for methanol production (in 'Chemicals') and diesel use for on-farm machinery (in 'Primary Industries').

Note that this category does not include non-combustion emissions from industrial processes (e.g. steel production), which are reported separately. It also excludes fugitive emissions and emissions from transformation (mostly oil refining) which are separate energy categories covered below.

The 6NC does not provide separated projections for any of these categories or subcategories. We estimate the emissions for the entire category by subtracting estimated electricity, transformation and fugitive emissions from the energy total based on information provided. This results in a large increase from 2012 to 2015 (8.4 MtCO2e to 10.3 MtCO2e). However this seems credible due to the expected scaling up of methanol production by Methanex.

*Assumptions:*

| ***Moderate ambition*** | ***High ambition*** |
|---|---|
| Methanol production accounts for 0.8 MtCO2-e of estimated emissions growth from 2012-2015, and the remainder is equally distributed between coal, liquid fuel and gas. | |
| Zero thermal coal use by 2030 (linear phase out). | Coal and liquid fuel use reduced to 10% and 60% of 2015 values. |
| No change in liquid fuel and gas use from 2015 to 2030. | No change in gas use from 2015 to 2030. |

Methanex made investments in 2013 which have increased its annual production capacity to 2.4 Mt of methanol, compared with production of 1.1 Mt in 2012.[8] With an assumed emissions factor of 0.67 tonnes of CO2 per tonne methanol,[9] Methanex moving to near-capacity will cause an emissions increase of 0.8 MtCO2e.

Emissions by fuel in 2012 were calculated from the 2014 GHG Inventory data tables. We add the estimated increase from methanol production to natural gas, and assume the remainder of the projected emissions growth from 2012-15 is equally distributed between coal, liquid fuel and gas. This leads to the following breakdown in 2015:

| | |
|---|---|
| Coal | 2.6 |
| Liquid fuels | 3.4 |
| Natural gas | 4.3 |
| **Total** | **10.3** |

*Assumed emissions by fuel in 2015 (MtCO2-e)*

8 Methanex 2013 Annual Report, https://www.methanex.com/sites/default/files/investor/annual-reports/Methanex-2013-Annual-Report.pdf

9 http://www.stuff.co.nz/taranaki-daily-news/news/2900627/Methanex-to-escape-ETS-penalties

Our moderate ambition scenario assumes thermal coal use (for heat) is phased out by 2030 while emissions from liquid fuel use and natural gas do not grow from 2015.

The majority of thermal coal use is in the food processing sector to provide heat for drying milk (especially in the South Island where there is no reticulated gas supply). We assume this and other uses can be progressively switched to carbon neutral biomass, geothermal heat, or electricity. There could also be some substitution to gas if other gas use is reduced elsewhere.

We assume gas and liquid fuels can be held steady through a combination of efficiency gains, electrification and fuel switching, and a shift away from emissions-intensive industries under the influence of a robust carbon price. In practice it may be very difficult or costly to eliminate the last remaining coal by 2030 and it may be easier to make gains in other areas – this scenario is simply indicative.

Our high ambition scenario is based on the New Zealand Energy Revolution scenario modelled by the German Aerospace Centre. This sees thermal coal consumption decline by around 90% and non-transport liquid fuel consumption decline by over 40% from 2015-30, while gas consumption stays roughly steady to 2030. We assume these percentage changes from our own 2015 baseline figure. In the Energy Revolution scenario this is achieved through energy efficiency combined with large growth in the use of heat pumps, geothermal heat and solar collectors to provide low-grade heat.

*Results*

| MANUFACTURING & OTHER (Mt CO2-e) | | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|
| | | | | | |
| **Baseline** | | **10.3** | **10.7** | **12.5** | **12.4** |
| | | | | | |
| **Green moderate ambition** | | **10.3** | **9.5** | **8.6** | **7.7** |
| | Difference from baseline | 0.0 | -1.2 | -3.9 | -4.6 |
| | | | | | |
| **Green high ambition** | | **10.3** | **9.1** | **7.9** | **6.6** |
| | Difference from baseline | 0.0 | -1.6 | -4.6 | -5.7 |

## 2.4 Fugitive emissions

Fugitive emissions arise from the production, processing, transmission and storage of fuel, and from non-productive combustion (e.g. gas flaring). The 6NC does not provide separated projections for fugitive emissions but states that they "make up approximately 10 per cent of projected energy emissions [excl. transport] each year between 2013 and 2030". In the absence of better information we estimate total fugitive emissions based on this statement, using 10 per cent exactly.[10,11]

*Assumptions:*

| ***Both scenarios*** |
|---|
| Geothermal emissions as per our electricity assumptions. |
| Other fugitive emissions equal to baseline projection. |

As discussed in the electricity section, we use scenarios from MBIE's Electricity Insight report to attain projections for geothermal fugitive emissions in the baseline and our scenarios. We can then calculate the remainder of fugitive emissions from other sources in the baseline scenario (by subtracting geothermal from the total). We assume no change to these in our scenarios, as they already show a significant decline based on the calculations.

Permits for most current mines expire by 2027[12] so under this policy fugitive emissions from coal mining (0.4 MtCO2e in 2012) could be expected to decline to near-zero by 2030. We would also expect a reduction in fugitive emissions from gas processing relative to the baseline scenario.

The issue of fracking also needs to be addressed. It appears that fracking is not explicitly considered in the baseline scenario, but if it were to expand in New Zealand, this could lead to significant growth in fugitive emissions.

*Results*

| **FUGITIVE EMISSIONS (Mt CO2-e)** | | **2015** | **2020** | **2025** | **2030** |
|---|---|---|---|---|---|
| | | | | | |
| **Baseline** | | **2.0** | **2.0** | **2.0** | **2.0** |
| | *Geothermal* | 0.8 | 1.1 | 1.3 | 1.4 |
| | *Other* | 1.2 | 0.9 | 0.8 | 0.6 |
| | | | | | |
| **Green moderate & high ambition scenarios** | | **2.0** | **2.0** | **1.9** | **1.7** |
| | Difference from baseline | 0.0 | 0.0 | -0.2 | -0.3 |
| | *Geothermal* | 0.8 | 1.1 | 1.1 | 1.1 |
| | *Other* | 1.2 | 0.9 | 0.8 | 0.6 |

10 We then adjust for the updated GWPs, assuming that fugitive methane emissions continue at 45 kt (approximate historical average; varied between 40 kt & 57 kt from 1990-2012).

11 We suspect that fugitive emissions are biased slightly low under this assumption, which would lead to emissions from the manufacturing & other category being biased high.

12 Coal Action Network Aotearoa (2014), Jobs After Coal.

## 2.5 Transformation

'Transformation industries' covers all energy transformation industries other than electricity generation. In 2012, petroleum refining accounted for 70% of emissions in this sector.

*Assumptions:*

| ***Moderate ambition*** | ***High ambition*** |
|---|---|
| No change from 2012. | Reduced proportional to total consumption of oil products. |

The 6NC does not provide any information about projections for transformation industries. In MBIE's Energy Outlook 2011, transformation industries are simply assumed constant at 1.3 MtCO2-e from 2012-2040. We assume that the 6NC projection does the same, and assume this in the moderate ambition scenario too – even though emissions from refining will very likely fall with reduced domestic demand for oil products.

In the high ambition scenario, we assume that there will be a reduction in proportion to the total oil product use, which is roughly halved from 2015 to 2030 under the assumptions detailed in previous sections.

*Results:*

| **TRANSFORMATION (Mt CO2-e)** | | **2015** | **2020** | **2025** | **2030** |
|---|---|---|---|---|---|
| | | | | | |
| **Baseline** | | **1.3** | **1.3** | **1.3** | **1.3** |
| | | | | | |
| **Green moderate ambition** | | **1.3** | **1.3** | **1.3** | **1.3** |
| | Difference from baseline | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | | |
| **Green high ambition** | | **1.3** | **1.1** | **0.9** | **0.7** |
| | Difference from baseline | 0.0 | -0.2 | -0.4 | -0.7 |

## (ii) Industrial Processes

This appendix explores the modest, yet significant, potential for reducing New Zealand's emissions in the industrial processes and product use sector.

Summary

New Zealand's emissions in this category occur from:

- non-combustion industrial processes that emit $CO_2$ as a waste stream, notably the manufacture of steel, aluminium and concrete; and
- release of fluoro gases (mostly HFCs) used in refrigeration, air conditioning and some other niche applications.

Total emissions for the sector in 2013 were 5.1 MtCO2-e. We estimate emissions could be cut by up to 2.1 Mt by 2030 by:

- Following EU regulation to cut fluoro gas emissions by two thirds by 2030 (1.0 Mt)
- Reducing $CO_2$ process emissions by one third - for example through uptake of New Zealand-developed technologies such as CO2 capture and 'green coke' in steel manufacture, and the closure of the Tiwai Point aluminium smelter by 2030 (1.1 Mt).

1. Breakdown of current emissions

It is helpful to divide the sector into CO2 process emissions and emissions of fluoro gases (HFCs, PFCs and SF6), known as F-emissions.

*2014 GHG Inventory*

Total emissions for the sector in 2012 were 5.3 MtCO2-e.

**(a)** CO2 emissions

Total in 2012 was 3.4 Mt. Non-negligible categories are:

- Mineral products: 752 kt.
  - Cement production: 569 kt.
  - Lime production: 112 kt.
  - Limestone and Dolomite use: 63 kt.
- Chemical industry: 419 kt.
  - Ammonia production (for urea): 168 kt.
  - Hydrogen production (at Marsden Point): 251 kt.
- Metal production: 2,240 kt.
  - Steel production: 1,719 kt.
  - Aluminium production: 521 kt.

**(b)** F-emissions

HFC emissions are most significant and almost all of these are from 'Refrigeration and air conditioning equipment'.

**Table 1**

| | HFC-32 | HFC-125 | HFC-134a | HFC-143a | HFC-227ea | Total |
|---|---|---|---|---|---|---|
| CO2-e emissions (kt) | 49.61 | 660.13 | 445.16 | 648.01 | 1.77 | 1,804.69 |

PFCs and SF6 negligible. Big contributors are HFC-125, HFC-134a and HFC-143a.

**(c)** Solvent and other product use

Negligible

*2015 GHG Inventory*

Total emissions for the sector in 2012 were 5.1 MtCO2-e

(a) F-emissions

There seems to have been a slight revision to the previous year's data, but there is insufficient information given.

*For the current Inventory of 2013 emissions, Fisher & Paykel staff revealed the complexity of their business as the key New Zealand manufacturer as well as the main importer and exporter of household refrigerators and freezers. Most of their manufacturing base shifted to a new plant in Thailand during 2012 and 2013 and the transition to hydrocarbon refrigerants is further advanced than previously reported. It was concluded only 50 per cent of household refrigerator/freezer imports in 2013 contained HFC and the hydrocarbon proportions for 2011 and 2012 were revised to 5 per cent and 15 per cent respectively (CRL Energy, 2014).*

Total of 1.6 MtCO2-e, broken down into:

- Stationary refrigeration and air conditioning (1317 kt)
- Mobile air conditioning (200 kt) - this is in cars
- Other small categories

(b) CO2 emissions

Total of 3.4 Mt, the same as in 2012.

*Sixth National Communication*

Industrial CO2 process emissions are assumed to remain constant from 2012 to 2030 at 3.4 Mt. F-emissions are projected to fall slightly to 1.5 Mt in 2015 and then grow to 2.7 Mt by 2030, with all of that growth coming from HFCs.

2. Mitigation options

(a) F-emissions / HFCs

Climate-friendly alternatives exist for refrigeration and air-conditioning systems.[13]

The EU has introduced a package of regulations to cut total F-emissions by two-thirds from 2014 levels by 2030.[14] The package includes:

- Limiting the total amount of the most important F-gases that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth of 2014 sales in 2030. This will be the main driver of the move towards more climate-friendly technologies;
- Banning the use of F-gases in many new types of equipment where less harmful alternatives are widely available, such as fridges in homes or supermarkets, air conditioning and foams and aerosols;
- Preventing emissions of F-gases from existing equipment by requiring checks, proper servicing and recovery of the gases at the end of the equipment's life.[15]

The 2015 New Climate Economy report, *Seizing the Global Opportunity*, highlights phasing down HFCs as one of its 10 key recommendations which can deliver climate benefits as well as economic benefits through improved energy efficiency.[16]

(b) $CO_2$ emissions

Aluminium manufacturing at Tiwai Point causes about 0.5 tonnes of $CO_2$ process emissions. Assuming this will close before 2030 and not be replaced, these emissions would be eliminated.

Technologies for $CO_2$ capture and re-use from industrial waste streams are being developed by the likes of Lanzatech, who have demonstrated a successful pilot at the Glenbrook steel mill.[17] Lanzatech's process can apparently capture one third of the $CO_2$ produced in steel production and convert this into ethanol, which displaces fossil fuel use.[18]

Another New Zealand company, Carbonscape, is developing technology to produce 'green coke' from biomass, which can replace coking coal as a reducing agent for steel production. Carbonscape is in the commercialisation phase and has a contract to provide 9,000 tonnes of green coke to New Zealand steel as a test sample.[19]

13 http://ec.europa.eu/clima/policies/f-gas/alternatives/index_en.htm
14 http://ec.europa.eu/clima/policies/f-gas/index_en.htm
15 http://ec.europa.eu/clima/policies/f-gas/legislation/index_en.htm
16 http://2015.newclimateeconomy.report/
17 http://www.lanzatech.com/facilities/
18 http://biotechlearn.org.nz/news_and_events/news/2012_archive/lanzatech_waste_to_fuel_tech_goes_trans_tasman
19 http://carbonscape.com/news/carbonscape-locks-down-minimum-400000-in-crowdfunding/

Such technologies could potentially be deployed at scale by 2030.

## 3. Achievable reductions

(a) F-emissions

If New Zealand could follow the EU effort of a two-thirds reduction by 2030, this would reduce F-emissions from around 1.5 Mt to 0.5 Mt - a reduction of 1.0 Mt. By comparison, emissions are projected to grow by around 1.2 Mt from current levels in the baseline.

(b) $CO_2$ emissions

Reducing CO2 emissions by roughly one third (a reduction of 1.1 Mt) by 2030 seems achievable. This could be achieved, for example, through a one third reduction in emissions from steel production (0.6 Mt), and the closure of the Tiwai Point aluminium smelter (0.5 Mt). Other process efficiencies driven by a carbon price and other measures could also contribute emissions reductions, as could structural changes to the economy (such as a decline in demand for cement).

Total

Together this gives a total emissions reduction of 2.1 Mt from 2015 (5.0 Mt, projected) to 2030 (2.9 Mt). This is approximately a 44% reduction.

## (iii) Agriculture

In this Annex we explore the potential for emission abatement in the agricultural sector. We conclude that abatement in agricultural emissions from 38.9 Mt in 2012 to within a range from 37.7 to 29.3 Mt is possible, depending on policy signals pertaining to animal numbers, productivity per animal, technology improvements and good farming practice.

In arriving at this conclusion, we address the following issues:

1. Basic Assumptions on Agriculture in Climate Protection
2. New Zealand's Agriculture Emissions Profile
3. Ambitious Abatement Potential: Scenarios
   (a) Livestock Numbers
   (b) Animal Productivity
   (c) Technology Improvements
   (d) Good Farming Practice
4. Potential Agriculture Emissions Abatement 2030

### 1. Basic Assumptions on Agriculture in Climate Protection

The extent to which agricultural emissions can be abated, using current technology, depends on underlying assumptions towards the role of NZ agriculture in the global economy.

The Government's approach rests on the following assumptions:

1. The proportion of agricultural emissions in New Zealand is much higher than other 'developed' countries (46% compared with the next highest country, Ireland at 31%).
2. The high proportion of agricultural emissions makes it difficult to reduce its overall gross emissions because of the difficulty of reducing methane from livestock and nitrous oxide from soils.
3. The country has an obligation (coupled with an export income interest) to 'feed the world' (4 m. people feeding 20 m.), responding to the projected increase in global food demand of 50% by 2050.
4. New Zealand is one of the most agriculturally productive countries; therefore the principle of 'global least cost' requires it to produce such quantities of food, rather than less other productive countries.

In contrast, the departing assumptions we adopt are the following::

1. The proportion of agriculture in national emissions is not relevant. While abatement in agricultural emissions is difficult, this is no excuse for its exclusion. As the North-South divide in climate negotiations cedes to a universal approach to global mitigation based on equity, agriculture will inevitably play a role. New Zealand must be prepared to phase in agriculture in the near future, as the 2011 Independent Panel urged.
2. FAO has estimated that, based on current technology and through feasible improvements in manure management, energy use, feed quality and animal performance, the emissions could be significantly reduced, including in New Zealand. This is explored in more detail in this paper.
3. Global food security is naturally subordinate to global sustainability. If global (and NZ national) policy does not recognise this fact, extreme weather will impose it upon us, and indeed already is. New Zealand is historically responsible for the kind of economy it has chosen to develop; if it transpires that this is a climate-dangerous economy, we are obliged to transform our economy rather than search for rationalisations. New Zealand's dairy export drive should be determined, not by maximising return from volatile short-term prices or even long-term demand projections, but by optimising production patterns within the constraints of national and global sustainability.
4. The principle of global least cost correctly applies to external mitigation by other countries assisted by New Zealand (under our Responsibility Target); but this is separate from, and must not interfere with, our national obligation to ensure ambitious domestic abatement, including in agriculture.

It is on the basis of the above judgements that we explore the abatement potential of New Zealand agriculture as part of our 2030 INDC, consistent with Green policy on agriculture.

## 2. New Zealand's Agricultural Emissions Profile

New Zealand's agricultural profile is shown in Table A.

**Table A**
**NZ Agricultural Profile 1990 and 2013**

| Category | Gas | Emissions ($CO_2$-e) | | % change | % share of agriculture sector | |
|---|---|---|---|---|---|---|
| | | 1990 | 2013 | | 1990 | 2013 |
| Enteric fermentation | $CH_4$ | 26.3 | 28.4 | 8 | 77 | 73 |
| Manure management | $CH_4$ | 0.7 | 1.2 | 65 | 2 | 3 |
| Rice cultivation | | 0 | 0 | | | |
| Agricultural soils | $N_2O$ | 6.9 | 8.5 | 23 | 20 | 22 |
| Prescribed burning | | 0 | 0 | | | |
| Field burning | | 0 | 0 | | | |
| Liming | | 0.4 | 0 | | 1 | 1 |
| Urea application | $CO_2$ | 0 | 0.5 | 490 | | 1 |
| Other | | 0 | 0 | | | |
| **Total** | | **34.3** | **38.6** | | | |

*Source: NZ National Greenhouse Gas Inventory 1990-2013, Table 5.1.1, (MfE; 15 April 2015) p. 121*

The two sub-sectors that invite attention in ensuring ambitious emissions abatement in New Zealand's agriculture are enteric fermentation and agricultural soils. A third, manure management, is also significant and there is scope for some abatement in this as well. We therefore explore the potential for abatement in each of these.

*Enteric Fermentation (Methane)*

Because of the importance of enteric fermentation (three-quarters of total agriculture emissions), we explore the emissions per animal in more depth. Table B sets out the enteric fermentation emissions per livestock category.

**Table B**
**Enteric Fermentation Emissions per Livestock Category (Mt $CO_2$-e)**

| | 1990 | 2013 | % change |
|---|---|---|---|
| Dairy cattle | 5.952 | 13.216 | 122 |
| Non-dairy cattle | 5.737 | 5.392 | -6 |
| Sheep | 13.956 | 9.223 | -34 |
| Deer | 0.415 | 0.556 | 34 |
| Other | 0.250 | 0.054 | -79 |
| **Total** | **26.310** | **28.441** | |

*Source: NZ National Greenhouse Gas Inventory 1990-2013, Table 5.2.1, (MfE; 15 April 2015) p. 142*

There is limited scope to reduce emissions per animal in the short-term, based on currently available technologies. However, reductions would be possible through increased productivity per animal over time, while reducing the number of animals, to maintain total production. Technologies currently under research and development have significant potential to increase abatement options by 2030.

***Agricultural Soils (nitrous oxide)***

**Table C**
**Agricultural Soils (Mt $CO_2$-e)**

| Category | Gas | 1990 | 2013 | % change |
|---|---|---|---|---|
| Synthetic fertilisers | $N_2O$ | 0.218 | 0.935 | 329 |
| Organic fertilisers | $N_2O$ | 0.079 | 0.148 | 88 |
| Grazing manure | $N_2O$ | 5.255 | 5.679 | 8 |
| Crop residue | $N_2O$ | 0.175 | 0.251 | 43 |
| Cropland mineralisation | | 0 | 0 | |
| Organic soil cultivation | | 0.030 | 0.030 | 0 |
| Volatilisation | $N_2O$ | 0.727 | 0.914 | 26 |
| Leaching & run-off | $N_2O$ | 0.391 | 0.496 | 27 |
| **Total** | | **6.875** | **8.453** | **23** |

*Source: NZ National Greenhouse Gas Inventory 1990-2013, Table 5.2.1, (MfE; 15 April 2015) p. 142*

- Grazing manure (5.679 Mt) is livestock manure (urine and dung) deposited by grazing livestock on ranges, paddocks and pasture, which directly emits nitrous oxide.
- Organic fertiliser (0.148 Mt) is direct nitrous oxide from adding nitrogen to the soil in the form of organic fertiliser (primarily manure), crop residue, forage and soil cultivation.
- Synthetic fertiliser (0.935 Mt) is nitrogen fertiliser, imported mainly from Western Sahara, and applied directly to agricultural land.
- Volatilisation (0.914 Mt) gives indirect nitrous oxide from the vaporisation of fertiliser applied.
- Leaching and run-off (0.496) is nitrous oxide emissions from the run-off of synthetic fertiliser.

There is scope already, based on current technologies, for reduction in some of these categories through:

1. Increased efficiency of fertiliser use (i.e., reduced fertiliser use per animal); and
2. Use of low-nitrogen feeds for dairy systems that use supplementary feeding.

*Manure Management*

Manure management differs from the other categories identified under Agricultural Soils (fertilisers and grazing manure). It comprises the emissions during the storage of livestock manure before being distributed on the land. Table D shows the two gas categories for manure management.

**Table D**

**Manure Management (Mt $CO_2$-e)**

| | | 1990 | 2013 | % change |
|---|---|---|---|---|
| Methane | Post-application | 0.685 | 1.130 | 65 |
| Nitrous Oxide | Pre-application | 0.054 | 0.089 | 67 |
| **Total** | | 0.739 | 1.219 | 65 |

Emission reductions are possible through improved manure storage of methane for flaring or biogas production for large dairy herds.

It is on the basis of the above GHG profile that we explore the potential for an ambitious agricultural emissions abatement pathway in Section 3. In exploring the total abatement potential, we therefore adopt the following approach:

- We first note the Government projection of agriculture emissions, at 44.5 Mt in 2030, up from 38.6 Mt in 2013.
- We then construct three alternative Green scenarios for agriculture in 2030, as follows:
  (a) Stabilisation scenario: the dairy and beef herds stabilise at broadly current levels according to future market influences (dairy at double the 1990 levels), while the sheep flock declines a little more before stabilising (at 40%, or 0.4 of the 1990 level).
  (b) 1990 scenario: a return to the 1990 levels for all three major livestock categories;
  (c) Co-benefit scenario: having regard to the synergy between the local environment (soil and water quality) and the global environment (emissions reduction), we use the catchment nitrate cap approach agreed in the Land and Water Forum, with different consequential impact on livestock numbers (the dairy herd falls slightly to 1.7 of the 1990 level, the beef herd to 0.7 of 1990, and sheep to 0.4 of 1990).

For each scenario, we have entered common assumptions pertaining to:

(i) Continued improvement in productivity per animal.
(ii) Some modest effect through the application over the next two decades, of methane and nitrification inhibitors consistent with Green agriculture policy.[20]
(iii) A policy goal of 50% organic production by 2025.[21]

[20] Green Agricultural & Rural Affairs Policy: "Principle 5.5: Support ways of reducing methane production per hectare & per animal, including intensified research into alternative feeds, breeding & selection of lower emitting animals, & rumen biochemistry. This may include the use of new genetic technologies in the laboratory as part of the research, but not the release of living genetically modified organisms, whether cows or bacteria, into the farm environment."

[21] Green Agricultural & Rural Affairs Policy: "Principle 3.1: 1. Promote the target of half of New Zealand's production becoming certified organic by 2025, with the remainder in the process of conversion …"

## 3. Ambitious Abatement Potential: Scenarios

The pathway for abatement in the agriculture sector is based on informed estimates of emissions that would result from a combination of factors.

*Agricultural emission drivers: developing the abatement equation*

Because virtually all agricultural emissions in New Zealand results from the farming of livestock, abatement potential is broadly correlated across all drivers, namely: livestock numbers, productivity per animal, technology improvements (including farmer uptake) and good farming practice. The measures applied are likely to have a broadly comparable effect in the major categories of gases (methane from enteric fermentation, nitrous oxide from agricultural soils, methane from manure management, and carbon dioxide from urea application).

For enteric fermentation and agricultural soils, increasing productivity per animal is expected to reduce the emissions intensity of livestock production. Without constraints on animal numbers, this would increase absolute emissions, as more productive animals produce higher emissions per head. However, they also produce more food. As a result, it would be possible to reduce absolute emissions, without reducing total food production in New Zealand, simply by further increasing the efficiency of production, continuing historical trends.

FAO has estimated that, based on current technology, "with feasible improvements in manure management, energy use, feed quality and animal performance, the emissions could be reduced … from 11% to 17% in Australia and New Zealand".[22] FAO contends that this is possible through dietary lipid supplementation (3% to 9% abatement) and improvements in manure management. While experiments in New Zealand have not yet shown such levels of reduction, some reduction should prove possible by 2030. Taking the low range of 3%, this could mean reduction on livestock emissions from 38.6 Mt in 2013 to 37.4 Mt by 2030. Emission reductions through other means should also prove possible.

*Organic agriculture and emissions*

Because of the increasing interest in New Zealand in organic farming, we explore the impact of this on New Zealand's abatement potential in more depth. FAO advances clear and positive, albeit generalised, statements about the potential role of organic farming in all countries.[23]

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[22] FAO: Tackling Climate Change through Livestock: A Global Assessment of Emissions & Mitigation Possibilities (2013), p. 77.

[23] "FAO promotes organic agriculture as an alternative approach that maximises the performance of renewable resources & optimises nutrient & energy flows in agro-ecosystems. Life-cycle assessments show that emissions in conventional production systems are always higher than those of organic systems, based on production area. Soil emissions of nitrous oxide & methane from arable or pasture use of dried peatlands can be avoided by organic management practices. Many field trials worldwide show that organic fertilization compared to mineral fertilization is increasing soil organic carbon & thus, sequestering large amounts of $CO_2$ from the atmosphere to the soil. Lower greenhouse gas emissions for crop production & enhanced carbon sequestration, coupled with additional benefits of biodiversity & other environmental services, makes organic agriculture a farming method with many advantages & considerable potential for mitigating & adapting to climate change." http://www.org/organicag/oa-specialfeatures/oa-climatechange/en/
&: "An important potential contribution of organically-managed systems to climate change mitigation is identified in the careful management of nutrients &, hence, the reduction of $N_2O$ emissions from soils. Another high mitigation potential of organic agriculture lies in carbon sequestration from soils. In a first estimate, the emission reduction potential by abstention from mineral fertilizers is calculated to be about 20% & the compensation potential by carbon sequestration to be about 40-72% of the world's current annual agricultural greenhouse gas (GHG) emissions, but further research is needed to consolidate these numbers. [p. 158] The highest mitigation potential of organic agriculture lies in carbon sequestration in soils & in reduced clearing of primary ecosystems. The total amount of mitigation is difficult to quantify, because it is highly dependent on local environmental conditions & management practices. Should all agricultural systems be managed organically, the omission of mineral fertilizer production & application is estimated to reduce te agricultural GHG emissions by about 20% – 10% caused by reduced $N_2O$ & about 10% by lower energy demand. These avoided emissions are supplemented by an emission compensation potential through carbon sequestration in croplands & grasslands of about 40-72% of the current annual agricultural GHG emissions. However, further research is needed to confirm these figures, as long-term scientific studies are limited & do not apply to different kinds of soils, climates & practices. …. Finally, certified organic products cater for higher income options for producers & hence a market-based incentive for environmental stewardship. The scaling-up of organic agriculture would promote & support climate-friendly farming practices worldwide." [p. 165] Renewable Agriculture & Food Systems: 25(2): 158-169. 'Organic agriculture & climate change, Nadia El-Hage Scialabba & Maria Műller-Lindenlauf (Cambridge University Press)
& "There is scientific evidence for lower nitrous oxide emissions from organically-managed soils when scaled to the area. However, further data from farming system comparisons are required, particularly from long-term GHG measurements covering several cropping seasons or ideally entire crop rotations. …. Substantial reductions of nitrous oxide emissions as well as enhancement of methane uptake can be reached by consequent application of 'good agricultural practice' & simple adoptions of soils management, forming together a balanced set of GHG mitigation mechanisms." Greenhouse gas fluxes in agricultural soils

To date, no study has been completed within New Zealand that produces conclusive evidence of emission reductions in specific areas directly from organic farming of livestock. It is clear, however, from the FAO studies with global application that the potential exists for organic farming, including in New Zealand, that will have a co-benefit relationship between a range of positive socio-economic goals and emissions reduction. The abatement equation we develop in Section 4 takes into account a trend towards greater organic farming.

*The effect of price signals on agriculture*

Each of our three scenarios take into account expected market developments from a carbon price signal commencing at $12.50/tonne for methane from dairy emissions, with no immediate price on emissions from sheep and beef. It also projects continuing market price volatility for milk and meat products within the context of long-term rise in global food demand.

It would, however, be left to the independent Climate Commission to propose whatever price signals it deems necessary to ensure ambitious abatement in agriculture, taking also into account other relevant policies such as water quality targets. This would be based on agreement that a certain emissions level was the official goal for New Zealand, with consequential herd/flock numbers.

*Analysing the emission drivers*

(a) Livestock Numbers

The livestock numbers in each scenario are set out below, in Table E (i, ii, and iii). We assume the same continued increase in productivity per animal based on historical trends. This implies that even where animal numbers are held constant, total food production would continue to increase (e.g. between 2020 and 2030 in the stabilisation scenario).

**Table E**
**Livestock Numbers for Three Scenarios**

***(i) Stabilisation Scenario***

| | Numbers | | | Emissions increase per animal | | |
|---|---|---|---|---|---|---|
| **Year** | **Dairy** | **Beef** | **Sheep** | **Dairy** | **Beef** | **Sheep** |
| 1990 | 3,441 | 4,593 | 57,852 | | | |
| 2012 | 6,446 | 3,734 | 31,263 | 0.93% | 1.05% | 1.15% |
| 2020 | 6,882 | 3,734 | 23,140 | 1.00% | 1.00% | 1.00% |
| 2030 | 6,882 | 3,734 | 23,140 | 1.00% | 1.00% | 1.00% |
| | Factor on 2030 / 1990 | | | | | |
| 2020 | 2.0 | 0.8 | 0.4 | | | |
| 2030 | 2.0 | 0.8 | 0.4 | | | |

***(ii) 1990 Scenario***

| | Numbers | | | Emissions increase per animal | | |
|---|---|---|---|---|---|---|
| **Year** | **Dairy** | **Beef** | **Sheep** | **Dairy** | **Beef** | **Sheep** |
| 1990 | 3,441 | 4,593 | 57,852 | | | |
| 2012 | 6,446 | 3,734 | 31,263 | 0.93% | 1.05% | 1.15% |
| 2020 | 5,000 | 4,000 | 40,000 | 1.00% | 1.00% | 1.00% |
| 2030 | 3,441 | 4,593 | 57,852 | 1.00% | 1.00% | 1.00% |
| | Factor on 2030 / 1990 | | | | | |
| 2020 | 1.5 | 0.9 | 0.7 | | | |
| 2030 | 1.0 | 1.0 | 1.0 | | | |

***(iii) Co-benefit Scenario***

| | Numbers | | | Emissions increase per animal | | |
|---|---|---|---|---|---|---|
| **Year** | **Dairy** | **Beef** | **Sheep** | **Dairy** | **Beef** | **Sheep** |
| 1990 | 3,441 | 4,593 | 57,852 | | | |
| 2012 | 6,446 | 3,734 | 31,263 | 0.93% | 1.05% | 1.15% |
| 2020 | 6,300 | 3,500 | 23,140 | 1.00% | 1.00% | 1.00% |
| 2030 | 6,000 | 3,200 | 23,140 | 1.00% | 1.00% | 1.00% |
| | Factor on 2030 / 1990 | | | | | |
| 2020 | 1.8 | 0.8 | 0.4 | | | |
| 2030 | 1.7 | 0.7 | 0.4 | | | |

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under organic & non-organic management, Andreas Gattinger, C. Skinner, A. Muller, H-M Krause, A. Fliessbach, P. Mäder Rahman G & Aksov U (Eds.) (2014) Proceedings of the 4th ISOFAR Scientific Conference. 'Building Organic Bridges' at the Organic World Congress 2014, 13-15 Oct. Istanbul, Turkey, pp. 1069-1072

(b) Productivity per Animal

Productivity per animal has been increasing for at least the past two decades through continued R&D and increased efficiency on-farm. This trend is almost certain to continue, although the rate of change is inevitably uncertain and to some extent dependent on policy. Table F shows the improvement to date, and projected improvements out to 2030.

**Table F**
**Productivity per Animal: 1990 to 2030 (Straight-line Projections)**

| | Dairy | | Beef | | Sheep | |
|---|---|---|---|---|---|---|
| **1990** | 9.7 | | 406 | | 42.6 | |
| **2012** | 13.4 | | 526 | | 51.3 | |
| **2020** | 14.7 | 51% | 569 | 140% | 55.6 | 130% |
| **2030** | 18.9 | 95% | 706 | 175% | 64.3 | 150% |

A linear continuation of historical trends may be an overestimate especially for sheep and potentially for beef, where there may be market and physiological constraints on how much heavier and fast growing animals can become. If the positive trend were to slow, this would reduce the total amount of food produced in New Zealand but would also deliver additional climate benefits (at given animal numbers) through reduced absolute emissions.

We do not see productivity gains as an imperative instrument for increasing food production, but rather a co-benefit of continued R&D, within the constraints of an optimal mix of all factors in the overall food production / sustainability equation. This is explored in Section 4.

(c) Technology Improvements

Recent research findings[24] indicate that methane emissions in livestock could be reduced by 30% to 90%.[25] In addition, selective breeding for low-emission animals can further reduce emissions per head, with no negative side-effects identified to date. In estimating the net effects on emissions in Table G, we have had regard for the following:

- the lag-time for commercial development of these technologies (minimum of 5 years from 2015);
- farmer uptake compliance rate, with assumed easier application for dairy than beef or sheep;
- the differential in efficacy among livestock (assumed higher efficacy of mitigation technologies in dairy systems) application among livestock (easier application for dairy than beef or sheep).

**Table G**
**Livestock Emissions Mitigation through Technology (relative to baseline)**

| Livestock | | 2020 | 2030 | 2020 | 2030 |
|---|---|---|---|---|---|
| | | **Methane** | **Methane** | **Nitrous Oxide** | **Nitrous Oxide** |
| Dairy | Mitigation efficacy | 0.1 | 0.5 | | |
| | Compliance | 0 | 100% | | |
| | Net effect | 0% | -50% | -5% | -10% |
| Beef | Mitigation efficacy | 0 | 0.3 | | |
| | Compliance | 0 | 70% | | |
| | Net effect | 0% | -21% | 0% | 0% |
| Sheep | Mitigation efficacy | 0 | 0.2 | | |
| | Compliance | 0 | 70% | | |
| | Net effect | 0% | -14% | 0% | 0% |

(d) Good Farming Practice

Research reports suggest that most gains in emissions abatement are likely to be achieved, not by novel technology but through ongoing improvements in management practices and improved productivity and efficiency. Work done in 2007 for MAF shows that a mix of diet changes, high sugar grasses, stand-off pads and improved drainage of wet soils can reduce $N_2O$ emissions considerably – for sheep by 16%, dairy by 28%, and beef by 25%.[26] A Dairy NZ paper confirms the feasibility of reducing emission by changing management practices. It concludes that an average, all-pasture dairy farm could decrease emissions by 30-

[24] NZ Agricultural Greenhouse Gas Research Centre and Pastoral Greenhouse Gas Research Consortium, in collaboration with Research Alliance on Agricultural Greenhouse Gases. http://www.agresearch.co.nz/news/shortlist-of-five-holds-key-to-reduced-methane-emissions-from-livestock/

[25] The preconditions for this to occur are: confirmation of initial short-term trials; and proof of no residue in milk or meats and no other side-effects.

[26] Waghorn & Dewhurst, Feed efficiency in cattle -- the contribution of rumen function, (Dexcel and Lincoln University, 2007, in Getting There, p. 9 (2009)

35% while increasing profitability by 60% through higher reproductive performance, better genetic merit cows, and better pasture management.[27]

*Stocking rates*

In particular, stocking rates for dairy have intensified since 1990, from 2.35 cows/ha to 2.85 in 2013.[28] A 50% organic policy is likely to see a destocking of the more intensive dairy farms because of lower (or zero) nitrogen fertiliser inputs, with consequently less grass-feed. This would reduce absolute emissions, mainly through lower livestock levels.[29]

**4. Potential Agriculture Emissions 2030**

Based on the above considerations, we use the following equation to calculate the likely emissions abatement range for NZ agriculture in 2030:

E = A x D (1 – (B x C))

where E = methane or nitrous oxide emissions in Mt $CO_2$_e
A = livestock numbers
B = mitigation efficacy per animal
C = rate of commercialisation and farmer uptake
D = emissions per animal, taking into account increasing productivity

The results are shown in Tables H for each of the three scenarios. The 'no abatement' scenario assumes the same future changes in animal numbers and emissions per animal as the 'with abatement' scenario, but no dedicated mitigation technologies for enteric methane or nitrous oxide from soils. Calculations are done using inventory data from 2014 (up to the year 2012), and then scaled to take into account revised GWP factors.

The results of this analysis show that agricultural emissions, which in 1990 were 34.4 Mt in 1990 and 38.9 Mt in 2012, can, depending upon the policy signals and resulting livestock numbers, result in a range in 2030 of 29.3 Mt to 37.7 Mt.

The co-benefit scenario, which cleans up New Zealand's waterways, enhances the health of soils, and reduces its agricultural emissions by the greatest extent, is clearly the preferred outcome.

We note that even in this scenario, total dairy production would still be above today's levels despite the reduction in total animal numbers, given the expected continued increase in productivity per animal.

**Table H Potential Emission Reductions (Mt $CO_2$-e)**

**(i) Stabilisation scenario**

| Livestock | Gas | | | No Abatement | | With Abatement | |
|---|---|---|---|---|---|---|---|
| | | 1990 | 2012 | 2020 | 2030 | 2020 | 2030 |
| **Dairy** | Methane | 5.2 | 11.2 | 12.9 | 14.2 | 12.9 | 7.1 |
| | Nitr. Oxide | 2.2 | 5.5 | 6.3 | 7.0 | 6.0 | 6.3 |
| | **Sub-total** | **7.4** | **16.7** | **19.3** | **21.2** | **18.9** | **13.4** |
| **Beef** | Methane | 4.8 | 4.7 | 5.1 | 5.6 | 5.1 | 4.4 |
| | Nitr. Oxide | 1.5 | 1.6 | 1.7 | 1.9 | 1.7 | 1.9 |
| | **Sub-total** | **6.3** | **6.3** | **6.8** | **7.5** | **6.8** | **6.3** |
| **Sheep** | Methane | 12.0 | 8.0 | 6.4 | 7.0 | 6.4 | 6.0 |
| | Nitr. Oxide | 3.8 | 2.7 | 2.2 | 2.4 | 2.2 | 2.4 |
| | **Sub-total** | **15.8** | **10.7** | **8.6** | **9.4** | **8.6** | **8.4** |
| **Other** | Methane | 0.6 | 0.6 | 1.2 | 1.2 | 1.2 | 1.2 |
| | Nitr. Oxide | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | **Sub-total** | **0.9** | **0.9** | **1.5** | **1.5** | **1.5** | **1.5** |
| **Sub-totals** | Methane | 22.6 | 24.5 | 25.6 | 28.0 | 25.6 | 18.8 |
| | Nitr. Oxide | 7.8 | 10.1 | 10.5 | 11.6 | 10.2 | 10.9 |
| **All livestock** | **Total** | **30.4** | **34.6** | **36.1** | **39.6** | **35.8** | **29.6** |
| | **New GWP** | **34.4** | **38.9** | **40.6** | **44.5** | **40.3** | **32.8** |

[27] Beukes, Gregorini, Romera & Waghorn, Modelling the efficacy and profitability of mitigation strategies for GHG emission on pastoral dairy farms in New Zealand (Dairy NZ for PGGRC, Dec 2008) in Getting There, p.9.
[28] NZ Dairy Statistics 2012-13, p. 7
[29] For some farms, reducing fertiliser input could reduce feed availability and hence production per animal, with some increase in emissions intensity. If farms reduce their stocking rate to adjust to the absence of fertiliser, production per animal and emissions intensity could remain constant or in some cases even increase. In that situation, farm profitability could increase through reduced input costs. This would be determined at the farm level, and thus could be influenced through optimal policy signals.

**(ii) 1990 Scenario**

| Livestock | Gas | | | No Abatement | | With Abatement | |
|---|---|---|---|---|---|---|---|
| | | **1990** | **2012** | **2020** | **2030** | **2020** | **2030** |
| **Dairy** | Methane | 5.2 | 11.2 | 12.9 | 14.2 | 9.4 | 3.6 |
| | Nitr. Oxide | 2.2 | 5.5 | 6.3 | 7.0 | 4.4 | 3.1 |
| | **Sub-total** | **7.4** | **16.7** | **19.3** | **21.2** | **13.8** | **6.7** |
| **Beef** | Methane | 4.8 | 4.7 | 5.1 | 5.6 | 5.4 | 5.4 |
| | Nitr. Oxide | 1.5 | 1.6 | 1.7 | 1.9 | 1.9 | 2.3 |
| | **Sub-total** | **6.3** | **6.3** | **6.8** | **7.5** | **7.3** | **7.8** |
| **Sheep** | Methane | 12.0 | 8.0 | 6.4 | 7.0 | 11.1 | 12.0 |
| | Nitr. Oxide | 3.8 | 2.7 | 2.2 | 2.4 | 3.7 | 5.9 |
| | **Sub-total** | **15.8** | **10.7** | **8.6** | **9.4** | **14.8** | **17.9** |
| **Other** | Methane | 0.6 | 0.6 | 1.2 | 1.2 | 1.2 | 1.2 |
| | Nitr. Oxide | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | **Sub-total** | **0.9** | **0.9** | **1.5** | **1.5** | **1.5** | **1.5** |
| **Sub-totals** | Methane | 22.6 | 24.5 | 25.6 | 28.0 | 27.1 | 22.2 |
| | Nitr. Oxide | 7.8 | 10.1 | 10.5 | 11.6 | 10.3 | 11.7 |
| **All livestock** | **Total** | **30.4** | **34.6** | **36.1** | **39.6** | **37.3** | **33.9** |
| | **New GWP** | **34.4** | **38.9** | **40.6** | **44.5** | **42.1** | **37.7** |

**(iii) Co-benefit scenario**

| Livestock | Gas | | | No Abatement | | With Abatement | |
|---|---|---|---|---|---|---|---|
| | | **1990** | **2012** | **2020** | **2030** | **2020** | **2030** |
| **Dairy** | Methane | 5.2 | 11.2 | 12.9 | 14.2 | 11.8 | 6.2 |
| | Nitr. Oxide | 2.2 | 5.5 | 6.3 | 7.0 | 5.5 | 5.5 |
| | **Sub-total** | **7.4** | **16.7** | **19.3** | **21.2** | **17.3** | **11.7** |
| **Beef** | Methane | 4.8 | 4.7 | 5.1 | 5.6 | 4.8 | 3.8 |
| | Nitr. Oxide | 1.5 | 1.6 | 1.7 | 1.9 | 1.6 | 1.6 |
| | **Sub-total** | **6.3** | **6.3** | **6.8** | **7.5** | **6.4** | **5.4** |
| **Sheep** | Methane | 12.0 | 8.0 | 6.4 | 7.0 | 6.4 | 5.5 |
| | Nitr. Oxide | 3.8 | 2.7 | 2.2 | 2.4 | 2.2 | 2.4 |
| | **Sub-total** | **15.8** | **10.7** | **8.6** | **9.4** | **8.6** | **7.9** |
| **Other** | Methane | 0.6 | 0.6 | 1.2 | 1.2 | 1.2 | 1.2 |
| | Nitr. Oxide | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | **Sub-total** | **0.9** | **0.9** | **1.5** | **1.5** | **1.5** | **1.5** |
| **Sub-totals** | Methane | 22.6 | 24.5 | 25.6 | 28.0 | 24.2 | 16.7 |
| | Nitr. Oxide | 7.8 | 10.1 | 10.5 | 11.6 | 9.6 | 9.8 |
| **All livestock** | **Total** | **30.4** | **34.6** | **36.1** | **39.6** | **33.8** | **26.5** |
| | **New GWP** | **34.4** | **38.9** | **40.6** | **44.5** | **38.0** | **29.3** |

## (iv) Waste

Summary

Waste emissions in New Zealand are primarily methane caused by anaerobic degradation of biodegradable waste disposed in landfills and other dumps (e.g. on farms). These emissions can be reduced by reducing the quantity of biodegradable waste created and disposed of (including through increased recycling and composting), and increasing the capture of methane at landfill sites and through use of biodigesters, particularly on farms.

Total emissions for the sector in 2013 were estimated at 5.3 MtCO2-e. New Zealand's waste emissions per capita are the second highest in the developed world and more than double the average. Several other countries (Austria, Belgium, Germany, Netherlands, Sweden and UK) have successfully reduced their waste emissions by more than 50% since 1990. Based on this, it should be achievable to reduce New Zealand's waste emissions by 40-70% by 2030. This would deliver a reduction of 2 to 3.6 MtCO2-e.

### 1. Breakdown of current emissions

Estimates of emissions from waste are subject to reasonably high uncertainties, on the order of ±40%.[30] Emissions reported in New Zealand's Greenhouse Gas Inventory increased significantly from 2014 to 2015. This is partly explained by the updated Global Warming Potential values (increasing from 21 to 25 for methane) but also indicates a significant upwards revision of the underlying gas emissions.

2015 GHG Inventory (1990-2013)

Total waste emissions are estimated at 5.1 MtCO2-e in 2013. This is approximately the same as in 1990, although emissions increased to a peak of ~5.4 MtCO2-e in 2005 before declining at roughly 1% per annum.

Waste emissions are primarily from methane (96.4%) followed by nitrous oxide (3.5%) and $CO_2$ (0.04%). $CO_2$ emissions from waste of biogenic origin are not reported.

Estimated emissions in 2013 break down as follows:

**Table 1**
**Waste emissions by category**

| | Solid waste disposal | Incineration | Wastewater | Total |
|---|---|---|---|---|
| Emissions (kt CO2-e) | 4,600.3 | 3.10 | 450.5 | 5,054.0 |
| Percentage of total | 91% | 0.06% | 8.9% | 100% |

The Common Reporting Format tables accompanying the 2015 GHG Inventory allow us to see a further breakdown of emissions from solid waste disposal, shown in Table 2.[31]

**Table 2**
**Methane emissions from solid waste disposal, by site**

| | Managed waste disposal sites (municipal landfills) | Unmanaged waste disposal sites (including farm dumps) | Uncategorised waste disposal sites | Total |
|---|---|---|---|---|
| Methane emissions (kt CH4) | 80.66 | 101.32 | 2.03 | 184.01 |
| Percentage of total | 44% | 55% | 1% | 100% |

[30] MFE (2015), Greenhouse Gas Inventory 1990-2013, p. 293.

[31] Note that the 2015 Common Reporting Format tables were not published until late-July. In other sectors we have relied on the 2014 CRF tables, but here we have updated the analysis because the waste sector showed a significant revision from the previous year. Other sectors were largely unchanged.

## 2. Mitigation options

Methane emissions from solid waste can be reduced by reducing the quantity of biodegradable waste created and disposed of in landfills or unmanaged dumps (including through increased recycling and composting),[32] and increasing the proportion of methane capture.

According to the UNFCCC GHG database,[33] New Zealand has the second highest waste emissions per capita of developed countries, behind only Cyprus (see Figure 1). New Zealand's level is more than double the developed country average; simply reducing to this level would be a 56% cut. Note that this data predates the 2015 Greenhouse Gas Inventory, which has seen New Zealand's methane emissions from solid waste disposal revised up by about 24% from the previous estimate used here (from the 2014 GHG Inventory).

The UNFCCC database also shows that developed countries overall reduced waste emissions by around 10% from 1990-2012 (see Figure 2). Several countries (Austria, Belgium, Germany, Netherlands, Sweden and UK) reduced their waste emissions by more than 50% over this period.

The UK Committee on Climate Change reports that the UK has reduced waste emissions by 67% since 1990.[34,35] Emissions were approximately flat to 1999, meaning this reduction has occurred over a period of roughly 15 years. This is almost entirely due to reduced methane emissions from landfill sites. Biodegradable waste sent to landfill was reduced by 70% since 1990, and the overall methane capture rate at landfills is estimated to have increased from 1% in 1990 to 61% today. By comparison New Zealand's overall methane capture rate (across all landfills) is estimated at ~40%, up from ~10% in 1990.[36,37] We could not find any data on quantities of biodegradable waste landfilled in New Zealand.

These figures suggest considerable potential to further reduce emissions through reducing biodegradable waste to municipal landfills (e.g. through food waste collection in urban areas) and by improving overall methane capture rates through new system installations and improved practices.

However the bigger problem, shown in Table 2, is smaller, unmanaged waste disposal sites, which contribute 55% of total methane emissions from solid waste. Farm dumps are estimated to make up around 60% of this.[38] Such sites have apparently been regulated out of existence in the UK,[39] as all waste disposal on land must be run as a properly managed landfill requiring a permit or license.[40] They remain unregulated in New Zealand, and are not covered by either the waste levy or the Emissions Trading Scheme.

By bringing unmanaged waste facilities and farm dumps under regulation, and/or offering education and incentive-based schemes, methane emissions could be reduced through:

- Reducing dumping of biodegradable waste (such as green waste) in favour of composting;
- Diverting biodegradable waste to larger-scale facilities with methane capture systems (e.g. through rural waste collection subsidised by waste levy revenue)[41];
- Uptake of anaerobic biodigesters (e.g. on farms), producing and capturing methane which can then be used as a renewable energy source on-site.

3. Achievable reductions

Given New Zealand's per capita waste emissions far exceed the current developed country average, and based on reductions achieved over the last two decades in several countries, it seems achievable to reduce waste emissions by around 40-70% from current levels by 2030.

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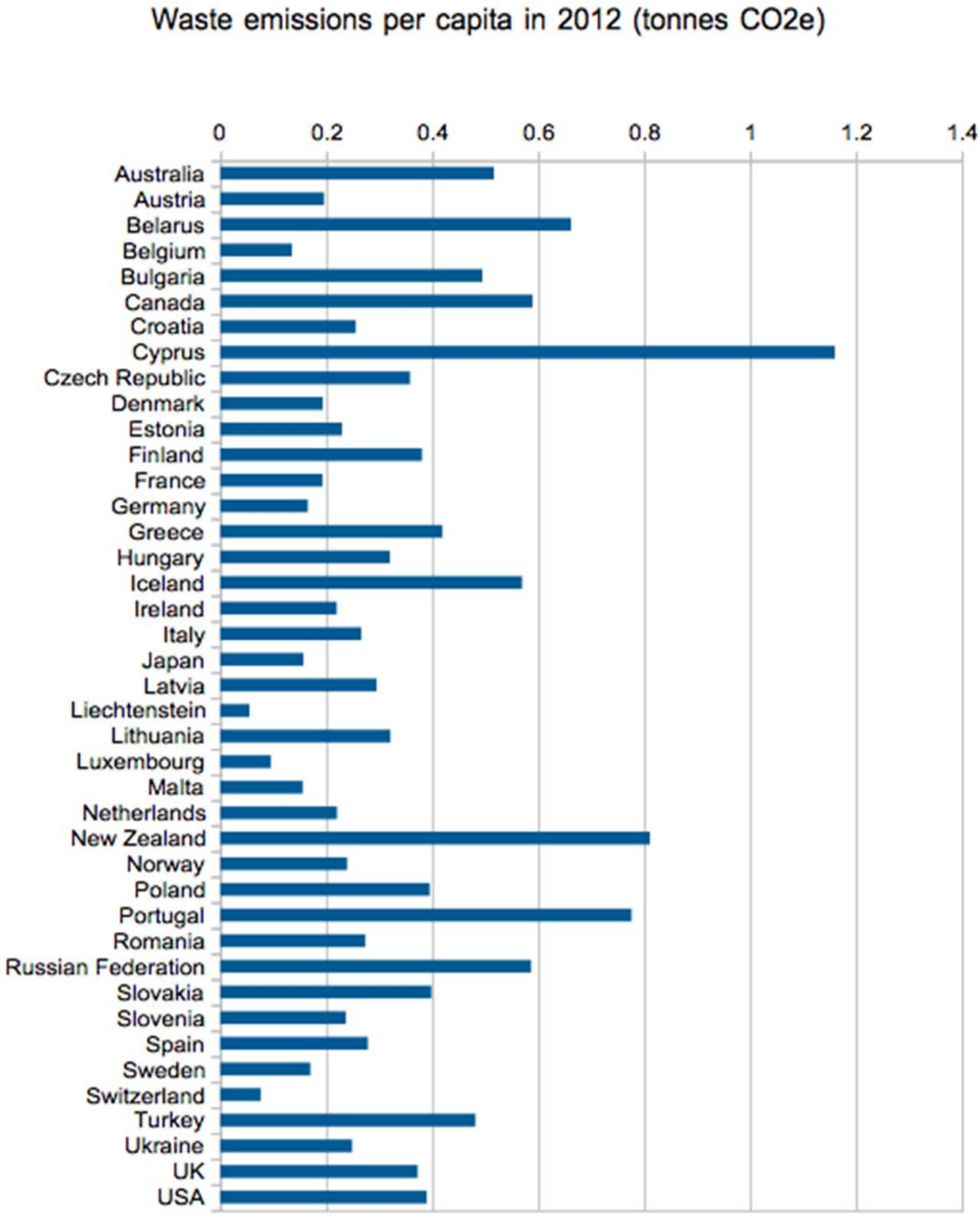
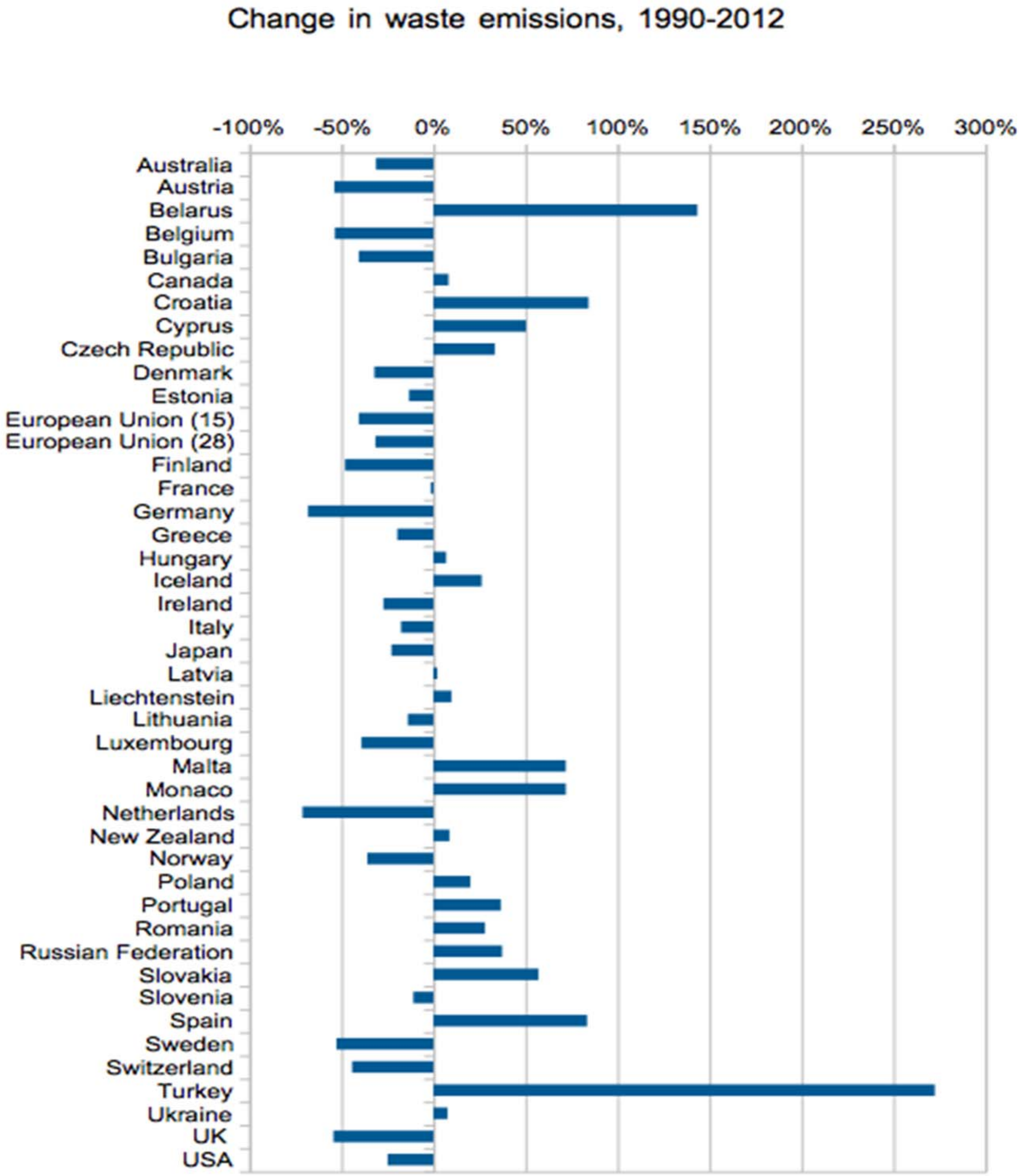
32 Composting food and organic waste does not produce significant methane as it is an aerobic process rather than anaerobic
33 http://unfccc.int/di/FlexibleQueries/Event.do
34 Committee on Climate Change (2015). Meeting Carbon Budgets - Progress in reducing the UK's emissions 2015 Report to Parliament https://www.theccc.org.uk/wp-content/uploads/2015/06/6.737_CCC-BOOK_WEB_030715_RFS.pdfhttps://www.theccc.org.uk/wp-content/uploads/2013/06/CCC-Prog-Rep_Chap7_singles_web_1.pdf
35 Note that this is higher than the reduction reported in the UNFCCC GHG database (54%).
36 MFE (2015), Greenhouse Gas Inventory 1990-2013, p. 298.
37 New Zealand's Sixth National Communication, p. 119.
38 Emissions from farm dumps are reported separately from other unmanaged landfill sites in the Common Reporting Format tables for the Greenhouse Gas Inventory 1990-2012 (produced in 2014).
39 http://uk-air.defra.gov.uk/assets/documents/reports/cat07/1501271259_Waste_sector_2006GL_compliance_report.pdf
40 http://www.fwi.co.uk/news/farm-dumps-to-be-run-as-landfill.htm
41 http://www.mfe.govt.nz/publications/waste/waste-policy-discussion-potential-unintended-consequences-national-waste-levy/6

**Figure 1**



Waste emissions per capita in 2012 (tonnes CO2e)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Australia
Austria
Belarus
Belgium
Bulgaria
Canada
Croatia
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Japan
Latvia
Liechtenstein
Lithuania
Luxembourg
Malta
Netherlands
New Zealand
Norway
Poland
Portugal
Romania
Russian Federation
Slovakia
Slovenia
Spain
Sweden
Switzerland
Turkey
Ukraine
UK
USA

**Figure 2**



Change in waste emissions, 1990-2012
-100%
-50%
0%
50%
100%
150%
200%
250%
300%
Australia
Austria
Belarus
Belgium
Bulgaria
Canada
Croatia
Cyprus
Czech Republic
Denmark
Estonia
European Union (15)
European Union (28)
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Japan
Latvia
Liechtenstein
Lithuania
Luxembourg
Malta
Monaco
Netherlands
New Zealand
Norway
Poland
Portugal
Romania
Russian Federation
Slovakia
Slovenia
Spain
Sweden
Switzerland
Turkey
Ukraine
UK
USA

## (iv) Land Use, Land-use Change & Forestry

This Annex explores the potential for ambitious abatement in New Zealand, in terms of land use, land-use change, and forestry (LULUCF). This potential rests on optimal government policy for both the public and private sectors.

## 1. Total NZ Land Availability

Table 1 shows the current utilisation of land in New Zealand.

**Table 1**

**Land Use in New Zealand 2013**

| Land Use Category | Sub-category | Area (ha) | | % Total Area | |
|---|---|---|---|---|---|
| Forest Land | Natural forest | 7,834,943 | | 29% | |
| | Pre-90 planted forest | 1,437,525 | | 5% | |
| | Post-89 forest | 659,332 | | 2% | |
| | Subtotal | | 9,931,801 | | 37% |
| Cropland | Annual | 371,791 | | 1% | |
| | Perennial | 104,534 | | 1% | |
| | Subtotal | | 476,325 | | 2% |
| Grassland | High-producing | 5,808,111 | | 22% | |
| | Low-producing | 7,544,632 | | 28% | |
| | With woody biomass | 1,363,634 | | 5% | |
| | Subtotal | | 14,716,377 | | 55% |
| Wetlands | Open water | 511,245 | | | 2% |
| | Vegetated | 139,124 | | | |
| | Subtotal | | 680,922 | | |
| Settlements | | | 224,733 | | 1% |
| Other land | | | 895,010 | | 3% |
| **Total** | | | **26,925,168** | | **100%** |

Source: *New Zealand's Greenhouse Gas Inventory 1990-2013, MfE, 10 April 2015. Table 6.1.2, p. 194*
*NB: The two Wetlands areas are taken from LUCAS table (MfE) and do not equate to 680,922*

The country is comprised of nearly 27 m. ha. of which 55% is grassland (exotic and native tussock), 29% is natural forest and 7% is plantation forestry. It is the trade-off between the two land uses of pasture production and forestry that determines the economic and ecological fate of the country, and its climate profile. This paper assumes that existing native forest cover remains in native species.

## 2. Reporting and accounting basis for New Zealand's Target

Reporting and accounting of LULUCF is complex because of different rules between the Framework Convention and the Kyoto Protocol. The Convention reporting requirements are simply for reporting and are broader in scope; those under the Protocol are for the purpose of ensuring compliance with legal commitments and are narrower in scope.

- The Convention reporting covers the entire LULUCF sector;
- The Protocol reporting covers a subset of the LULUCF sector, namely selected activities since 1990.

New Zealand has taken its 2020 target under the Framework Convention (and the target is not therefore legally-binding) in preference to a binding target for the second commitment-period (2013-20) under the Kyoto Protocol. It has, nonetheless, committed to remain a party to the Protocol and report under the Kyoto accounting rules, at least for the 2013 - 20 target.[42]

*Application of Framework Convention Accounting Rules for NZ Land Use, Land-use Change and Forestry*

Reporting under the Framework Convention, New Zealand has reported the following emissions in the LULUCF sector (Table 2).

[42] NZ Greenhouse Gas Inventory 1990-2013 (MfE; April 2015), p. 334

**Table 2**
**NZ Emissions for the LULUCF Sector, 1990-2013 (Mt $CO_2$–e)**

| | | | |
|---|---|---|---|
| **Category** | **1990** | **2013** | **%** |
| Forest land | -30.2 | -33.7 | 11% |
| Cropland | 0.4 | 0.4 | -7% |
| Grassland | 1.1 | 6.5 | 486% |
| Wetlands | 0 | 0 | -122% |
| Settlements | 0 | 0 | -300% |
| Other land | 0 | 0 | 299% |
| Total LULUCF | -28.7 | -26.8 | -7% |

*Source: NZ Greenhouse Gas Inventory 1990-2013, MfE, 10 April 2015. Table 6.1.1, p. 191*

As Table 2 shows, New Zealand's LULUCF activities amount to a considerable carbon sink. Not all of the above activities, however, qualify for the Kyoto Protocol accounting. In fact, of the 27 Mt net removals in 2013, only 12 Mt were reported under the Kyoto Protocol (see Table 3 below). This is explained in the next section.

*Application of Kyoto Accounting Rules for NZ Forestry*

The Kyoto Protocol distinguishes between two types of forest reporting and accounting:
- Article 3.3 concerns afforestation, reforestation and deforestation of post-'89 'Kyoto' forests (plus any deforestation of pre-90 forest);
- Article 3.4 concerns land use, land use change and forest management of pre-90 forests (both natural and exotic plantation). The categories are forest management; cropland management; grazing land management; re-vegetation plus wetland drainage and re-wetting).

The Protocol has different reporting/accounting rules for 3.3 and 3.4:
- For Kyoto's 1st commitment period of 2008-12 (CP-1), states were obliged to account only for article 3.3 activities, and it was optional whether or not to account for article 3.4 activities. New Zealand elected not to account for article 3.4 activities in CP-1.
- For Kyoto's 2nd commitment period (CP2 2013-20), reporting of forest management under Article 3.4 is mandatory. For the other activities under 3.4 (cropland management; grazing land management; re-vegetation plus wetland drainage and re-wetting), reporting remains voluntary. New Zealand has elected not to report on these.

Given the large land area in New Zealand under natural forest, the mandatory requirement to report/account for forest management of pre-90 forest under 3.4 makes a major difference to our reporting and accounting for the period from January '13. Table 3 shows the net sequestration of forestry activity in New Zealand for the first such relevant year (in 2013) under 3.3 and 3.4.

**Table 3**
**NZ Emissions Reported under Article 3.3 and 3.4 of the Kyoto Protocol in 2013**

| **Kyoto Protocol Article** | **Activity** | **Gross Area (ha) 1990-2013** | **Net Area (ha) 2013** | **Emissions ($CO_2$ Mt–e) 2013** |
|---|---|---|---|---|
| 3.3 | Afforestation/reforestation | 682,189 | 659,332 | -17.057 |
| | Deforestation | 168,024 | 8,453 | 4.892 |
| | Accounting quantity | | | -12.165 |
| 3.4 | Forest Management: | | | |
| | Emissions from land | | | -5,074 |
| | Harvested wood products | | | -3,225 |
| | | | 9,272,279 | -8.299 |
| | Total net emissions | | | -20.464 |
| | Natural disturbance | | 0 | 0 |
| | FMRL[43] | | | 11,150 |

[43] FMRL: Forest Management Reference Level:
- Accounting for emissions from forest management under Article 3.4 will be against a business-as-usual projected reference level (FMRL);
- New Zealand therefore takes responsibility for emissions from land under forest management where these emissions are greater than the reference level (FMRL);
- New Zealand's FMRL for CP2 (2013-20) is 11.15 Mt. $CO_2$–e net emissions.
- New Zealand's forest management emissions for 2013 (net removal of -8.299 Mt.) is below the FMRL and thus New Zealand has no accounting liability in 2013 for forest management.

*Source: NZ Greenhouse Gas Inventory 1990-2013, MfE, 10 April 2015. Table 11.1.1, p. 333; & p. 340*[44]

In clarifying the methodological basis of forestry for New Zealand's INDC for 2030, we make the following assumptions:

1. The reporting/accounting basis for Article 3.3 remains the same;
2. The reporting/accounting basis for Article 3.4 remains the same (including the same FMRL of 11.15 Mt), but we develop an estimate of potential further net removals under forest management beyond the 2013 figure of -8.299 Mt. and enter that increment net removal as part of our INDC target.

The task is therefore to assess the potential amount of further net removals under both article 3.3 and 3.4: what can New Zealand achieve between 2016 and 2030 for its 2030 INDC? Section 3 explores this, calculating what available land might be dedicated for forestry and what tree species might best be planted.

## 3. Ambitious Abatement Potential for NZ Forestry (under Kyoto Accounting Rules)

### *(a) Kyoto 3.3: Post-89 Exotic Plantation Forests*

The information below explores what we judge to be possible, given optimal policy signals for both public and private sectors, with regard to exotic plantation forests under Kyoto's 3.3.

Our analysis below concerns a dual-scenario for the period 2016 to 2030:

(i) Minimising the deforestation of post-89 exotic plantation.
(ii) A 'Rapid Afforestation Scheme'.[45]

#### *(i) Minimising Projected Deforestation*

The 'low emission scenario' entered in the 6th National Communication assumes a carbon price of NZ$25 / tonne $CO_2$-e, and 'average' annual rates of change: deforestation at 3,400 ha and afforestation at 14,300 ha. The scenario assumes post-'89 forest rotation ages of 32 years.[46] Table 4 shows the resulting net emissions:

**Table 4**
**Net Emissions from LULUCF as presented in the 2013 GHG Inventory**
**(1990 – 2011) and projected (2010-30): Low Scenario (Mt $CO_2$-e)**

| 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|---|---|---|
| -26.995 | -24.150 | -25,975 | -23,738 | -20,370 | -16,101 | | | | |
| | | | | | | -8,972 | -9,144 | +6,795 | +2,561 |

*Source: 6th National Communication*

In our judgement, this 'low emissions' scenario of $25/tonne is inadequate to respond to the climate change crisis; indeed the projected transformation of New Zealand's forestry from a carbon sink to a source is the direct result of two factors: an absence of a national sustainable forestry plan and an inadequate ETS carbon price. While it will be the task of the Climate Commission, we assume here that an appropriate carbon sequestration price would be put in place to ensure both the minimisation of the projected deforestation and a rapid afforestation scheme described in sub-section (ii) below.

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[44] Note:

1. The net figure of -12.165 Mt. is the total of all emissions and removals under Article 3.3 and includes:
   - Removals from growth of post-89 forest;
   - Removals from harvested wood products from afforestation land;
   - Emissions from harvested wood products from afforestation land;
   - Emissions from conversion of land to post-89 forest;
   - Emissions from harvesting of forests planted on non-forest land post-89;
   - Emissions from deforestation of all Forest Land categories;
   - Emissions from biomass burning plus mineralisation of soil nitrogen, post-89.
2. The net figure of -8.299 Mt is the net emissions from forest management under Article 3.4 and includes:
   - Removals from growth of pre-90 natural forests;
   - Removals from growth of pre-90 planted forests;
   - Emissions from harvesting of these forests;
   - Emissions and removals from harvested wood products;
   - Emissions from biomass burning.

[45] The schemes currently underway are the Afforestation Grant Scheme (AGS), the East Coast Forestry Scheme (ECFS) and the Permanent Forest Sink Initiative (PFSI). In May 2015, the Govt. announced a boost to the AGS, with grants of $1,300 / ha for new forest planting, in order to ensure 15,000 ha. planted from 2015-20. Our Plan envisages greater financial incentives.

[46] New Zealand's Sixth National Communication under the UN Framework Convention on Climate Change and Kyoto Protocol (Dec. 2013), pp. 114-118)

It is a reasonable assumption that, under a strong carbon price and other policies to contain further expansion of dairying, the projected level of deforestation could be limited to the lower bound projection in MPIs' 2014 Deforestation Survey (about 2,500 ha per year from 2020). At the extreme, we could assume that deforestation is completely halted, or that any which does occur is offset, but we have entered a high-ambition scenario of a 4 Mt reduction in deforestation through the 2020s, including in 2030. This improves the projected deforestation from a baseline figure in 2030 of 4.7 Mt to 0.7 Mt. and this is entered into Table 9 below.

We have not entered any calculation pertaining to delayed harvests of crop forest (through increasing rotation age) by way of higher carbon price signals.

*(ii)* Rapid *Afforestation Scheme*

In this subsection we develop a Rapid Afforestation Scheme that will significantly assist maximising New Zealand's abatement potential. The Scheme is based on new planting forest of 1.3 m. ha over the next 26 years (2016 to '40) at a rate of 50,000 ha. per year. The figures entered in Table 1 are based on the following:

- Geographic Information System layers describing land titles[47],
- Land Use Capability classes from the New Zealand Land Resource Inventory[48], and
- Erosion Susceptibility classes defined by Mark Bloomberg et al. in 20113[49].

The classes included and excluded in our analysis are shown in Table 5.

**Table 5**
**Potential Land for Rapid Afforestation Scheme (ha.)**

| | North Island | South Island | New Zealand | % |
|---|---|---|---|---|
| **Included** | | | | |
| Depleted Grassland | 163 | 84,337 | 84,500 | 6% |
| Gorse and/or Broom | 67,159 | 119,328 | 186,487 | 14% |
| Low-producing Grassland | 219,758 | 850,905 | 1,070,663 | 78% |
| Mixed Exotic Shrub-land | 7,178 | 29,974 | 37,152 | 2% |
| **Excluded** | | | | |
| Nth. Island land over 900 m ASL | | | | |
| Sth. Island ;and over 700 m ASL | | | | |
| **Total** | **294,258** | **1,084,544** | **1,378,802** | |

*Source: Land Cover Database v. 4*

We created a mask that provided estimates of "Kyoto compliant" land: that is, land not currently in forest but which could reasonably be planted in forest, based on the LCDB v4.0 dataset in Table 5. The included environments are thus a subset of Table 5. These are:

| |
|---|
| Gorse and/or broom |
| High producing exotic grassland |
| Low producing exotic grassland |
| Short-rotation cropland |
| Landslides |

We have confined ourselves to land where erosion potential is high or very high, and in the mixed native & exotic options, we confined exotic planting to threatened environment (classes 4-6).

In developing a rapid afforestation scheme, the approach we have adopted is as follows:

1. *Main factors:*
   (a) There is over 1.3 million ha of erosion-prone land that is Kyoto-compliant, which has predominantly exotic vegetation cover (mostly low-producing grassland) where rapid-sequestering exotic tree species can grow.
   (b) The premium that exists with rapid exotics (such as pinus radiata, eucalyptus, and to a lesser extent, firs and redwoods) over other species in terms of its faster sequestration commencement (about 4 years rather than 17), which is a major consideration for urgent and ambitious emissions abatement. We also note, however, the imperative of protecting and promoting biodiversity in New Zealand. The two goals of ambitious emissions abatement and biodiversity protection need to be fully respected.

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47 https://data.linz.govt.nz/layer/804-nz-property-titles/
48 https://lis.scinfo.org.nz/layer/76-nzlri-land-use-capability/
49 Bloomberg, M., Davies, T. & Morgenroth, J., 2011, Erosion Susceptibility Classification and Analysis of Erosion Risks for Plantation Forestry, https://data.mfe.govt.nz/layer/2373-erosion-susceptibility-4-classes-2012/

(c) We have simulated sequestration rates using models for three sites representing low, medium and high productivity, all estimates are weighted by estimated productivity of the 1.3 m ha.
(d) For radiata pine, we simulated planting 1,000 stems/ha, and leaving this to grow, with a typical pruned and harvested regime on each site type, with sequestration rates of at least 27 tonnes $CO_2$/ha/year,.
(e) We have allowed for average sequestration rates for native forest from 3.8 to 9.1 tonnes $CO_2$/ha/year, depending on site type, with a slowed development that otherwise mirrors that of planting and leaving radiata pine.

2. *Nine Scenarios*
On the basis of the above factors, we have constructed nine scenarios:
(i) Plant and leave the entire area in radiata pine or other rapid exotics, at a planting rate of 50,000 ha/year over 26 years;
(ii) Plant at the same rate but prune, thin and harvest all of it at an appropriate time then replant;
(iii) A 50/50 mixture 1 and 2
(iv) Plant the total area in native forest at 100,000 ha/year;
(v) A 50:50 mix of 1 and 4 with 1 confined to the 3 least threatened environments;
(vi) A 50:50 mix of 3 and 4 with 1 confined to the 3 least threatened environments
(vii) A 50-50 mix, planting all the pine in the first 13 years, then the native species in the second 13 years.
(viii) A75% exotics / 25% natives mix, confining the exotics to the least-threatened environments, planting both for 26 years, no harvesting.
(ix) A 75-25 mix, planting all the exotics in the first 20 years, followed by the native species; no harvesting.

In the Appendix (Table 9) we calculate the total sequestration from each of the nine scenarios, and we have entered the sequestration results, for both 2020 and 2030, for eight of these scenarios in Table 6 below (Scenario 4 has been discounted).

**Table 6**

**Sequestration under Article 3.3 (1.3 m ha New Planting; first phase 2016-30)**

| | | 2030 |
|---|---|---|
| Scenario 1 | 100% rapid exotics, left | 30.5 |
| Scenario 2 | 100% rapid exotics, pruned, thinned, harvested | 15.2 |
| Scenario 3 | 100% rapid exotics, 50% left; 50% harvested | 22.8 |
| | 50% rapid exotics, 50% native; benign environment | 14.6 |
| Scenario 6 | 50% rapid exotics [mixed treatment], 50% native left | 11.0 |
| Scenario 7 | 50% rapid exotics [mixed], 50% native left; all exotics first | 29.1 |
| Scenario 8 | 75% rapid exotics, 25% native, left, 3 least-threatened areas | 22.9 |
| Scenario 9 | 75% rapid exotics, 25% native, left, | 31.4 |

The range of potential sequestration for 2030 is thus from 12.4 Mt to 34.9 Mt. This range is entered in Table 9.

The financial incentives for such sizeable planting areas, whose exotic species would be left unharvested, would require a robust carbon price signal. Forestry sequestration involves encouraging carbon farmers assuming an indefinite liability that can impact on land values. The economics of carbon framing are not explored in this paper but will be a matter for a separate paper and, ultimately, an independent climate commission. A robust price signal would be required (minimum of NZ$20), but this is probably in line with global price trends over the next two decades.

*A Long-term Sustainable Land-use Plan*

These scenarios are driven by the need to address the climate crisis in the short-term – between 2015 and 2030 (the target-year for the Paris Agreement). The 2°C threshold requires global emissions to peak around 2030, for global emissions to remain within the Global Carbon Budget, and for New Zealand to do everything it is capable of doing during this period; hence the emphasis on rapid-sequestering exotics in the short-term. The sequestration rates used are shown in the Appendix (Figure 2).

This can be depicted in terms of the effect on the global temperature. In broad terms, a 10 Mt differential in New Zealand's emissions, emulated on a global scale at about 10 Gt,, is equivalent to about 0.3°C difference in global temperature. So the difference between, for example, scenario 6 (11.0 Mt) and scenario 9 (31.4 Mt) is equivalent to some 0.6°C. That is a major consideration.

Once the global climate crisis is properly addressed, the emphasis can switch from emissions abatement to biodiversity values. Post-2030 or post-2050, the emphasis can switch to indigenous species, which are much less effective in sequestration but of greater biodiversity value. Indeed, it is possible to envisage an overall sustainable land-use plan in which the short-term focus on emissions abatement becomes compatible with a longer-term focus on biodiversity, involving primarily indigenous species..

*The issue of wilding pines*

While the $CO_2$ sequestration analysis outlined here has been done using functions applicable to radiata pine, it is recognised that a variety of species may be employed by landowners. Many of these species grow more slowly than radiata pine and hence sequester $CO_2$ at a lower rate. In addition, most alternative species pose a far greater wilding risk than radiata pine does, particularly on less fertile sites where downwind management is likely to be less intense than on more fertile sites. Commonly used exotic species have been rated for wilding risk into five groups, in order from least risky to most risky: 1. Radiata pine, Muricata pine; 2. Ponderosa pine; 3. Larch; 4. Lodgepole pine and Douglas fir; 5. Scots pine and Corsican pine

The extent of risk will depend also on the exposure of the planting site ("take off" sites are most risky), and also the intensity of downwind land management, with lower intensity conferring higher risk. Provision should be made for management of wildings in any afforestation incentive scheme."

### *(b) Kyoto article 3.4: Forest Management of Pre-90 Forests*

For the subsequent period, from 2013 onward, all states must account for forest management of pre-90 forests (both natural and exotic) under Article 3.4. For New Zealand, with its vast natural forest (7.8 m. ha) and significant pre-90 exotic (1.4 m. ha) covering 34% of our land cover, this has far-reaching implications.

For 2013, management of pre-90 forests returned a net mitigation of -8.299 Mt. Under Kyoto, reporting of emissions on forest management land is against a BAU reference level (FMRL) which for New Zealand is 11.15 Mt for each year. Emissions below the FMRL are excluded from New Zealand's accounting during the period 2013-20. Given that New Zealand's reported FM emissions for 2013 are some 19 Mt below the FMRL (-8.299 Mt as opposed to +11.15 Mt), New Zealand is not obliged to account for these for 2013-20. In fact, it would have been preferable for New Zealand to have done so, because it represents a large net sink.

In any event, determining an INDC for 2030, and accounting for the outcome in that year, we make two assumptions: (a) the reference level (FMRL) will not exist or will be zero; and (b) if the FMRL does exist, New Zealand will waive it on the grounds of reporting a significant net sink.

The challenge is to see whether this net mitigation can be increased between 2015 and 2030. In its 2009 study of potential mitigation, the Green Party estimated that some 10.75 Mt could be sequestered during Kyoto CP-2 (2013-20) as follows:

- pest control on 219,000 ha DOC land 8.75 Mt
- pest control on 54,000 ha private land 2.0 Mt[50]

We have entered these estimates into the period 2020-2030, assuming an annual sequestration of 1.5 Mt.[51]

Table 7 sets out potential mitigation opportunities under forest management beyond the 2013 net level.

**Table 7**
**Mitigation under Article 3.4 (9.2 m for ha Forest Management)**

| | | 2013 | 2020 | 2030 |
|---|---|---|---|---|
| | Natural | | | |
| | Exotic | | | -1.5 |
| | Total | -8.299 | | -9.75 |

We have added this 1.5 Mt additional sink to the 2030 forest management figure in Table 9 below.

### *(c) Kyoto article 3.4: All Activities*

Article 3.4 extends to activities beyond simply forest management, namely: management of cropland, grassland and wetlands; settlements; and other land. Unlike forest management for which reporting is mandatory from 2013, the other activities are elective and New Zealand has elected not to declare these activities for accounting purposes under Kyoto for the 2013-20 period and the 2020 target.

Despite this, New Zealand does report the emissions for these activities under the Framework Convention (LULUCF). The emissions for article 3.4 emissions are in Table 8, with our estimates of future emissions. For 2030, we judge that New Zealand should include all Kyoto article 3.4 activities in reporting and accounting for the INDC.

[50] 'Getting There (Green Party, August 2009), p. 12. The estimates are based on Burrows et al, Effects of the control of wild animal herbivores on carbon stocks (Landcare Research 2008).
[51] See MfE comment on 'Getting There': "The Greens' Emission Reduction Plan" (MfE, 4 Sept. 2009) released under OIA, p. 7. The Ministry estimates that the 10.75 Mt sequestration over the 2013-20 period gives an annual figure of 1.095 Mt in the year 2020. We have estimated a sequestration figure of 1.5 Mt for the year 2030 – utilising the delay which now allows over a longer time-period (and greater funding) that will ensure more effective pest control practices.

**Table 8**

**Total Article 3.4 Emissions reported under the Framework Convention**

| | Emissions (Mt $CO_2$–e) | | | | |
|---|---|---|---|---|---|
| **Land use category** | **1990** | **2012** | **2013** | **2020** | **2030** |
| Forest management | | | -8.299 | | -9.750 |
| Cropland | 0.479 | | 0.443 | 0.443 | 0.443 |
| Grazing land | 1.104 | | 6.470 | 5.991 | 5.511 |
| Wetlands | -0.022 | | 0.005 | 0.005 | 0.005 |
| Settlements | 0.002 | | -0.005 | -0.005 | -0.005 |
| Other land | 0.008 | | 0.031 | 0.031 | 0.031 |
| **Total** | | | | | **-3.765** |

*Source:* *NZ Greenhouse Gas Inventory 1990-2013, Table 6.1.1, p. 191*
*The figures in green are estimates entered in this paper.*

*Grazing land management:*
Table 8 shows that apart from forest management, grassland management is the only significant category. This has increased considerably as a result primarily of the recent switch to dairying, from 1.1 Mt to 6.5 Mt. There should therefore be scope for significant reduction in this by 2030. The IPCC has indicated various ways in which emissions from grazing land management can be reduced, namely reduced grazing intensity, increased productivity, nutrient management, better fire management, species introduction, improved feeding practices, dietary additives, and longer-term management changes and animal breeding.[52] In light of this, we have entered a reduction of 15% in emissions from grazing land management, consistent with the reduction in agricultural emissions of scenario 3, adopted in the Agriculture Annex.

## 4. Determination of All Kyoto Article 3.3 and 3.4 Activities for NZ's 2030 Target

Having regard to the above considerations, our estimate of emission trends for all Kyoto Article 3.3 and 3.4 activities for New Zealand's 2030 target is shown in Table 9.

**Table 9**

**Potential Emission Outcomes under Kyoto Article 3.3 and 3.4**

| | Emissions (Mt $CO_2$–e) | | | | |
|---|---|---|---|---|---|
| | | **1990** | **2013** | | **2030** |
| **Article 3.3** | Minimising deforestation | | | | 0.700 |
| | Rapid afforestation High | | | | -31.400 |
| | Aspirational | | | | -29.100 |
| | Moderate | | | | -11.000 |
| | **Total 3.3** High | **-26.995** | **-16.218** | | **-30.700** |
| | Aspirational | | | | -28.400 |
| | Moderate | | | | **-10.300** |
| | | | | | |
| **Article 3.4** | Forest management | | | | -9.750 |
| | Cropland management | 0.479 | 0.443 | | 0.443 |
| | Grazing land management | 1.104 | 6.470 | | 5.511 |
| | Wetlands | -0.022 | 0.005 | | 0.005 |
| | Settlements | 0.002 | -0.005 | | -0.005 |
| | Other land | 0.008 | 0.031 | | 0.031 |
| | **Total 3.4** | | | | **-3.765** |
| | | | | | |
| **Total** | **High** | | | | **-34.465** |
| | **Aspirational** | | | | **-32.165** |
| | **Moderate** | | | | **-14.065** |

[52] IPCC AR-4 2007, Working Group III, Section 8.1.4.2 (Grazing land management and pasture improvement) and Section 8.4.1.5 (Livestock management).

# Appendix

This Appendix explores the potential for ambitious $CO_2$ sequestration from a rapid planting programme under Kyoto Protocol 3.3, on erosion-prone land throughout New Zealand.

There is approximately 1.3 m. ha. of such land that is Kyoto-compliant and which has predominantly exotic vegetation cover. At the height of planting in the 1990s, about 100,000 hectares were planted. We therefore envisage an orchestrated programme of similar planting that is the result of action on public land through ministerial directive, and on private land through a strong financial incentive scheme.[53]

We have commissioned the sequestration results of six scenarios for 1.3 m. ha planting over the next 26 years, at 50,000 ha. per year. The scenarios are as follows:

1. Plant 100% rapid exotics, and leave the plantation area to develop naturally;[54]
2. Plant 100% rapid exotics, but prune, thin and harvest at appropriate times, with replanting;
3. Plant 100% rapid exotics, with 50% left naturally, and 50% cultivated (as in 2 above);
4. Plant 100% native forest;[55]
5. Plant 50% rapid exotics and 50% native, left natural, with all the pine confined to the 3 least-threatened environments;
6. Plant 50% rapid exotics and 50% native, with half the pine cultivated, and all the exotics confined to the 3 least-threatened environments.
7. Plant 50% rapid exotics and 50% native, planting all the pine in the first 13 years, then all the natives in the second 13 years.
8. Plant 75% rapid exotics and 25% native, confining the pine to the least-threatened environments, planting both exotics and natives for 26 years, no harvesting.
9. Plant 75% rapid exotics and 25% native, planting all the pine in the first 20 years, followed by the natives; no harvesting.

The sequestration outcome for each scenario for the first 15 years, from 2016 to 2030, planting 750,000 ha, is shown in Table 10.[56]

**Table 10**
**Sequestration under Article 3.3 (50,000 ha/yr. new planting; nine scenarios 2016-30)**

| Year | | Hectares | Sequestration (Mt. $CO_2$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Scenarios | | | | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 2016 | 50,000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | 2017 | 50,000 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 2 | 2018 | 50,000 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 3 | 2019 | 50,000 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| 4 | 2020 | 50,000 | 1.1 | 1.4 | 1.2 | 0.2 | 0.6 | 0.7 | 1.0 | 0.9 | 1.2 |
| 5 | 2021 | 50,000 | 2.6 | 1.9 | 2.2 | 0.2 | 1.3 | 1.2 | 2.4 | 2.0 | 2.7 |
| 6 | 2022 | 50,000 | 4.7 | 3.1 | 4.0 | 0.2 | 2.3 | 1.9 | 4.4 | 3.6 | 4.9 |
| 7 | 2023 | 50,000 | 7.5 | 3.7 | 5.6 | 0.2 | 3.6 | 2.7 | 7.0 | 5.7 | 7.8 |
| 8 | 2024 | 50,000 | 10.6 | 4.6 | 7.6 | 0.2 | 5.0 | 3.7 | 9.9 | 8.0 | 10.9 |
| 9 | 2025 | 50,000 | 13.8 | 5.8 | 9.8 | 0.2 | 6.6 | 4.7 | 13.0 | 10.4 | 14.2 |
| 10 | 2026 | 50,000 | 17.1 | 7.8 | 12.2 | 0.1 | 8.1 | 5.8 | 16.1 | 12.8 | 17.6 |
| 11 | 2027 | 50,000 | 20.4 | 9.0 | 14.7 | 0.1 | 9.7 | 7.0 | 19.3 | 15.3 | 21.0 |
| 12 | 2028 | 50,000 | 23.7 | 10.9 | 17.3 | 0.1 | 11.3 | 8.3 | 22.5 | 17.8 | 24.4 |
| 13 | 2029 | 50,000 | 27.1 | 13.0 | 20.0 | 0.2 | 13.0 | 9.6 | 25.8 | 20.3 | 27.9 |
| 14 | 2030 | 50,000 | 30.5 | 15.2 | 22.8 | 0.2 | 14.6 | 11.0 | 29.1 | 22.9 | 31.4 |

*Source: Modelling run on request by Prof Euan Mason, Forestry Dept., University of Canterbury. The sequestrations). figures for the exotics relate to pinus radiata, are brodaly accurate for other 'rapid-sequestration exotics' (eucalyptus have slightly higher rates than pine while Douglas fir and Redwoods have slightly lower rates.*

Of the nine scenarios, we have discounted scenario 4, and have incorporated in Table 9 above and in the main Paper a range of eight sequestration options for 2030 of 11.0 Mt to 31.4 Mt. The sequestration results calculated in Table 10 are depicted graphically in Figure 1, for scenarios 1 to 6.

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[53] It is our understanding that a carbon cash credit of $20/tonne minimum, guaranteed over the long-term, will ensure this rate of planting. The public cost of this is high, at $1.35 bn. / year, but would be hypothecated through a pollution levy on carbon-equivalent emitters.

[54] We have simulated radiata pine sequestration rates using models for three sites representing low, medium and high productivity. The simulation envisages planting 1,000 stems/ha.

[55] Sequestration rates used are 27 tonne/ha/yr. for radiata pine, and for native forest a range of 3.8 to 9.1 tonnes/ha/yr. depending on the site type, with slowed development that otherwise mirrors that of planting and leaving radiata pine.

[56] We have also run the results of the six scenarios at twice the rate (100,000 ha/yr.), but have not included these.

**Figure 1**
**Sequestration of Scenarios 1 to 6**

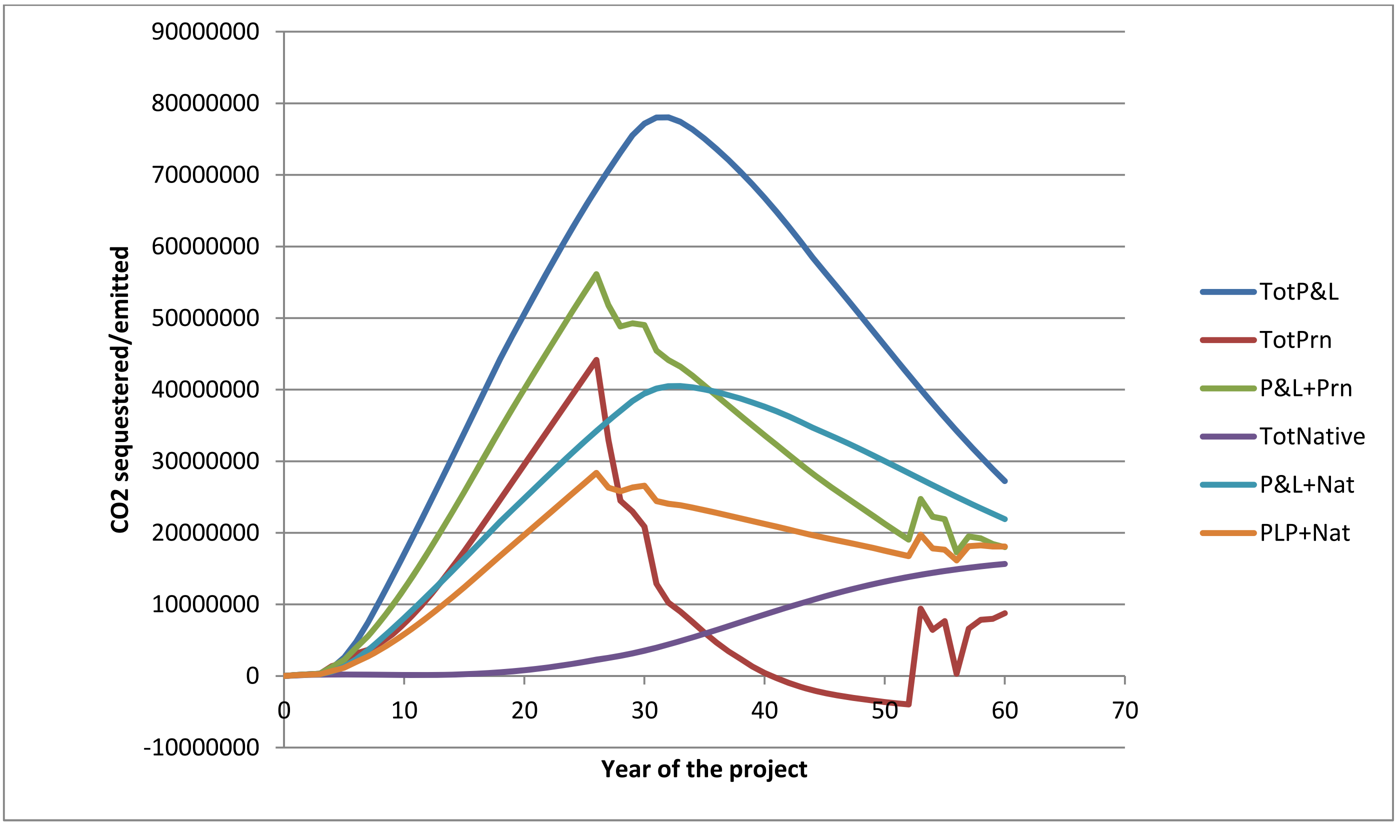
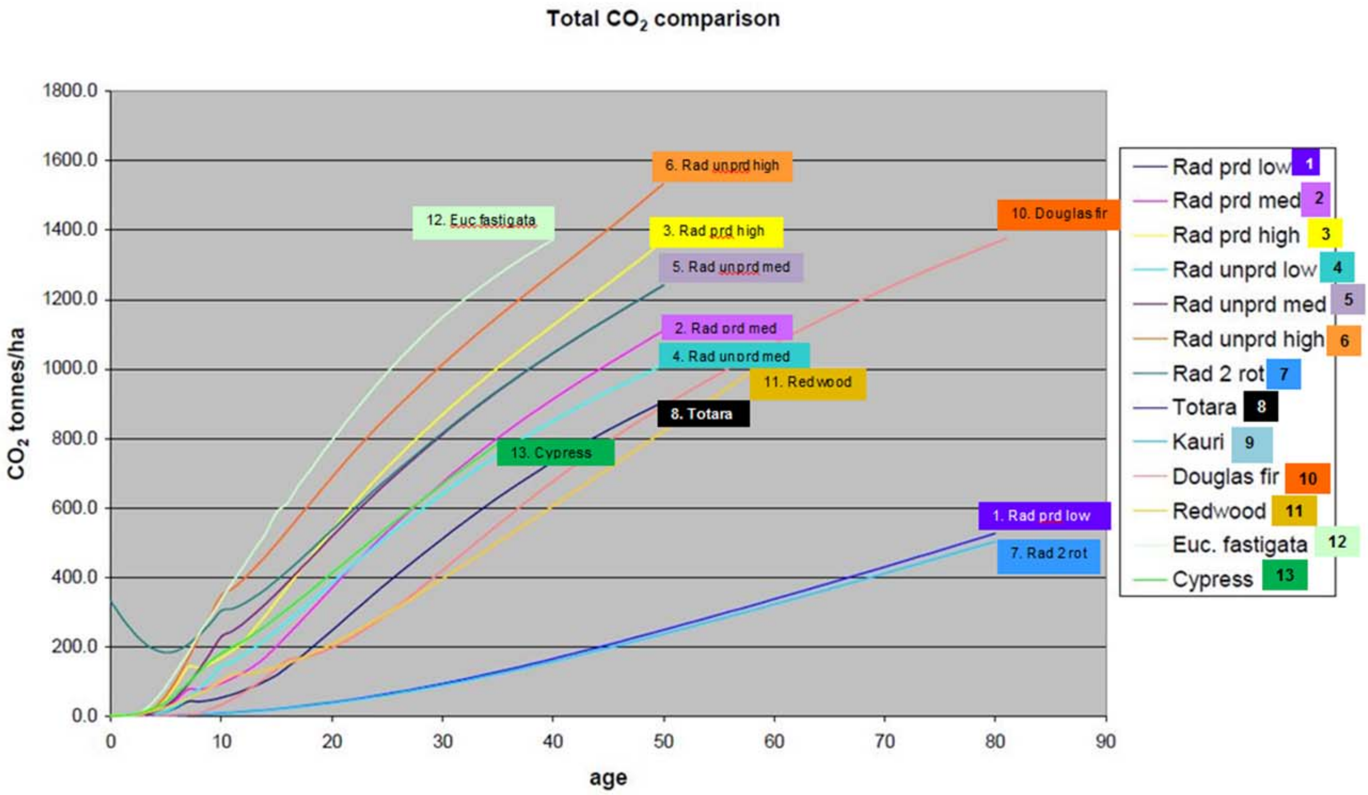



**Figure 2**
**Carbon Sequestration for Tree Species in New Zealand**




*Source: Indicative Forest Sequestration Tables, Paul, T., Kimberley M. & Beets, P.,(SCION; 2008)*