



# Review of New Zealand's 2007 Net Position Report



Report to the Ministry for the Environment, New  
Zealand

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## Executive summary

This report presents the findings of a review by AEA Energy and Environment, the Policy Studies Institute and the Centre for Ecology and Hydrology of New Zealand's 2007 net position report (MfE 2007). Under the terms of the Kyoto Protocol of the UN Framework Convention on Climate Change (UNFCCC) (to which New Zealand is a signatory) developed countries have agreed to limit their overall emissions of a basket of greenhouse gases from a given base year (1990 in most cases) by the period 2008-12 (the first commitment period). For New Zealand, the limit set in the Kyoto Protocol is that sets average emissions of the basket of greenhouse gases over this commitment period will be 100% of 1990 emissions, i.e emissions over the five year commitment period must total no more than five times 1990 emissions.

The 2007 net position report, which was published in September 2007, describes the most recent estimation of New Zealand's net position with respect to its Kyoto target over the first commitment period. The report suggests that New Zealand's net position is estimated to be a deficit of 45.5 million tonnes of carbon dioxide equivalent over the first commitment period compared to the Kyoto target. This figure has been revised upwards from the May 2006 estimate, which estimated that there would be a deficit of 41.2 million tonnes of carbon dioxide equivalent.

In 2005, the same team completed an in-depth review of New Zealand's 2005 greenhouse gas projections methodology. Their report (AEA, 2005) made a number of recommendations for improving the projections methodology. The aims of this 2007 review were to assess whether the recommendations made in the 2005 review have been implemented, identify any further areas for improvement and to examine the approach taken to assess uncertainty.

Overall we have found the methodologies employed to project emissions and sinks across the sectors for the 2007 net position report to be generally sound and reasonable in their approach. Furthermore we consider that the improvements, which have been made since the 2005 projections, mean that the 2007 projections are more robust and better documented than the 2005 projections. While any projection of greenhouse gas emissions will be subject to uncertainty, we consider that the projections form a reasonable assessment of New Zealand's net position over the first commitment period.

Overall, there has been significant progress towards implementing the recommendations made in the 2005 review. In the energy and transport sector, key improvements have been made to the modelling methodology, particularly in the industrial and commercial sectors. However, we still believe the use of a more technologically explicit, bottom up model to address energy efficiency and consumer preferences for different energy services in the residential sector may be appropriate. In the land use, land use change and forestry (LULUCF) sector all recommendations have been implemented, although in some cases implementation is not complete as data is required from the Land Use and Carbon Analysis System (LUCAS) project, which is due to become operational in 2010. High priority recommendations in the agriculture sector have been implemented. The compilation process has also been improved, with the introduction of a steering group, requirements for 'sign-off' by departments of projections, and improved documentation.

Improvements, however, could still be made to the quality assurance and quality control (QA/QC) procedures. We suggest that the Ministry for the Environment continue to build on the work, which has already been done by ensuring that the processes being put in place are documented, monitored and reviewed.

Documentation and explanation of how the effects of policies on emissions are estimated could also be improved further. For example, it is recommended that further information be provided with regard to the basis of the attributed emission savings anticipated from climate change policies.

All greenhouse gas emission projections will be uncertain because many of the factors that affect the emissions and the removal by forestry are in doubt. The uncertainties in the land use, land use change and forestry emissions make the biggest contribution to the uncertainty in the net position. It is recommended that the Treasury and the Ministry of Economic Development develop a range of consistent economic scenarios including the most likely, optimistic and pessimistic scenarios. The

estimates of the uncertainty from each of the sectors can then be combined by Monte Carlo simulation.

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# 1 Introduction

In 2005, AEA Energy & Environment (AEA), in collaboration with the Policy Studies Institute (PSI) and the Centre for Ecology and Hydrology (CEH), completed an in-depth review of New Zealand's greenhouse gas projections methodology and report titled 'Projected balance of emission units during the first commitment period of the Kyoto Protocol'. The review (AEA, 2005) made a number of recommendations for improving the projections methodology.

The Ministry for the Environment has now commissioned AEA, PSI and CEH to review the 2007 update of the net position report. The report is a compilation of projections by sector from across government. Agriculture and forest sink projections are provided by the Ministry of Agriculture and Forestry, energy (including transport) and industrial process projections are from the Ministry of Economic Development and waste and solvent emission projections are from the Ministry for the Environment. The projections reflect the agreed policies as at the end of April 2007, and include a number of improvements that have been made to previous projections.

## 1.1 Background to the Kyoto Protocol

Combating climate change and minimising its potential consequences are key objectives of the UN Framework Convention on Climate Change (UNFCCC). A key objective of the UNFCCC is to achieve stabilisation of atmospheric greenhouse gas concentrations, which will ultimately require substantial reductions in global greenhouse gas emissions. As an initial step in this process, parties to the UNFCCC adopted the Kyoto Protocol in 1997. This requires developed countries as a whole to reduce their emissions of a basket of greenhouse gases to 5.2% below their levels in a given base year (1990 in most cases) by the period 2008-12 (the first commitment period). For New Zealand, the target is that the average basket of greenhouse gas emissions over the first commitment period is 100% of the emissions in 1990. Emissions may also be offset by increasing the amount of greenhouse gases removed by carbon sinks, such as forest planting, that have occurred since 1990.

## 1.2 Overview of net position report

The 2007 net position report (MfE, 2007) suggests that New Zealand's net position is estimated to be a deficit of 45.5 million units over the first commitment period<sup>1</sup>. This figure has been revised upwards from the May 2006 estimate, which estimated that there would be a deficit of 41.2 million units. The main reasons for these changes are (MfE, 2007):

- New Zealand's assigned amount increasing (1.9 million units) due to improvements in New Zealand's Greenhouse Gas Inventory. Increasing the assigned amount lowers the net position deficit.
- New Zealand's agriculture greenhouse gas emissions are now projected to be 4.3 million tonnes of carbon dioxide equivalent higher than projected in 2006. This is mainly attributable to projected increases in dairy cow numbers as a consequence of higher world commodity prices for dairy products.
- New Zealand's emissions from energy (excluding transport) are now projected to be 1.5 million tonnes carbon dioxide equivalent higher than projected in 2006. A projected increase in emissions from the 'other industrial' and commercial sectors and a projected higher level of dairy processing contributed to the increase. However, these increases were largely offset by a reduction in projected emissions from electricity generation (due mainly to increased confidence about gas supply, reducing the projected amount of coal-fired generation).
- New Zealand's transport emissions are projected to be 1.3 million tonnes carbon dioxide equivalent higher as a result of integrating the more comprehensive vehicle fleet emissions model to project transport emissions.

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<sup>1</sup> One emission unit is equivalent to one tonne of greenhouse gas emissions expressed as carbon dioxide equivalent.

## **1.3 Scope of the review**

The 2007 net position report provides information on the methodologies used to forecast emissions, how the new estimates compare with the 2006 estimates and describes the uncertainties surrounding the emissions estimates. In addition to the net position report, a range of additional information has been made available to the review team. These are documented in section 6. The 2005 net position review involved members of the project team meeting up with key contacts in various government departments. No meetings have taken place for the 2007 review, although e-mail, phone and video conferencing were used to discuss issues and obtain clarification as required.

The aims of this project (as outlined in the Ministry for the Environment's work specification) are to assess whether the recommendations made in the previous review in 2005 have been implemented, identify any further areas for improvement, and to assess the approach taken to assess uncertainty.

Section 2 reviews the general approach taken and section 3 reviews the energy, transport, industry, waste, agriculture and land use, land use change and forestry (LULUCF) sectors in detail. Section 4 provides further information on the suggested combined approach to assessing uncertainty, and section 5 summarises the conclusions of the review.

## 2 General review

The overall approach taken in compiling the net position report was reviewed in 2005. In general it was considered that the government approach used in compilation of the projections assessment is appropriate, allowing those having technical expertise and sectoral knowledge to actively contribute to the projections work. It was, however, suggested that as the first commitment period approaches and the importance of reports concerned with projection estimates increases, the New Zealand Government might wish to consider moving the process of compiling the projection estimates on to a more formal basis to help ensure the delivery of robust data. A number of actions were suggested. As the commitment period moves ever nearer, then the development of a more formal basis for the projections and compilation process becomes increasingly important. The recommendations made in 2005 are discussed below, together with our assessment of progress towards their implementation, and suggestions for further improvements which could be made.

### 2.1 Improving planning and quality assurance/quality control (QA/QC)

Three actions were suggested to improve planning and QA/QC:

- Establish a steering group to oversee the projection compilation process
- Improve project planning and documentation
- Introduce and implement a formal QA/QC plan for the projection compilation

A steering group has been established and includes representatives from the Ministry for the Environment, the Ministry of Economic Development, the Ministry of Agriculture and Forestry, Department of the Prime Minister and Cabinet and the Treasury. They met in September 2006 to review the 2006 compilation process, and in January, March and April 2007 to discuss the compilation of the 2007 net position report. A smaller group of technical officers also met more frequently to progress the compilation of the report.

Minutes from the steering group meeting and discussion with Ministry for the Environment officials suggest that project planning for compilation of the report has improved (for example, departments are given guidance on writing up the projections and on treatment of uncertainty). In terms of QA/QC, chief executives are now asked to sign a letter stating the figures provided are, in the opinion of the relevant department, the best available estimate. This encourages internal review of the reports before submission of final reports to the Ministry for the Environment.

The Ministry for the Environment informed us that it then reviews the sectoral reports and discusses any issues with the contributing departments. Once the net position review report has been drafted, then this is reviewed by the departments and by senior officials at the Ministry for the Environment. In addition, a member of the inventory team is asked to perform numerical checks.

We would suggest that the Ministry for the Environment continue to build on work done to improve project planning and QA/QC by ensuring that the processes being put in place are documented, monitored and reviewed. More specifically:

- All those providing projections for compilation in the net position report should prepare a written QA/QC document covering the preparation of projections. The letter from the chief executives accompanying submissions could be amended to state that the projections have been prepared according to this QA/QC document. The Ministry for the Environment should also produce a written project plan for compilation of the projections and a QA/QC document covering the written projections. From discussions with the officials in New Zealand, it appears that there is already significant checking and review of the projections, but it is important that this process is recorded so that there is a written audit trail.
- A written plan to improve the quality of projections should be produced. This should set out a timetable for specific actions over the next two to three years to continue to improve the

quality of the projections. Actions should be allocated to named individuals, progress against the plan reviewed periodically, and further actions added as necessary.

- Actions should focus on sectors/sub-sectors where data or modelling is judged to be weak, and should be prioritised according to how significant the associated emissions are judged to be in the projections.

## 2.2 Improving internal consistency of projections

The 2005 review recommended that the internal consistency of the projections be improved by reinvigorating efforts to ensure the use of common datasets across all sectors, and by ensuring consistency in assumptions common to different sectors.

The Ministry for the Environment has put considerable effort into ensuring that this happens and that common datasets are used (for example, population, gross domestic product (GDP) growth and fuel prices) and common assumptions are made wherever possible. For example the projections of dairy herds made by the Ministry of Agriculture and Forestry are now used as a basis for estimating the energy requirements of the dairy processing industry.

It was specifically noted in the previous review that different assumptions of deforestation rates for land converted to pasture had been used in the LULUCF and agriculture sector projections. A post-model adjustment had been made to the Pastoral Supply Response model to allow for the conversion of grazing land to forestry and deforestation (with land going to dairy farming), but the assumptions made were not consistent with those made in the LULUCF sector, which led to the above recommendation. We were informed that in the 2007 net position report there was no post model adjustment to account for afforestation and deforestation, and that information from experts in the forestry sector suggest that land conversion only marginally impacts the pastoral sector emissions. Therefore any land use changes in the forecast period are assumed to be captured by the residuals (errors) of the forecasts. A simple, approximate calculation of the emissions involved confirms that annual emissions from agricultural use of deforested land would be of the order of 1% of those arising from deforestation<sup>2</sup>, supporting the assertion that the emissions from deforestation dwarf those which could arise from additional livestock emissions if the land was used for grazing.

## 2.3 Treatment of uncertainty

The review of the 2005 net position report recommended improving the transparency of the uncertainty calculations by clearly defining the basis for calculating the uncertainty ranges and using a consistent approach to quantifying uncertainties across sectors in terms of deciding what to quantify; that is, the uncertainty caused by future unpredictability (for example, uncertainty in the forecasts of key drivers) or value uncertainty (such as, uncertainty in data values).

The Ministry for the Environment has attempted to improve the treatment of uncertainty and has provided guidance to contributing departments on how uncertainty should be dealt with. The departments have also expanded the number of causes of uncertainty that they are examining. For example, the Ministry of Agriculture and Forestry has improved its treatment of uncertainty by examining how variations in commodity prices affect the modelled estimates of livestock numbers, and the Ministry for Economic Development has explored the effect that a number of discrete events (for example, Methanex not operated) might have on the projections, as well as, for example, the impact of high and low population growth. However, there is still no differentiation between uncertainty introduced by future unpredictability, value uncertainty and uncertainty caused by discrete events (for example the lifetime of Methanex plant), and/or assumptions about the outcome of policies. The treatment of uncertainty is discussed in more detail in section 4 of this report.

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<sup>2</sup> The net position review report states that deforestation emissions could be as high as 41 million tonnes carbon dioxide equivalent if deforestation rose to 50,000 ha over the first commitment period, giving emissions from deforestation as about 820t per ha of deforestation. Assuming conversion to dairy grazing, and based on a stocking rate of 3 dairy cows per ha, and using the emission factors for methane from enteric fermentation and manure management and nitrogen excretion for 2010 set out in the Net Position Report, and assuming 1% of nitrogen excreted is released as nitrous oxide, gives emissions of about 9 tonnes of carbon dioxide equivalent per ha from use as grazing for dairy cattle.

## 2.4 Impact of policies

General recommendations made in 2005 regarding the analysis of policy impacts were:

- Improve the documentation available concerning the basis of the attributed emission savings anticipated from climate change policies (particularly for the optimistic and pessimistic estimates).
- Further integrate the analysis of policy impacts to ensure that there is no double-counting of savings; with regard to this recommendation particular concerns identified were that emission savings attributable to the National Energy Efficiency and Conservation Strategy (energy audits and loans and grants) may overlap with those arising from the Small and Medium-sized Enterprises/Energy Intensive Businesses (SME/EIB) policies.

Better documentation is now included with the net position report, but it is felt generally that a transparent quantification of the impact of Government policies is still not provided in all cases. In some cases references are not provided for documentation setting out the assessment of impacts.

The 2007 draft net position report states that emissions savings from the National Energy Efficiency and Conservation Strategy and the Energy Intensive Businesses programme are explicitly represented in the SADEM energy model projection. As this current review is not as detailed as the 2005 review, it has not been possible to check whether this has resolved potential double counting of savings.

The 2005 review also recommended that a discrepancy concerning 'Projects to Reduce Emissions' (PREs) was resolved. The liabilities arising from PREs (which are used in the compilation of the overall net position and are discussed in section 3.1) were not consistent with the internal results of the Supply and Demand Energy Model (SADEM) in relation to the assumed success rate for projects going forward. However, most of the PREs are generation projects in the electricity sector, and so they are now modelled in the electricity sector's Generation Expansion Model (GEM) rather than the SADEM energy model. In consultation with the Electricity Commission, only those projects which are sufficiently advanced that they are likely to be installed over the commitment period are included. The assessment of PRE liabilities is made by the Ministry for the Environment which estimates the number of project units likely to be awarded based on contact with the PREs. It is not clear whether the assumptions in the GEM are cross-checked with the Ministry for the Environment assessment.

## 3 Sector reviews

### 3.1 Energy

#### 3.1.1 Modelling approach

Projections of emissions from the energy sector are derived from the Ministry for Economic Development's SADEM model. As a partial equilibrium model, SADEM describes energy supply by fuel and energy demand by sector, together with a more complex electric power simulation tool. Hence, it is a collection of modules, interacting with other modules. On the supply side, while oil and coal supply are assumed to be perfectly elastic, the natural gas market operates in equilibrium. On the demand side, five sectors have been defined: residential, transport, heavy industry, other (light) industry and commercial demand. All sectoral energy demands (except transport) are fed into the electric power and renewables module as well as fuel prices. This section will focus on energy emissions from the residential, commercial, heavy industry (excluding specific emissions from industrial processes) and other (light) industry sectors, as well as providing general comment on the SADEM model and the modelling of electricity generation. Transport and industrial process sectors are covered in more detail in sections 3.2 and 3.3 respectively.

Our conversations with the Ministry of Economic Development indicated that emissions from electricity generation over the first commitment period is forecast by the Electricity Commission's Generation Expansion Model (GEM), a shorter-term model focused on the New Zealand electricity sector.<sup>3</sup> GEM is a more detailed sector-specific electricity model used for grid planning analysis. Beyond the Kyoto period, the SADEM model is used.

Since the review of 2005 net position report, the Ministry of Economic Development has focused on implementing recommendations around the commercial and industrial sectors. Improvements include the disaggregation of the 'other industrial and commercial' model into two separate models. Within the 'heavy industry' sector, there are industry-specific models for metals (steel and aluminium), petrochemicals (urea and methanol), refining, forestry and dairy. These industry sub-models have been significantly redeveloped since 2005, based on the findings of a 2006 report on heavy industry energy demand commissioned by the Ministry for Economic Development (Covec et al, 2006). This report provided a basis for more detailed industry-specific (bottom-up) modelling and informed the development of a separate model for the dairy sector.

The industrial and commercial sectors together have a much greater influence on emissions projections than the residential sector. The Ministry for Economic Development's work on the industrial and commercial models represents a significant improvement to the modelling of energy emissions in this year's net position. The residential sector has had less attention, due to its relatively low impact on overall emissions projections.

In projecting emissions from the residential, commercial and industrial sectors, the SADEM model is used. A two-step approach is employed, first estimating overall demand and then attributing this demand out to individual fuels. Yearly energy saving potentials are also calculated off line for the residential and commercial sectors, and then subtracted from projections. The 2007 projections also include policies on which Cabinet has made a substantive decision. One of these is the solar water-heating programme, which was not included in the 2006 net-position report.

In addition to these domestic emissions, an international policy instrument that may effect New Zealand's net emissions is "Projects to Reduce Emissions" (PREs). PREs provide an incentive, in the form of Kyoto Protocol emission units, for projects that reduce emissions below business as usual levels during the first commitment period. As such, they also contribute to achieving the outcomes of the National Energy Efficiency and Conservation Strategy (NEECS). As the vast majority of all projects funded are in the electricity sector, PREs are applied to this sector. They are modelled as an

<sup>3</sup> For further details, refer to the Electricity Commission's website:  
<http://www.electricitycommission.govt.nz/opdev/modelling/gem/index.html>.

effective discount on the capital costs for new generation projects at the margin of viability. The 2007 net position report states that tradable emissions credits have been allocated for a number of projects already.

### 3.1.2 Reasonableness of approach taken

The major input assumptions to SADEM, including GDP, exchange rates and fossil fuel prices appear reasonable. Macroeconomic forecasts have been taken from Treasury projections, and fossil fuel prices are consistent with those used in New Zealand Energy Strategy. Since 2005, particular care has been taken in addressing the uncertainty in future fossil fuel prices, and several studies have been carried out on prices of coal, oil and gas, as discussed in the next section.

From a modelling perspective, the SADEM model gives a reasonable depiction of the specifics of the New Zealand energy sector and hence is an appropriate tool for projecting energy related greenhouse gas emissions. In order to represent electricity sector in greater detail, the GEM is used in the 2007 net position analysis. GEM was originally developed to support the derivation of Grid Planning Assumptions (GPAs), a regulatory requirement on the Commission in undertaking its oversight of Transpower's proposed grid investments. It is a capacity-planning model with a time span of 20 to 40 years. In particular, from a given list of potential new generation plants, it determines which ones to build in what year.

Each plant option is characterized by parameters such as location, technology, fuel type, capacity, capital cost, and operating costs. GEM is run under a series of scenarios for given levels of electricity demand and fuel availability as well as being subject to Government energy policies. The model minimizes aggregate capital and operating costs, while satisfying a number of technical, physical and economic constraints.

In estimating emissions from the residential sector, firstly overall demand is estimated and then it is distributed to individual fuels. The price of fuel, historical levels of energy demand and GDP, and degree days are used as the explanatory inputs. Even though this type of top-down approach in analysis of energy use is not uncommon, due to saturation effects, historical relationships between energy demand and other factors, such as GDP, may break down. Also, the 2005 review expressed concerns over way in which the influence of degree days on energy demand was estimated, as equal weighting was given to both cooling and heating degree days. In reality, the former would presumably necessitate electric air conditioning while the latter may require other fuels for space heating. A report commissioned by the Ministry of Economic Development in 2005 (Covec, 2005) highlighted the statistical insignificance of degree days on model results, and therefore the Ministry of Economic Development have placed more focus on improving modelling of the commercial and industrial sectors. They report that this issue will be resolved as part of future work to redevelop the residential model.

The emissions projections from the residential sector have been reviewed to include the new Government policies that are in place, for example the solar water heating programme. An approximate saving of 2,100 kWh per unit per annum is assumed for the 2007 projections. Hence, during the first commitment period, a total saving of 37.8 GWh is calculated.<sup>4</sup> While it is not uncommon to calculate such savings off line from an energy model, a technologically explicit model would provide physical interpretations for energy use and energy saving potentials. The 2007 projections also include overall 1.70 PJ of energy savings per year during the first commitment period due to residential energy efficiency improvements<sup>5</sup>, but it is not clear how this figure is derived.

### 3.1.3 Implementation of previous recommendations

The 2005 review included a list of modelling improvements that the Ministry of Economic Development had committed to deliver. Table 1 summarises this list and the improvements made since then, based on information provided in the 2007 net position report, information on the Ministry of Economic Development's website and communication with experts in the Ministry of Economic Development.

<sup>4</sup> As the Government's programme is funded for three and a half years, this estimation assumes no solar water heating installation beyond 2010.

<sup>5</sup> Energy savings from the Government's solar water heating programme are in addition to the projected 1.7PJ savings in the residential sector.

**Table 1: Modelling improvements that MED committed to deliver following the 2005 review\***

<b>Improvements, rated A:</b>	<b>Implementation:</b>
Energy Outlook (including Assumptions Document, Model Runs, and Write-up)	Completed <sup>1</sup>
NIWA Model Runs	Completed
Fourth National Communication	Completed <sup>2</sup>
Input to Post-Maui Analysis	Completed
PRE Analysis	Completed
Oil Price Paper	Completed <sup>3</sup>
Emerging Supply Side Technologies Project	Completed <sup>4</sup>
Two sections of Model Documentation requiring updating	In Progress
Gas & Coal Assumptions Papers	Completed <sup>5</sup>
Improvements to non carbon dioxide emissions from energy use	Completed
<b>Improvements, rated B:</b>	
Energy Outlook Workshops	Completed: x3 stakeholders engagement workshops were held between 2005 & 2006 <sup>6</sup>
Integrating demand models and fuel shares models for residential sector	Not implemented.
Greenhouse gas paper	Completed <sup>7</sup>
<b>Additional modelling papers:</b>	
LNG pricing	Completed <sup>8</sup>
Alternative liquid fuels	Completed <sup>9</sup>

\* While 'A' rated improvements include all the issues mentioned in the 2005 review, 'B' rated improvements are selective as many of them are on modelling of electricity generation in SADEM, which is replaced by GEM model for first commitment period in 2007 review.

<sup>1</sup> For details, please see <http://www.med.govt.nz/energy/eo/>

<sup>2</sup> For details, please see <http://www.mfe.govt.nz/publications/climate/national-communication-2006/>

<sup>3</sup> For details see [http://www.med.govt.nz/templates/Page\\_10612.aspx](http://www.med.govt.nz/templates/Page_10612.aspx)

<sup>4</sup> For details see [http://www.med.govt.nz/templates/MultipageDocumentTOC\\_20918.aspx](http://www.med.govt.nz/templates/MultipageDocumentTOC_20918.aspx)

<sup>5</sup> Part of Energy Outlook workshop presentation, for details see <http://www.med.govt.nz/upload/27041/gas-coal.pdf>

<sup>6</sup> For details, please see [http://www.med.govt.nz/templates/StandardSummary\\_15288.aspx](http://www.med.govt.nz/templates/StandardSummary_15288.aspx)

<sup>7</sup> For details, please see [http://www.med.govt.nz/templates/MultipageDocumentTOC\\_17799.aspx](http://www.med.govt.nz/templates/MultipageDocumentTOC_17799.aspx)

<sup>8</sup> For details, please see [http://www.med.govt.nz/templates/MultipageDocumentTOC\\_23939.aspx](http://www.med.govt.nz/templates/MultipageDocumentTOC_23939.aspx)

<sup>9</sup> For details, please see [http://www.med.govt.nz/templates/MultipageDocumentTOC\\_26587.aspx](http://www.med.govt.nz/templates/MultipageDocumentTOC_26587.aspx)

### 3.1.4 Treatment of uncertainty

The 2007 net position analysis report provides a non-exhaustive list of factors that could affect actual emissions from the energy sector during the first commitment period. The extensive list includes all the major sources of uncertainty.

In addition to these, we suggest that the possible effects of energy efficiency programmes are expanded upon. Energy efficiency results in cost savings, hence allowing consumers to be able to use more energy, the so-called *rebound effect*. The academic literature identifies three types of rebound effects: i) increases in demand for the same type of energy services; ii) increases in demand for different types of energy services; and iii) emerging of demand for new types of energy services (for example, paying lower power bills in winter due to more efficient boiler and appliances, and hence being able to afford a winter holiday in a ski resort).

In addition to the uncertainty about the actual size of the energy savings which might be realised, there is uncertainty about the composition of these energy savings. SADEM assumes an aggregate energy saving of 1.70 PJ in the residential sector, but the actual composition of these savings<sup>6</sup> (for example, whether they would be realised in space heating or lighting or another type of end-use category) could depend on a number of factors.

<sup>6</sup> In the residential sector, 34% of energy is used for space heating, 29% water heating, 31% for refrigeration, lighting and appliances (direct electricity demand) and the rest for cooking (BRANZ 2006).

The extensive list of sources of uncertainty in the energy sector projections (including the transport sector) is accompanied by an upper and lower emission scenario, with 187.7 million tonnes carbon dioxide equivalent and 162.8 million tonnes carbon dioxide equivalent reported respectively. The upper and lower scenarios were included as requested in the net position 2007 report to indicate the range of uncertainty associated with emissions projections, rather than to provide a detailed sensitivity analysis. However, these scenarios are defined by different sets of variables rather than changing a single variable as inputs to scenario, hence making it difficult to disentangle the relationships between these selected variables. An alternative approach would be running a large number of sensitivity runs on individual parameters in order to get a better understanding of which changes have the most impacts on the results. It should be noted that some sensitivity analysis of energy sector emissions has already been undertaken in the Ministry of Economic Development's *New Zealand's Energy Outlook to 2030*. These then can be used in a Monte Carlo type of analysis to obtain a distribution of results.

Further recommendations on treating uncertainty are included in section 4.

### 3.1.5 Proposals for future improvements

A brief review of the GEM model indicates that it is reasonable to use it in projecting emissions from the energy sector. It contains a simple representation of the electricity network by simulating two nodes, the North and South Islands. Hence, transmission losses on the High Voltage Direct Current (HVDC) are modelled using average loss factors, whereas alternating current (AC) losses are accounted for by adjusting load.

Currently, it does not allow for hydro storage, therefore inflows are used or spilled contemporaneously, whereas the previously used SADEM model did employ a stochastic approach on availability of hydro resources. However, this issue is partially addressed by allowing the user to select among 74 annual hydro inflow sequences (based on historical data from 1932), even though one might argue that future inflow pattern might be different from the historical ones. Equally important is improving the representation of transmission and distribution losses in GEM<sup>7</sup>. Nonetheless, although simple in its approach, our brief review indicates that these improvements should have limited effects on GEM outputs for the first commitment period of the Kyoto Protocol.

On the other hand, the projection of emissions from the residential sector is conducted in a top-down manner. However, bottom-up methods are very useful for policy analysis, particularly for non-price instruments. Hence, we still believe that use of bottom-up models to compare (if not incorporate) the residential energy use is of great importance as they address efficiency and consumer preferences directly.

### 3.1.6 Conclusions

Overall, the SADEM model provides a reasonable depiction of the specifics of the New Zealand energy sector and is an appropriate tool to project energy-related carbon dioxide emissions over the first commitment period. While energy savings are factored into the model, further work could be done to refine the modelling of energy efficiency improvements and other non-price based climate policies.

Many of the recommendations made on the projection of emissions from the energy sector in the 2005 review have been implemented, providing the analysis with a more solid structure and background. Specifically, improvements to separate the 'other industrial' and commercial models within SADEM, and to include demand elasticities into these models, have refined the modelling of these sectors since the 2005 review. The development of a separate sub-model for the dairy industry has also improved projections, as have revisions to existing industrial sub-models. Focus was placed on improving the industrial and commercial sectors since the last net position report, as these sectors have a significantly greater impact on emissions projections than the residential sector. As briefly summarized in the previous section, we still believe modelling of residential sector can be improved further. In particular, use of a more technologically explicit, bottom-up model to address energy efficiency and consumer preferences for different energy services may be appropriate. We note that

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<sup>7</sup> The Electricity Commission have stated that it plans to improve modelling of the network and improve characterisation of losses.

the issue raised over degree days in the previous review is planned to be addressed in the proposed redevelopment of the residential energy model.

## 3.2 Transport

### 3.2.1 Modelling approach

Emissions from the transport sector have grown significantly since 1990, averaging over 3% growth per annum. For the first commitment period of the Kyoto Protocol, emissions from the transport sector are projected to be 80.1 million tonnes carbon dioxide equivalent (41% of total emissions) in the 2007 net position report.

One of the key recommendations from the 2005 review was to adopt a bottom-up modelling approach, which would capture the technology-dependent nature of the transport sector and its energy demand. The 2007 net position report shows that this recommendation has been implemented through the use of the Ministry of Transport's Vehicle Fleet Emissions Model (VFEM). VFEM models changes to the on-road vehicle fleet, including the number of vehicles, kilometres travelled per vehicle and average fuel economy. In addition to improving the estimation of on-road transport energy demands, the 2007 net position report also states that use of VFEM improved estimates of petrol and diesel use by off-road vehicles and other types of transport.

The 2007 net position report also includes the impacts of new Government policies, including the recently introduced biofuels sales obligation. This policy requires that 3.4% of total diesel and petrol demand will be supplied by biofuels (bio-ethanol and bio-diesel) by 2012. Companies not complying with the Government's obligation levels will face a financial penalty. Hence, the biofuels sales obligation is expected to reduce carbon dioxide emissions in the transport sector.<sup>8</sup>

It is anticipated that all of the biofuel consumed in the 2008-2012 period will be produced in New Zealand, and most will be derived from the agricultural by-products whey and tallow and from fuel crops such as maize. Second generation biofuels are not anticipated to be used (and therefore do not feature in the model) until the post-2015 period. It is estimated that bioethanol production will have associated production emissions that are 11% of those that would be emitted by the displaced petrol, whilst biodiesel's greenhouse gas emissions will equate to 54% of those emitted by conventional diesel. We consider that the value of 11% of conventional petrol emissions for bioethanol may be low, even given that bioethanol is expected to be produced from whey where the emissions are already associated with dairy production, or produced from maize with geothermal energy used as a production heat source. The value of 11% quoted in the derivation of the savings is for second generation production of bioethanol produced by acid hydrolysis of wood<sup>9</sup>. We recommend that the international literature is reviewed to establish a more representative carbon dioxide reduction figure for bioethanol production as it would occur in New Zealand. We do not believe, however, that the change in the estimated saving would have a significant impact on the estimate of the net position over the first commitment period.<sup>10</sup>

### 3.2.2 Reasonableness of approach taken

The VFEM is used to project road transport emissions. The model works in a bottom-up manner and considers a number of technical and economic parameters. The vehicle type, engine size, fuel type and vehicle age come from Land Transport New Zealand Vehicle Registry data. In order to account for the economic drivers of travel demand, population, GDP and/or GDP per capita are used. In particular, as presented in the New Zealand's Energy Outlook to 2030, the VFEM computes fuel use as follows:

<sup>8</sup> Discussions with MED confirm there will be some increase in energy used to produce this biofuel in the agricultural and industrial sectors, but this is expected to be significantly less than the fossil fuel replaced in the transport sector.

<sup>9</sup> Enabling Biofuels: Biofuel Economics 2006 COVEC report for the Ministry of Transport, <http://www.mot.govt.nz/assets/NewPDFs/Covec-Biofuels-Economics-Final-Report-16.06.06.pdf>

<sup>10</sup> We estimate, very approximately, that if bioethanol CO<sub>2</sub> emissions were 50-to-75% of petrol emissions, rather than 11%, then the savings from the biofuels sales obligation might be reduced by 0.2 to 0.3 million tonnes over the first commitment period, and the net position would increase by this amount.

Fuel use = number of vehicles x kilometres per vehicle x average fuel economy

Fuel use demand for road transport is calculated for cars, light commercial vehicles and heavy commercial vehicles based on this formula. All three variables on the right-hand side are projected in the VFEM. The total number of cars and light commercial vehicles is projected by considering the historical growth in vehicle numbers and its relationship with population. For heavy commercial vehicles, a relationship between GDP and vehicle numbers is used. For cars, vehicle ownership is expected to approach a saturation level of 700 cars per 1,000 people. The vehicle kilometres travelled data are based on the Ministry of Transport's estimates of the kilometres travelled by the entire on-road vehicle fleet. The estimates have been determined from traffic count surveys, which are then extrapolated over the entire road network. The future projections are based on the historical relationship of vehicle kilometres travelled with population, GDP per capita, and fuel price. Vehicle fuel economy is input into the VFEM at a detailed level by vehicle type, engine size and fuel type, and also allows for the road conditions in terms of congestion level and urban versus rural running. The VFEM assumes that current ratios of new and used vehicles and their age profile will continue through to 2030.

New Zealand's energy statistics identify the diesel used by rail and sea, and some of that used by industry in either stationary applications or by vehicles off-road. These amounts, together with the diesel identified as used on-road, are subtracted from total fuel to give an estimate of the remaining off-road diesel use. The future off-road, rail, and non-transport energy demand is then modelled as being driven by population, GDP and fuel price. The off-road projections are then added to the VFEM's on-road transport projections to yield total land transport energy demand.

While this approach to on- and off-road transport takes into account the characteristics of the vehicle fleet, we have concerns over multiple uses of the same explanatory variables (GDP and population) for different factors in vehicle fuel use for road transport. However, lack of data is an issue and the approach adopted to calculate off-road, rail and non-transport energy demand seems to be a reasonable one to follow.

Air and sea transport energy demands have been projected by applying simple time series methods to the historical demand data. The conversations we have had with the Ministry of Economic Development indicate that previous projections using these methods have proved reasonably accurate and this is expected to remain so through the first commitment period projections. However, further research into modelling aviation demand and reliable econometric drivers is envisaged.

### **3.2.3 Implementation of previous recommendations**

One of the key recommendations from the 2005 review was the integration of the Ministry of Transport's bottom-up VFEM with SADEM model. The 2007 net position report confirms that this recommendation has been implemented.

### **3.2.4 Treatment of uncertainty**

As listed in the 2007 net position report, the overall performance of the New Zealand economy, the impact of Government policy measures, and fluctuations in fuel commodity prices are the key drivers of uncertainty for transport sector emissions projections.

At a more detailed level, improvements in vehicle technologies (through imports) would also have an effect on New Zealand's emissions from the transport sector, even though in the short term (between 2008 and 2012) this should not result in a radical change unless there is a significant breakthrough in the efficiency or cost of vehicles.

### **3.2.5 Proposals for future improvements**

The projections of sea and air transport have been simplified to utilize simple time series models to project trends into the future. Even though the use of current trends into the future is problematic in

many ways in the long term (mainly due to changes in the characteristics of population and saturation effects), in the short term this may not be an issue. Nonetheless, the growing energy use of air transport may require enhanced modelling to include the drivers of demand.

Also, a split between freight and passenger transport demand would allow a better characterization of transport demand.

### **3.2.6 Conclusions**

Modelling of transport emission has been improved, as following the recommendations of the 2005, a bottom-up model (the Ministry of Transport's VFEM) is now used to estimate on-road motor vehicle transport emissions. This model takes account of a number of technical parameters, including vehicle type, engine size, fuel type and vehicle age (from Ministry of Transport statistics) and uses socio-economic drivers (population, GDP and/or GDP per capita) to project future travel demand.

The projections of emissions from sea and air transport are made by applying time series methods to historical demand data. In the future, it is recommended that due to the growing energy use of air transport, modelling which include the drivers of demand is considered. In addition, a split between freight and passenger transport demand would allow a better characterization of transport demand.

## **3.3 Industrial Processes**

### **3.3.1 Modelling approach**

Direct emissions (that is, non-energy related) emissions from industrial processes contribute around 6% of New Zealand's total greenhouse gas emissions.

The majority of these emissions are from six major industrial processes:

- Production of iron and steel.
- The oxidisation of anodes in aluminium production.
- The production of hydrogen.
- The calcination of limestone of use in cement production.
- The calcination of limestone for lime.
- The production of ammonia and urea.

The industrial processes sector is dominated by emissions from the metal industry. Assumptions on future production (that it remains constant) are based on work done for the Ministry for Economic Development on the energy demand of heavy industry and are consistent with assumptions on energy modelling for heavy industry.

For the industrial processes, the Ministry for Economic Development models carbon dioxide emissions only. Emissions of other greenhouse gases (methane, nitrous oxide and the fluorinated gases<sup>11</sup>) are not modelled explicitly, but are allowed for by increasing the modelled emissions of process carbon dioxide emissions from industry by 19%. This is the average ratio within the industrial processes sector of non-carbon dioxide emissions to carbon dioxide emissions over the period 1990 to 2005. Projected carbon dioxide equivalent emissions from the industrial processes are provided in Table 2. The Ministry for the Environment informed us that projections of fluorinated gases are not modelled explicitly, primarily as a result of the source and type of fluorinated gas emissions changing recently and therefore no robust historic dataset being available on which the projections could be based.

### **3.3.2 Reasonableness of approach taken**

The methodologies used for industrial projections are those in use at the time of the 2005 review, at which point they were considered to be appropriate. The scaling of non-carbon dioxide greenhouse gases to carbon dioxide emissions from industry was considered to be an appropriate approach given that the non-carbon dioxide emissions are less than 1% of the inventory. However, the sources of the non-carbon dioxide gases are not the same as for process gases, and if New Zealand wishes to

<sup>11</sup> Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>)

continue to improve the quality of its projections then we suggest that it considers how these emissions might be better modelled on a gas-by-gas basis. In particular, emissions of hydrofluorocarbons have been identified as a key category in the level and trend analysis of the 2005 inventory. It should be possible to model perfluorocarbon emissions on the basis of assumptions in the energy modelling about future aluminium production.

Year	Industrial Processes (kt CO <sub>2</sub> ) (Provided by MED)	Industrial Processes (kt CO <sub>2</sub> – e) Estimated by MfE
2008	3,684	4,384
2009	3,710	4,415
2010	3,735	4,445
2011	3,759	4,473
2012	3,781	4,499
<b>Total CP1</b>	<b>18,670</b>	<b>22,217</b>

Note: CP1: 'first commitment period'

### 3.3.3 Implementation of previous recommendations

There were no specific recommendations in the 2005 review report on industrial processes.

### 3.3.4 Proposals for future improvements

- A fuller description of the assumptions, methods and data sources behind the industrial process emission projections should be given.
- An explicit modelling approach should be taken for the non-carbon dioxide industrial process emissions, particularly hydrofluorocarbons, which are a key category in the inventory,

### 3.3.5 Conclusions

Carbon dioxide equivalent emissions are expected to increase from the industrial process sector between 2008 and 2012. However, there is limited information available to explain why this is the case. Although the predicted increase is small, it is recommended that the Ministry for Economic Development should provide a full description of the assumptions, methods and data sources that have been used to forecast emissions from this sector.

## 3.4 Waste

### 3.4.1 Modelling approach

Annex D of the 2007 net position report sets out the approach taken to projecting emissions from landfill sites and domestic and industrial waste water treatment plants. For landfill sites, the methodology used to produce emissions estimates for the historical inventory is also used for projections. This is a tier-2 model consistent with the Intergovernmental Panel on Climate Change (IPCC) recommendations, which uses data specific to New Zealand on waste generation rates, waste composition and rates of landfill gas collection and combustion. Projections of population growth are used to drive the projections of waste generation rates.

The reductions associated with the New Zealand Waste Strategy (in particular, the diversion of biodegradable waste away from landfill), and with the national environmental standard for landfill gas collection, are then subtracted from the projected gross emissions to give a net value.

Projections of wastewater emissions are estimated by using a linear projection of emissions from 1990 to 2003 and extrapolating this trend.

### 3.4.2 Reasonableness of approach taken

The methodologies used for projections are very similar to those in use at the time of the 2005 review, at which point they were considered to be generally sound.

### 3.4.3 Implementation of previous recommendations

The 2005 AEA review found that methodologies and input assumptions were generally sound, but had four main recommendations and suggestions:

- 1) *Consideration should be given to whether future wastewater emissions could be modelled directly for future years using the inventory methodology, as while the linear projection has an acceptable  $r^2$ , it does not take account of the potential for the current upwards trend to plateau.* A linear extrapolation is still used for wastewater emissions, but there is an ongoing research project to examine the methodology used to estimate wastewater emissions which is due to report soon. This will use population growth as a driver for emissions.
- 2) *The population data set used should be consistent with those used in other sectors:* The Ministry for the Environment has confirmed that a single population dataset is now used in all sectors. This same population data set will also be used in the new projections of emissions from wastewater treatment.
- 3) *It was noted that no documentation was available to support the estimate of reductions due to the two waste policies and it was suggested that the 'most likely' value assumed might be too optimistic.* The draft 2007 net position report records that the 'most likely' value of the reduction arising from the Waste Strategy has now been scaled back to 75% of the original values. Further discussion with Ministry for the Environment officials clarified that the original estimate of the savings, which would be achieved through the New Zealand Waste Strategy, had been made by a consultant in 2002, and that the downward revision of the target was made in light of the 2006 review of progress towards Waste Strategy targets. It would improve the transparency of the net position report to include a reference to the original source document containing the estimate of the emissions reduction and to make clear that the downwards revision is due to a review of progress in the Waste Strategy. The reduction in emissions due to increases in landfill gas emissions comes from work by consultants estimating landfill gas recovery rates based on landfill owner intentions. While this is made clear in the draft report, it would again improve transparency if a full reference was included for the report.
- 4) *It was suggested it would be appropriate to build a measure of uncertainty into key input variables in the optimistic/pessimistic scenarios if data is available to allow a sensible estimate to be made.* The scenarios in the 2005 report were related to the outcome of the Waste Strategy policy rather than uncertainty in key input variables. This is still the case in the 2007 report: the high and low ranges represent the differences in assumptions about the outcome of this policy and additional causes of uncertainty have not been examined.

The only recommendation that has still to be progressed is the estimate of uncertainty in key variables.

The recommendation on improving wastewater treatment is being progressed, and the recommendation on improving documentation of estimated reductions could be implemented by adding references of the appropriate documents to the net position report.

### 3.4.4 Treatment of uncertainty

As discussed above, at present the only treatment of uncertainty is in terms of the impact of policy, other uncertainties are not assessed. The treatment of uncertainties is discussed in more detail in section 4.

### 3.4.5 Conclusions

The methodology used for the waste sector projections is broadly sound and, as recommended, the same population data set has been used across all sectors. Recommended improvements to the wastewater treatment emissions projections are in progress. Reporting of the estimated reductions

achieved from policies could be made more transparent and references for reports containing the estimated reductions should be included.

Estimated emission reductions from policies should be kept under review and should be linked to progress towards meeting the targets in the New Zealand Waste Strategy for diversion of biodegradable waste.

## 3.5 Agriculture

### 3.5.1 Modelling approach

The projections examined were based on the methodologies used in the National Greenhouse Gas Inventory submitted to the UNFCCC annually, and on econometric and physical models developed by the Ministry of Agriculture and Forestry. The inventory methodology is reported to conform to the Good Practice Guidance methodologies developed by the IPCC and adopted by the UNFCCC.

The emission factors quoted for methane, and annual estimates of nitrogen excretion, are the result of in-country calculations and therefore go beyond default values. The numbers quoted are reasonable when compared with estimates available from other sources; for example, the current and projected United Kingdom estimates for nitrogen excretion by dairy cows for 2010.

The likely increase in the size of the New Zealand dairy herd, in response to increased prices for milk on the world market, has been taken into consideration in the report. The outcome from this assessment was only a small change in emissions due to the increase in dairy cow numbers being counterbalanced by a decline in sheep numbers, but illustrates that new developments likely to impact on national greenhouse gas emissions have been taken into consideration. Moreover, the inherent uncertainty in projections has been explicitly addressed by estimating the 95% confidence intervals of the projections.

### 3.5.2 Reasonableness of approach taken

Projections were driven by future estimates of:

- Animal numbers by species: dairy cattle, beef cattle, sheep and deer in 2010 using the Ministry of Agriculture and Forestry's Pastoral Supply Response Model.
- Ruminant methane emissions per animal based on changes in past emissions per animal between 1990 and 2005.
- Nitrogen output per animal based on changes in past nitrogen output per animal between 1990 and 2005.
- Nitrogen fertiliser use based on an econometric model that projects future use from projected animal numbers, fertiliser prices and other variables (output prices, agricultural productivity growth).

Changes in estimation methodologies have been implemented to take into account new approaches and information obtained since the last update in May 2006.

Changes were implemented in two areas:

- The projection of nitrogen fertiliser usage in 2010 was based on an improved methodology developed by the Ministry of Agriculture and Forestry. This resulted in a 6% increase in nitrogen fertiliser use projections.
- Updating of the National Greenhouse Gas Inventory methodology in keeping with UNFCCC guidance for maintaining 'Good Practice'. Two changes were implemented in the agricultural section of the National Greenhouse Gas Inventory in 2007, in which the 2005 emission levels are reported. These were:
  - The crop residue-burning fraction for 2005 was reduced from 50% to 30% based on updated expert advice. This change had a minor impact on emissions output.
  - Beginning in January 1989, the commencement of the period over which animal emissions are reported was changed from a July-to-June year to a January-to-December year, as three-year averages are used to derive animal populations. This

change resulted in an approximate 1% increase in the 1990 emissions levels for agricultural methane and nitrous oxide.

### 3.5.3 Implementation of previous recommendations

The 2005 AEA review found that methodologies and input assumptions were generally sound, but had four main recommendations and suggestions

*1) We have noted that the assumptions about deforestation and afforestation through conversion to/from grazing land in the post model adjustments to the livestock projections from the Pastoral Supply Response model may not be consistent with the assumptions made in the land use change and forestry projections.*

*2) The linear extrapolation of enteric implied emission factors and factors for nitrogen excreted per head should be kept under review. It might be useful to examine the trend if single year rather than three-year average data is used. A check on the linear extrapolation method could be provided by estimating the implied emission factors if industry targets for productivity, or the increases in productivity assumed in the Pastoral Supply Response Model are met.*

*3). In the future it would be useful to understand the drivers for the rapid increase in nitrogenous fertiliser use and judge whether these can be expected to continue and whether other measures to limit fertiliser use may have an impact, before using a linear trend extrapolation to provide an estimate of future use.*

*4). A more useful optimistic and pessimistic scenario for livestock numbers might be derived by examining the effect of potential changes in the Pastoral Supply Response Model drivers rather than a range for the 2004 livestock numbers.*

The implementation of these recommendations was discussed with the Ministry of Agriculture and Forestry which reported that:

1) Information from experts in the forestry sector suggests that land conversion to forestry only marginally impacts on the pastoral sector. Furthermore, the change in the emissions from the pastoral sector is insignificant compared to those arising from deforestation. We have also examined this (see section 2.2.) and concur with this view.

2) Non-linear relationships for emission factors have been examined, but no significant improvement in relationship was gained. The effect of using a single year figure in deriving the trend has not been examined, as it is not believed it would have a material effect.

3) It appears that the drivers for the rapid increase in nitrogenous fertiliser use have been incorporated into the Pastoral Supply Response Model, and a revised estimate of nitrogenous fertiliser requirements has been made.

4) Optimistic and pessimistic scenarios for livestock numbers are now modelled with the Pastoral Supply Response Model by making changes to drivers (for example, commodity prices) in the model (see below).

### 3.5.4 Treatment of uncertainty

The report acknowledges that projections of livestock numbers and performance, and hence future emissions, need to be assessed within the uncertainties of biological systems as affected by climate and changing economic conditions, including changing international commodity prices and the New Zealand dollar exchange rate. The report states that every effort has been made to provide the best projections of future emissions as at June 2007.

As well as the baseline scenario, two further scenarios of projected emissions in 2010 were produced. These represent emission estimates using the 95% prediction intervals for the upper and lower bounds of methane and nitrous oxide emissions and animal numbers. These two scenarios gave an estimate of the values of the upper and lower bounds of future projected emissions at the 95% confidence level.

The report states that to derive livestock forecasts for different scenarios, exogenous price uncertainty was introduced into the Pastoral Supply Response Model through specifying the possible movements in commodity prices for the forecast period. Variation of prices (or the standard deviation of the 95% confidence level) during the last ten year period for each price series was used. This gave estimates for the upper and lower bounds of the stochastic forecasts that could be considered as lower and higher scenarios due to the movement in prices.

### **3.5.5 Proposals for future improvements**

Projected ruminant methane emissions, are based on changes in past methane output per animal between 1990 and 2005. Individual animal emissions between 1990 and 2005 are based on national data on individual animal performance and diet quality. Emissions per animal 1990 -2005 are obtained using the model developed by Clark et al (2003) which takes account of performance and diet. Projected emissions per head are obtained by fitting linear regressions to the 1990-2005 emissions data and extrapolating to 2010.

No attempts have been made to fit trends to the animal performance data and run the projected performance data through the Clark et al (2003) inventory model because of the large number of relationships that would be need to be estimated if this approach was adopted.

The justification for using a simple approach of projections to 2010 based on modelled output is that the 1990 - 2005 time series shows such a strong linear trend. We recommend that the trend is reviewed annually and that the approach is reviewed if the trend begins to become less strongly linear.

### **3.5.6 Conclusions**

The agricultural inventory appears well thought out, conforms to UNFCCC good practice and is likely to give accurate results. The approach has been improved in the light of comments made at the last review and gives a robust estimate of greenhouse gas emissions from agriculture for the period to 2010.

## **3.6 Land use, land use change and forestry (LULUCF)**

### **3.6.1 Modelling approach**

Net removals by the land use, land use change and forestry (LULUCF) sector for 2008 to 2012 are projected to be between 16.0 million tonnes carbon dioxide (pessimistic) and 98.3 million tonnes carbon dioxide (optimistic), with the most likely scenario being 58.0 million tonnes carbon dioxide. Estimates of net removals in the optimistic and pessimistic scenarios have changed due to allowances being made for the uncertainty of the Kyoto forest area and changes in future deforestation scenarios.

The projected removals are based on carbon modelling, using three projection scenarios (pessimistic, most likely and optimistic) to incorporate natural variability, measurement uncertainty, gaps in knowledge and alternative future outcomes (due to changes in policies or the economic context, for example). The carbon model simulates the Kyoto forest area, based on a carbon yield table of a typical forest stand and driven by annual planting rates (actual and predicted) between 1990 and 2012. Changes in the soil carbon pool and emissions from deforestation are estimated in separate model components. The net carbon uptake from the model is taken to be the carbon stock change during the first commitment period of the Kyoto Protocol. This approach is based on the methodology currently used to estimate forest carbon stock change for New Zealand's UNFCCC greenhouse gas inventory. This approach will be replaced by the Land Use and Carbon Analysis System (LUCAS), formerly known as the New Zealand Carbon Accounting System, which is due to be operational from 2010. The LUCAS project will report emissions and removals of greenhouse gases from forests planted since 1990 and land deforested during the first commitment period.

The key assumptions used in the projections (that is, those factors used to define the pessimistic, base and optimistic scenarios) are clearly described and discussed in the appendix to the net position report. They are: future afforestation rates, area of existing Kyoto forest, Kyoto forest growth rates,

changes in soil carbon with afforestation, area of ineligible Kyoto planting and future deforestation rates of plantations. Some of these factors are correlated, so the three sets of scenario assumptions were run in separate simulations to produce the combined model results.

Good practice, as described in the IPCC Good Practice Guidance for LULUCF, has been followed throughout, with the use of higher tier approaches commensurate with the contribution of these categories. Consistency with the Good Practice Guidance is embedded in the LUCAS project design (using Tier 3 approaches) and so the outputs from LUCAS will also follow good practice.

### **3.6.2 Reasonableness of approach taken**

The approach taken, in terms of the methodologies and input assumptions, is reasonable and clearly described. There are weaknesses in the data currently available for carbon stock accounting but these will be addressed by the LUCAS when it becomes operational in 2010. The production of robust estimates for the volume of carbon in New Zealand's carbon pools for reporting under Article 3.3 of the Kyoto Protocol, and hence the ability to claim removal units, is reliant on the full implementation of the LUCAS during the first commitment period. The risks associated with project slippage have been identified in the project charter; however, progress is currently on track for delivery in mid-2010.

### **3.6.3 Implementation of previous recommendations**

In the review of the 2005 net position report there were four issues (summarised in Table 3) where further consideration was recommended in order to minimise uncertainty in future projections.

The economic and policy environment of New Zealand forestry in recent years (described in the 2007 net position report) have induced substantial changes in the sector in the past five years. The current regime of afforestation and deforestation rates is so different from the historical trend (over the past 30 years) that there is considerable uncertainty as to their trend in the future. The first recommendation was to improve knowledge of the reasons and drivers for the downward trend in new forest planting to allow improved forecasting concerning the future possible intentions of forest owners. This has been achieved by a report on the financial returns from forestry (Horgan 2007) and deforestation intentions surveys undertaken in 2005 and 2006 for the Ministry of Agriculture and Forestry. In the 2007 net position report, three afforestation scenarios were presented (planting rates of zero (0), 5000 and 20,000 (5-year average) ha/year from 2007 for the pessimistic, most likely and optimistic scenarios respectively). Based on current afforestation rates these scenarios are expected to cover the range of afforestation levels expected under current market and policy conditions during the first commitment period. In terms of impact on New Zealand's net position, afforestation is of lesser importance than rates of deforestation. Any afforestation from 2006 onwards will have little impact on net removals during the first commitment period because newly established forests remove little carbon dioxide from the atmosphere during the early years of growth. For the same reason, the potential impact of any new policies encouraging afforestation will mostly be felt beyond the end of the first commitment period in 2012. The extent of existing (1990-2006) Kyoto forests will be verified by the land use mapping workstream in the LUCAS project.

The second recommendation was to improve quantification of the areas of planting of post-1990 forest at national scale into existing shrublands that meet the Kyoto Protocol definition of forest. The confusion in this area has arisen because New Zealand shrublands have never been considered 'forest' but some areas could be defined as such under New Zealand's single minimum values for accounting under Article 3.3 of the Kyoto Protocol: a tree crown cover of 30%, a minimum land area of 1 hectare, and a tree height of 5 metres. The projection scenarios in the 2007 net position report use estimates of 8%, 16% and 21% of post-1990 forest planting as ineligible under the Kyoto protocol due to it being planted into existing shrublands that come under the forest definition.

Further quantifiable information is required to assess the proportion of ineligible planting and therefore to reduce the range of uncertainty. Land use mapping for the LUCAS project will produce this information. There is also ongoing regional research (by LandCare Research and AgResearch) in support of the LUCAS mapping, including farm interviews, which may give a more accurate picture of the extent of post-1990 planting in shrubland that meets the Kyoto protocol definition of forest. Any regional variation in the proportion of ineligible planting will need to be taken into account when making the national assessment.

A secondary recommendation related to this was to improve the information on the burning and decay of scrub vegetation. Estimates have been made in the projections and have a small impact. The area of scrub cleared depends on the area of ineligible planting – so there are more emissions from scrub clearance in the optimistic scenario because more of the shrubland area remains eligible for Kyoto forest planting.

The third recommendation was to improve estimation of the area deforested and drivers for this process. Deforestation rates look likely to have a significant effect on New Zealand's net position in the first commitment period and there have been considerable efforts in this area. Surveys of forest owners' actual intentions to deforest were made in 2005 and 2006 for the Ministry of Agriculture and Forestry. ENSIS modelled five deforestation scenarios, including three based on the results from the forest owners' survey, from which the Ministry of Agriculture and Forestry selected the base, pessimistic and optimistic scenarios for the net position report. There was also discussion in the net position report of drivers that might increase deforestation beyond the pessimistic scenario. Decisions on deforestation policy options are anticipated by the end of 2007. These should enable additional refinement of the projection scenarios in the future.

There remains uncertainty about the level of clearance of indigenous forest or shrubland that meets the Kyoto forest definition, although it is thought to be insignificant and not to result in land use change. Deforestation of this type is not currently considered in the projections. The assessment of the level of this sort of deforestation will be possible once the LUCAS is operational.

The final issue was the need to undertake further research on the time pattern of loss of carbon from soils after afforestation. Currently the changes in soil carbon stocks following afforestation are modelled as occurring gradually at a linear rate of change over 20 years, rather than instantaneously. The soil carbon work stream in LUCAS will contribute to the investigation of this issue, through the harmonisation of existing soil data, the identification of knowledge gaps and additional sampling as required. Given that much planting of Kyoto forests has taken place on hill slopes prone to erosion and with high natural variability, this is a complex area of investigation that can only be fully addressed by an ongoing research/monitoring programme. Such a programme should be achieved when the LUCAS soil methodologies transition to business as usual when the system becomes fully operational. An additional recommendation was made that a single document should be produced for any future projection estimates that would provide detailed descriptions and sources for all calculations. The LULUCF appendix to the net position report largely fulfils this recommendation. The basis of the uncertainty ranges is clearly defined and the direction of possible changes in projections in the future is described in many cases. There has also been progress in refining the projections in areas that were not covered in the original review recommendations.

**Table 3: Summary of the status of previous recommendations**

Recommendations considered as being of high priority	Implementation
LULUCF: Improve knowledge of the reasons and drivers for the downward trend in new forest planting to allow improved forecasting concerning the future possible intentions of forest owners	Implemented. The net position report uses three afforestation scenarios that under current market conditions and policy settings cover expected afforestation levels out to 2012. Information on afforestation drivers has been gathered but this is considered to be more suited for longer term projections and evaluating policy options.
LULUCF: Improve quantification of the areas of planting of post-1990 forest at national scale into existing shrublands that meets the Kyoto Protocol definition of forest	Awaiting data from the LUCAS project (due to become operational in 2010).
LULUCF: Improve estimation of areas deforested and drivers for this process	Implemented. The LUCAS project will provide additional quantification.
LULUCF: Undertake further research on the time pattern of loss of carbon from soils after afforestation	Awaiting data from the LUCAS project (due to become operational in 2010).
Process: Improve written documentation to fully describe methodology and assumptions made across all sectors	Implemented.
Uncertainties: Improve the transparency of the uncertainty	Implemented. Data from the LUCAS

calculations by clearly defining the basis for calculating the uncertainty ranges and using a consistent approach to quantifying uncertainties across sectors in terms of deciding what is trying to be quantified, that is, the uncertainty caused by future unpredictability or value uncertainty	model will improve the quantification of uncertainties.
<b>Recommendations considered as being of lower priority</b>	
LULUCF: Improve the information/quantification on the burning and decay of shrub vegetation	Partially implemented. Awaiting additional data.

### 3.6.4 Treatment of uncertainty

The LULUCF sector is the greatest source of uncertainty for New Zealand's net position. Three scenarios are used to qualitatively assess uncertainty of the different factors used to estimate emissions and removals.

These scenarios have to incorporate considerable uncertainty in future outcomes, measurement uncertainty/knowledge gaps and high natural variability in the factors themselves (a major source of uncertainty). This is further discussed in section 4.6

The main uncertainties in terms of reduction of net removals are future rates of deforestation and the proportion of ineligible Kyoto afforestation. The main source of uncertainty in terms of increasing net removals is the Kyoto forest growth rate.

Data being collected for the LUCAS project will help to reduce the uncertainties associated with measurements and information gaps, specifically Kyoto forest growth rate, soil carbon change with afforestation and the area of ineligible Kyoto afforestation. The LUCAS data will also validate existing quantitative measures of uncertainty, such as the area of Kyoto forests that have already been planted (estimated 5% uncertainty). However, there are still large uncertainties over the future implementation of policy and changing economic conditions, particularly those concerning the deforestation cap and what the Government will do if the cap is exceeded. The uncertainty over future activities cannot be significantly reduced below the existing estimates at the present time.

### 3.6.5 Proposals for future improvements

The implementation of the LUCAS will meet the most pressing data requirements, which are the most obvious areas for improvement. Although LUCAS is due to be fully operational in 2010, some data work streams will be completed before that time, and it is expected that this data will be used to reduce uncertainties when it becomes available. The scope for future improvements will be clearer once the LUCAS is fully operational and sampling/monitoring has transitioned to business as usual.

It is recommended that the LULUCF documentation (in the appendix to the net position report) is kept up-to-date with the latest methodological developments. It would also be useful if more information could be included about the LUCAS project, such as the project objectives, a brief description of the main data work streams and progress towards full implementation.

In their 2007 projections report, Ensis gave options for improving removals estimates with the current methodology before LUCAS becomes fully operational. Some of these options may become appropriate if LUCAS is not fully operational by 2010. The choice of option would depend on the areas for which data was incomplete and would be influenced by the short time scale for implementation before the end of the first commitment period. The options are:

- Data from LUCAS should be used to reduce uncertainties in the projections as soon as they become available.
- More information about the LUCAS project should be included in the LULUCF section in the net position report.
- Documentation should be kept up-to-date with the latest methodological developments.

### **3.6.6 Conclusions**

The approach taken to estimating the LULUCF sector's contribution to New Zealand's net position is reasonable, given the current data limitations, and is clearly described. Many of the current data issues will be addressed by the implementation of the LUCAS, which should become operational in 2010. There has been significant progress on the implementation of the recommendations of the 2005 net position report review. The amount of effort put into different factors has sensibly been linked to their anticipated impact on New Zealand's net position, with estimates of the deforestation area receiving most attention. Where implementation of the recommendations is only partially complete, this is due to the requirement for data from the LUCAS project.

## 4 Uncertainties

### 4.1 Introduction

The most likely estimate of the net position is calculated as the sum of the sector emissions less the net removal by forestry. The calculation of the upper and lower bound estimates of the net position from the sector upper bound and lower bound estimates is more difficult because it is highly unlikely that all pessimistic or all optimistic situations will occur together. In 2005 and 2006, a Monte Carlo simulation was carried out to model the combined uncertainty. The Monte Carlo simulation is a repeated sampling technique in which a probability distribution is assumed for each of the sector emissions estimates and the net removal by forestry. Repeated samples are drawn from each distribution and the net position calculated each time. The resulting estimates of the net position have a modelled probability distribution from which a 95% confidence interval for the upper and lower bounds may be obtained. There is a debate as to whether the Monte Carlo method is a suitable tool for modelling the uncertainty in the emissions projections for New Zealand because of the limited number of modelled projections, and because the overall uncertainty is dominated by the large uncertainty in the estimates of net removal by land use, land-use change and forestry. No attempt has been made in the 2007 assessment to combine the uncertainties in the sector emissions estimates.

This section provides guidance on how best to treat this uncertainty. In section 4.2, consideration is given to the limitations of the Monte Carlo approach taken in 2005 and 2006 for combining sector estimates of uncertainties. A revised approach is recommended.

The combination of the uncertainties in the overall net position relies on the estimates of the uncertainties in each of the emission sectors, and in the estimation of the net removal by forestry. The uncertainty is dominated by the uncertainty in the land use, land use change and forestry sector. The method of combining the components of the uncertainty in this sector is considered in section 4.3. Section 4.4 provides a summary of our recommendations on combining uncertainties. Section 4.5 looks in more detail at estimating uncertainties in sectoral emissions estimates, and section 4.6, uncertainty in LULUCF emissions estimates. Our overall recommendations on uncertainty analysis are given in section 4.7.

### 4.2 The combination of uncertainty estimates

In an ideal world, the net position would be calculated by a single integrated model. All the inter-relationships and correlations between the input variables would be known accurately and a Monte Carlo simulation could be carried out by repeatedly sampling the input variables from their joint probability distribution. In reality, the expertise required to develop and maintain the models for each of the emission sectors lies within various bodies within and outside government. Projections of emissions from the agricultural sector are based on modelling by the Ministry of Agriculture and Forestry; the Ministry of Economic Development provides estimates of annual emissions from the energy, transport and industrial process sectors; the Ministry for the Environment provides estimates of emissions from the waste sector; projected removals from land use, land use change and the forestry sector are based on data and assumptions from the Ministry of Agriculture and Forestry and the Ministry for the Environment; carbon modelling for the forestry sector was undertaken by Ensis.

### 4.3 Common economic assumptions

The projections made for the various sectors depend to some extent on the general economic conditions. In our review of the 2005 assessment, AEA recommended that projections for each sector were based on a common set of economic assumptions. This recommendation was adopted in preparing the May 2006 projections. The Treasury and the Ministry of Economic Development prepared key assumptions for the most likely scenario for the 2006 assessment (Table 4). The draft 2007 assessment report does not present updated projections for the economic indicators.

**Table 4: Most likely economic scenario**

March year ending	Economic growth (GDP), % per annum	Exchange rate NZ\$/US\$	Population (000)	Oil prices, US\$ /bbl
2005	3.8	0.69	4093	60
2006	2.9	0.60	4130	60
2007	1.7	0.60	4166	60
2008	2.5	0.56	4204	60
2009	3.8	0.55	4240	60
2010	3.1	0.55	4275	60
2011	2.5	0.55	4312	60
2012	2.5	0.55	4350	60

It is not clear whether all departments have prepared common assumptions for the upper and lower bound scenarios.

In defining upper and lower bounds for the economic assumptions, it is necessary to consider the possibility that significant correlation exists between the growth in GDP, the exchange rate and the price of oil. It is also necessary to consider the extent to which these economic indicators are correlated between years. For example, it is possible that GDP would grow at rates above the most likely projection in one year, but increasingly unlikely that growth above projection would occur year on year into the future. On the other hand, a high oil price in one year may be followed by high oil price in subsequent years.

In an ideal world, the Treasury would produce large numbers of economic scenarios conforming to the joint probability distribution for economic growth, exchange rate, population and oil prices. These scenarios could then be used as inputs to the sector models. In reality, it may be only practical to limit the number of economic scenarios to the most likely, and the upper and lower bound scenarios.

## 4.4 Combining uncertainties

The modelling studies prepared by the relevant experts provide upper and lower bound estimates of the carbon emissions or net removal from various sectors. The IPCC Good Practice Guidance Annex on Uncertainty describes two basic approaches to the combination of emission uncertainties:

- Tier 1, based on simple linear analysis of variance.
- Tier 2, based on Monte Carlo simulation.

The Tier 1 approach is generally applicable in the case where the component uncertainties are relatively small and there is no correlation between the component uncertainties. These requirements are not met because there are relatively large uncertainties in the emissions from the agricultural sector and in the net removal from forestry and there may be significant correlation between sectors. It is therefore most appropriate to use the Monte Carlo simulation for combining uncertainties.

Table 5 shows the emissions and removals reported in the draft 2007 assessment of the net position.

The New Zealand Government's current policy is to cap the Crown's deforestation liability for pre-1990 forests at 21.0 million tonnes of carbon dioxide. A deforestation survey undertaken in 2006 indicated that deforestation is likely to exceed the 21.0 million tonne cap in the absence of policy interventions under current market conditions. The 2006 deforestation intention survey indicated that forest owners currently intend to deforest about 50,000 hectares during the first commitment period of the Kyoto Protocol. This area would generate deforestation emissions of approximately 41.0 million tonnes carbon dioxide. There are clearly two distinct scenarios possible, with potentially very different results. If the Government applies effective measures to limit deforestation to the cap, then the deforestation emissions will be 21.0 million tonnes carbon dioxide; if no measures are put in place the emissions will

be approximately 41.0 million tonnes carbon dioxide. It is not appropriate to include this policy uncertainty in the analysis of the overall uncertainty; rather the two scenarios should be considered separately. For this review, we will consider that effective measures to control the emissions to the level of the cap are put in place.

<b>Table 5: Emissions and removals reported in the draft 2007 assessment</b>			
	<b>Million tonnes of carbon dioxide equivalent</b>		
	<b>Upper scenario</b>	<b>Most likely scenario</b>	<b>Lower scenario</b>
<b>Emissions</b>			
Energy (excluding transport)	-103.0	-92.8	-86.1
Transport	-84.7	-80.1	-76.7
Industrial processes	-22.3	-22.2	-22.1
Solvent and other product use	-0.3	-0.3	-0.3
Agriculture	-228.3	-203.1	-180.0
Waste	-7.3	-7.0	-6.7
<b>Assigned Amount Units</b>			
Assigned	309.5	309.5	309.5
<b>Allocated to projects</b>	-7.5	-7.5	-7.5
<b>Removals based on afforestation</b>	57	79	119.3
<b>Deforestation emissions</b>	-41.0 (-21.0 with cap)	-21.0 (cap)	-21.0 (cap)

An important consideration is whether the emissions from each of the emissions sectors can be considered to be independent of each other. A Monte Carlo simulation was carried out for the 2006 assessment based on the assumption that the emission uncertainties in each sector were independent of the other sectors.

The analysis indicated a 95% confidence range in the projected balance of emission units of -76.1 to +1.4 million tonnes of carbon dioxide. Applying a similar analysis to the data presented in the 2007 draft report gives a projected range of -82 to +3 million tonnes carbon dioxide. The analysis assumed that the probability distribution of emission for each sector corresponded to a triangular distribution with mode equal to the most likely value and 5 % of the distribution lying outside the upper and lower scenario bounds. Ten thousand simulations were carried out.

The emissions from the energy sectors, including transport, are all dependent on the level of economic activity. The emissions in these sectors are therefore likely to be substantially correlated and it may not be appropriate to consider them to be independent. The Monte Carlo analysis was repeated assuming that the emissions from the energy, transport, industrial process, solvent and waste sectors were not independent. The upper bound range of emissions for the combined sector was calculated as the sum of the upper bound emissions from the sectors. Similarly, the lower bound was calculated as the sum of the lower bound emissions. This analysis gave a 95% confidence range in the projected balance of emission units of -83 to +3 million tonnes of carbon dioxide. Comparing the results with those obtained assuming independence between the energy sectors, it is clear that the assumption of independence for these sectors does not affect the results significantly.

Emissions from the agricultural sector are also dependent on the economic conditions. However, the correlation between the agricultural and energy sector emissions may not be strong and may in some circumstances be negative. For example, conditions giving rise to a high rate of economic growth may also lead to a reduction in the demand for agricultural exports. The assumption of negative correlation between the energy and agriculture sectors reduces the predicted 95% confidence range in the projected balance of emission units to -73 to -5 million tonnes of carbon dioxide. It is clearly important

to take account of how the agricultural and energy sector emissions are correlated and it is recommended that future work should establish this as set out in sections 4.5, 4.6 and 4.7.

## 4.5 Sector emissions

In the assessments carried out to-date, the upper bound emission for each of the emission sectors was calculated assuming worst-case values for each of the model input parameters. The lower bound emission was calculated assuming best-case values for each of the model input parameters. Thus the upper emissions scenario for agricultural emissions combined the upper 95<sup>th</sup> percentile projection for animal numbers, methane emissions per head, nitrogen output per head and nitrogen fertiliser use. It seems unlikely that all the optimistic or pessimistic options would occur together.

For each component within each sector, the emission is calculated as the product of the activity level and the appropriate emission factor, both of which are subject to uncertainty. The uncertainty in the activity levels is comprised of the uncertainty associated with the overall levels of economic activity and the uncertainty associated with other factors. Each of the sectors is affected to a greater or lesser extent by economic conditions and so there is the potential for correlation to occur between the emissions. As shown above, the overall uncertainty in the net position is affected by the extent to which the agricultural sector and energy sector emissions are correlated. It is thus important to distinguish between these two sources of uncertainty (economic and non-economic). It is therefore recommended that sector model runs are carried out for the most likely, pessimistic and optimistic economic scenarios with all other parameters set at their most likely values. This will provide an estimate of the uncertainty in the sector emissions resulting from the uncertainty in the overall economic factors.

The remaining task for each sector is then to assess the uncertainty associated with the non-economic factors. Pessimistic, most likely and optimistic assessments can be made for the most likely economic scenario based on the most optimistic or pessimistic non-economic input values.

The results from the different sectors can then be combined by Monte Carlo simulation of the sum of three independent distributions, each with triangular probability function:

- A triangular distribution with mode equal to the sum of the most likely energy and agriculture emissions for the most likely economic scenario; upper bound equal to the sum of the most likely energy and agriculture emissions for the pessimistic economic scenario; and lower bound equal to the sum of the most likely energy and agriculture emissions for the optimistic economic scenario.
- A triangular distribution with mode equal to zero; upper bound equal to the difference between the upper bound and most likely estimates of energy emissions for the most likely economic scenario; and lower bound equal to the difference between the lower bound and most likely estimates of energy emissions for the most likely economic scenario.
- A triangular distribution with mode equal to zero; upper bound equal to the difference between the upper bound and most likely estimates of agriculture emissions for the most likely economic scenario; and lower bound equal to the difference between the lower bound and most likely estimates of agriculture emissions for the most likely economic scenario.

The procedure is illustrated by example. Suppose that model results are obtained for the energy and agriculture sectors for high, most likely and low economic growth rates as shown in Table 6. The numbers are hypothetical and do not represent the actual situation.

Scenario	Million tonnes of carbon dioxide	
	Energy	Agriculture
High economic growth scenario, most likely non-economic factors	215	197

Most likely economic growth scenario, most likely non-economic factors	202	203
Low economic growth scenario, most likely non-economic factors	194	205
Most likely economic growth scenario, pessimistic non-economic factors	204	210
Most likely economic growth scenario, optimistic non-economic factors	200	197

The first distribution, representing the range of the total (energy plus agriculture) emissions for the most likely non-economic factors, has mode 405 (=202+203), upper bound 412 (=215+197) and lower bound 399 (=194+205). The second distribution, representing the uncertainty associated with non-economic factors in the energy sector, has mode 0; upper bound 2 (=204-202) and lower bound -2 (=200-202). The third distribution, representing the uncertainty associated with non-economic factors in the agriculture sector, has mode 0; upper bound 7 (=210-203) and lower bound -6 (=197-203).

The procedure is then to carry out a Monte Carlo simulation to calculate the distribution of the sum of these three distributions.

## 4.6 Land use, land use change and forestry emissions (LULUCF)

The estimates of the net carbon removal resulting from land use, land use change and forestry (LULUCF) introduce the largest element of uncertainty into the overall estimate of the net position

The Ministry of Agriculture and Forestry has run three simulations using all of the high emissions, most likely emissions and low emissions assumptions respectively to produce combined model results. The Ministry has also investigated the effect of changing the main model assumptions individually to investigate the sensitivity of the emissions to each of the main assumptions. Table 7 shows the results of these calculations presented in the draft 2007 report.

	Million tonnes of carbon dioxide equivalent		
	Upper scenario	Most likely scenario	Lower scenario
<b>Removals based on afforestation</b>			
Kyoto planted forest carbon dioxide emissions	96.8	96.8	96.8
Future afforestation	0	0.9	1.9
Adjustment in the area of Kyoto forest planted between 1990 and 2006	-4.8	0	4.8
Kyoto forest growth rate adjustment	-9.8	0	28.4
Soil carbon change with afforestation	-11.3	-3	0
Ineligible afforestation	-20.5	-15.7	-7.8
<i>Total removals from afforestation</i>	<i>57</i>	<i>79</i>	<i>119.3</i>
<b>Deforestation emissions</b>	-41.0 (-21.0 with cap)	-21.0 (cap)	-21.0 (cap)

The combined model results account for the interrelationships between adjustment factors (growth rates, new planting, soil carbon changes, over planting and scrub clearance during site preparation). The draft report states that the removals attributed to each factor are not additive because some factors are correlated. As an example, the report indicates that the soil carbon change is reduced as the result of ineligible planting because the total eligible area is reduced. This non-linearity results in a reduction in the range between the upper and lower bound estimates.

It seems possible that a further reduction in the estimate of the uncertainty of removal by afforestation is possible. It is unlikely that the uncertainty in the area of Kyoto forest planted between 1990 and 2006, the Kyoto forest growth rate per hectare, the soil carbon change per hectare, and the ineligible afforestation could be strongly correlated. It is unlikely that all the high emissions conditions would occur at the same time. It is not possible to quantify by how much the uncertainty range can be

reduced exactly because we do not have sufficient details of the combined model. However, a preliminary assessment can be made if the non-linearities in the combined model are ignored. We have carried out a Monte Carlo simulation of the removals based on afforestation. Each of the ranges shown in Table 6 was represented by a triangular probability distribution with mode equal to the most likely value, the high emissions value equal to the 97.5<sup>th</sup> percentile of the distribution and the low emissions value equal to the 2.5<sup>th</sup> percentile. The 95<sup>th</sup> percentile range of the predicted values was 69 to 109 million tonnes carbon dioxide equivalent.

The reduction in the uncertainty in the LULUCF net removal has a substantial effect on the overall uncertainty in the net position. We have combined the Monte Carlo above with the simulation of the net position assuming correlation between the energy sectors and waste. This analysis gave a 95% confidence range in the projected balance of emission units of -73 to -4 million tonnes of carbon dioxide. This range is substantially smaller than the equivalent range of -83 to +3 million tonnes of carbon dioxide calculated in section 2.

## 4.7 Recommendations

The following recommendations are made on the uncertainty analysis:

- That all departments should develop a range of consistent economic scenarios including the most likely, optimistic and pessimistic scenarios. In developing these consistent scenarios, the potential correlation between economic indicators should be taken into account.
- Modellers in the Ministry of Economic Development and the Ministry of Agriculture and Forestry should develop the most likely estimates of the emissions for the energy and agricultural sectors for each of the most likely, optimistic and pessimistic scenarios of economic factors. In addition, the uncertainty in the energy and agricultural emissions associated with non-economic factors should be assessed.
- The estimates of the uncertainty from each of the sectors can be combined by Monte Carlo simulation, provided that the potential correlation between sectors resulting from economic factors is taken into account. We have suggested a simple procedure.
- The New Zealand Government's current policy is to cap the Crown's deforestation liability for pre-1990 forests at 21.0 million tonnes of carbon dioxide. If this policy is not implemented effectively, deforestation emissions are expected to rise to 41.0 million tonnes. It is not appropriate to include this policy uncertainty in the analysis of the overall uncertainty; rather the two scenarios should be considered separately.
- The uncertainties in the LULUCF emissions make the biggest contribution to the uncertainty in the net position. Currently upper and lower bound estimates are calculated assuming all high and all low values respectively for each of the factors contributing to the net removal. Monte Carlo simulation within this sector has the potential to reduce the uncertainty in the net removal and the overall net position substantially.

## 5 Conclusions and recommendations

This report has assessed the extent to which recommendations made in the 2005 review (NP 2005) have been implemented in the 2007 emission projection methodology and 2007 net position report. In general we consider that the basis for the 2007 projections is more robust than the basis for the 2005 projections, and the projections are better documented. The progress made in implementing each of the recommendations from the 2005 review is summarised in Tables 8 and 9 (for high priority recommendations and lower priority recommendations respectively). Overall there has been significant progress towards implementing the recommendations. In the energy and transport sectors, as well as key improvements to the modelling suggested in the review, there have been additional improvements. However, recommendations on modelling of the residential sector have still to be implemented. In the LULUCF all recommendations have been implemented, although in some cases implementation is not complete as data is required from the LUCAS project, which is due to become operational in 2010. Similarly, high priority recommendations in the agriculture sector have been implemented. The compilation process has been improved, with the introduction of a steering group, requirements for 'sign-off' by departments of projections and improved documentation, but improvements to quality assurance and quality control (QA/QC) could still be made. Documentation and explanation of how the effects of policy on emissions are estimated could also be improved further, as could the treatment of uncertainty.

Recommendations from the 2005 review, which have not yet been implemented and are still valid are:

- Energy: use bottom up model of residential sector to cross-check results from SADEM and consider incorporating more bottom-up detail within SADEM for this sector.
- Energy: improve the treatment of uncertainty (see below).
- Energy: consider cooling and heating degree-days separately in the residential energy model. It is accepted however that this is not of key importance and that it will be addressed in the proposed improvements to the model.

Recommendations which have been implemented but where some further improvements could be made, together with new recommendations arising from this review, are detailed below:

- Compilation: improve project planning and documentation and introduce and implement a formal QA/QC plan for project compilation. Each department contributing projections should produce a written QA/QC document and the Ministry for the Environment should produce one for the compilation process.
- Compilation: produce a written plan, to improve over the next two-to-three years, the quality of the projections.
- Policies: continue to improve the documentation available concerning the basis of emissions savings anticipated from policies, ensuring that it is transparent and comprehensive.
- Energy: improve the representation of transmission and distribution losses in GEM.
- Energy: consider whether the treatment of hydro storage can be better addressed in GEM.
- Transport: consider whether the growing use of air transport requires that it is modelled using drivers of demand rather than using a time series model.
- Transport: consider if a split between freight and passenger transport demand would allow a better characterisation of transport demand.
- Transport: consider improving modelling of effect on emissions of biofuels sales obligation (bioethanol element).
- Industry: consider explicit modelling of fluorinated gas emissions.
- Agriculture: continue to keep the trends in ruminant methane and nitrogen excretion factors under review and consider an alternative approach to modelling if the linear trend becomes less strong.
- LULUCF: data from LUCAS should be used to reduce uncertainties in the projections as soon as they become available.
- LULUCF: more information about the LUCAS project should be included in the LULUCF section in the net position report.
- LULUCF: documentation should be kept up-to-date with the latest methodological developments.

This review also looked in some detail at how uncertainty is modelled and made the following recommendations:

- Modellers in the Ministry of Economic Development and the Ministry of Agriculture and Forestry should develop the most likely estimates of the emissions for the energy and agricultural sectors for each of the most likely, optimistic and pessimistic scenarios.
- The uncertainty in the energy and agricultural emissions associated with non-economic factors should be assessed.
- The estimates of the uncertainty from each of the sectors can be combined by Monte Carlo simulation, provided that the potential correlation between sectors resulting from economic factors is taken into account.
- The uncertainty over effectiveness with which the Government's current policy to cap the Crown's deforestation liability for pre-1990 forests at 21.0 million tonnes of carbon dioxide is implemented should not be included in the analysis of the overall uncertainty. Instead two scenarios, one where the target is reached, and one where deforestation emissions rise above this level should be considered separately.
- The use of Monte Carlo simulation within the LULUCF sector should be considered as this has the potential to reduce the uncertainty in the net removal and the overall net position substantially.

While it is not possible to judge conclusively, overall, on the basis of the information available at the time of this review, we believe that implementation of the outstanding recommendations and proposals for further improvements are unlikely to make a substantial change to the 'most likely' estimate of the net position result at the current time. The largest uncertainty in the net position arises from the LULUCF sector, where there is considerable uncertainty in future outcomes, measurement uncertainty, knowledge gaps and high natural variability in the factors affecting emissions. However, the approach taken to estimating the sector's contribution is reasonable given the current data limitations.

<b>Table 8: Assessment of Progress on High Priority Recommendations from 2005 Review</b>			
<b>Sector</b>	<b>Recommendation</b>	<b>Status</b>	<b>Comment</b>
Energy	Use existing bottom-up models of key sectors (e.g. transport and residential) to cross-check the results from SADEM and, in the longer term, consider incorporating more bottom-up detail within SADEM. This will also be useful for modelling policy impacts.	Partially implemented	A bottom-up transport model the (Ministry of Transport's Vehicle Fleet Emission Model) is now used but there is still no bottom-up modelling of residential sector.
Energy	Revisit usage of the degree-day variables in residential and other industry and commercial sectors.	Not implemented	A report commissioned by the Ministry for Economic Development highlighted the statistical insignificance of this parameter. This will be addressed with the proposed improvements to the residential-energy model.
Energy	Explore disaggregation of sectors in 'other industry and commercial', possibly at the 1-digit ANZSIC level.	Implemented	'Other industry and commercial' now separated; dairy processing now disaggregated from other industry; disaggregation of other sectors not considered possible.
Energy	Liase with Ministry of Transport to consider roles and responsibilities for transport energy demand modelling going forward.	Implemented	There appears to have been considerable dialogue between the Ministry for Transport and the Ministry for Economic Development on the projection of transport demand.
Energy	Consider the use of a modular demand function for estimating petrol and diesel demand (i.e., fuel demand = vehicle fleet x utilisation x fuel efficiency).	Implemented	The Vehicle Fleet Emission model which uses modular demand function now integrated with SADEM.
LULUCF	Improve knowledge of the reasons and drivers for the downward trend in new forest planting to allow improved forecasting concerning the future possible intentions of forest owners.	Implemented	The net position report uses three afforestation scenarios that, under current market conditions and policy settings, cover expected afforestation levels out to 2012. Information on afforestation drivers has been gathered but this is considered to be more suited for longer term projections and evaluating policy options.
LULUCF	Improve quantification of the areas of planting of post-1990 forest at national scale into existing shrublands that meets Kyoto Protocol definition of forest.	Initiated but not yet completed	Awaiting data from the LUCAS project (due to become operational in 2010).
LULUCF	Improve estimation of areas deforested and drivers for this process.	Implemented.	Surveys of forest owners' intentions undertaken in 2005 and 2006. The LUCAS project will provide additional quantification.
LULUCF	Undertake further research on the time pattern of loss of carbon from soils after afforestation.	Initiated but not yet completed	Awaiting data from the LUCAS project (due to become operational in 2010).

<b>Table 8: Assessment of Progress on High Priority Recommendations from 2005 Review</b>			
<b>Sector</b>	<b>Recommendation</b>	<b>Status</b>	<b>Comment</b>
Agriculture	Improve understanding of the drivers for the rapid increase in nitrogenous fertiliser use and judge whether these can be expected to continue and whether other measures to limit fertiliser use (e.g. environmental concerns) may have an impact.	Implemented.	Econometric model now used to project nitrogenous fertiliser use
Agriculture	Consider defining optimistic and pessimistic scenarios for livestock numbers by examining the effect of potential changes in the Pastoral Supply Response Model drivers (price data etc) rather than just for a somewhat arbitrary range based on the 2004 livestock numbers.	Implemented	Impact of uncertainty in forecast price on projected livestock numbers now modelled in PRSM.
Process	Establish a steering group to oversee the projection compilation process.	Implemented	Steering Group met regularly during the 2007 compilation period.
Process	Improve project planning and documentation and introduction/implementation of a formal QA/QC plan for the projection compilation.	Partially implemented	More project planning in place and departments now asked to 'sign off' projections provided as best estimate. Recommend that further improvements are made in this area.
Process	Improve written documentation to fully describe methodology and assumptions made across all sectors.	Partially implemented	In general, written documentation has improved. For example, in LULUCF there is now a single document describing methodology and assumptions.
Compilation	Ensure internal consistency both across sectors (e.g. the same rate of deforestation is used in the agriculture sector as in LULUCF sector) and in off-model calculation (e.g. liabilities from Projects to Reduce Emissions).	Partially implemented	Greater awareness of need for internal consistency (e.g. projected dairy herd numbers used in modelling energy consumption of dairy industry). Deforestation and afforestation not explicitly included in the Pastoral Supply Response Model in 2007 – this is acceptable as any error is small. See below for comment on PRE liabilities.
Policies	Further integrate the analysis of policy impacts to ensure that there is no double-counting of savings.	Undetermined in this review	As this review was not as in-depth as the 2005 review, it was not possible to establish conclusively that this has been implemented, but no double counting was apparent. The Ministry for the Environment has confirmed that the policies will be modelled in aggregate in the 2008 review to avoid any double counting.

<b>Table 8: Assessment of Progress on High Priority Recommendations from 2005 Review</b>			
<b>Sector</b>	<b>Recommendation</b>	<b>Status</b>	<b>Comment</b>
Policies	Give consideration to how the impacts of non-modelled policies can be incorporated into the SADEM projections. Once some of the impacts of the policy are allowed for in SADEM, it will no longer be appropriate to simply subtract the full saving attributable to the policy (as estimated outside of SADEM) from the SADEM carbon dioxide projections, as this will result in double counting of the savings.	See comment	Four energy policies are currently evaluated. Modelling of the impact of National Energy Efficiency and Conservation Strategy measures and Projects to Reduce Emissions are reported as now being explicitly modelled in GEM and SADEM respectively so problems of double counting should be avoided. The impact of solar water heating is estimated outside of SADEM. It is not clear whether the biofuels sales obligation has been incorporated into the Vehicle Fleet Emission Model or estimated off-line.
Compilation	Perform a consistency check between the results of SADEM in relation to the success rate for projects and the assumptions used to calculate the liabilities from Projects to Reduce Emissions (PREs) in the compilation of the overall net position.	See comment	While the effect of PREs is now modelled in GEM, it is not clear that a cross-check is made on the number of projects going ahead and the estimate of project units made by The Ministry for the Environment to assess liabilities.
Policies	Improve the documentation available concerning the basis of the attributed emission savings anticipated from climate change policies (particularly for the optimistic and pessimistic estimates).	Partially implemented	The basis of estimated savings from PREs, biofuels sales obligations and solar water heating is documented clearly although expected savings are not identified directly. In the waste sector, documentation could be improved, e.g., by including references for reports containing original estimates of savings.
Uncertainties	Improve the transparency of the uncertainty calculations by clearly defining the basis for calculating the uncertainty ranges and using a consistent approach to quantifying uncertainties across sectors in terms of deciding what is trying to be quantified i.e. the uncertainty caused by future unpredictability (e.g. uncertainty in the forecasts of key drivers) or value uncertainty (e.g. uncertainty in data values).	Ongoing	Guidance was given to departments to encourage a uniform approach to treating uncertainty, but this area still requires further work.

<b>Table 9: Assessment of Progress on Lower Priority Recommendations from 2005 Review</b>			
<b>Sector</b>	<b>Recommendation</b>	<b>Status</b>	<b>Comment</b>
LULUCF	Improve the information/quantification on the burning and decay of scrub vegetation.	Partially implemented.	Estimates made but awaiting additional data from LUCAS project.
Agriculture	Keep under review the use of a linear extrapolation of enteric emission factors and factors for nitrogen excreted per head. Consideration should be given to examining the trend if single year rather than three-year average data is used.	Partially implemented	Other relationships have been tested; use of single year figure to determine trend not examined as believed would have no material effect. Recommend that trend be reviewed annually to check there is no saturation effect.
Waste	Consider using an alternative calculation methodology for emissions from wastewater treatment to increase the robustness of this forecast estimate.	Implemented	Research study almost complete; methodology will be changed.
Energy	Consider revising the methodology for calculating non-carbon dioxide greenhouse gas emissions from fuel combustion to a UNFCCC Tier 1 approach (emission factor X fuel consumption).	Implemented	Non-carbon dioxide fuel combustion emissions now calculated using specific emission factors; i.e., consistent with UNFCCC tier 1 approach.
Policies (waste)	Revisit the basis of the savings forecast from policies in this sector and document the attributed savings in a clear and transparent fashion.	Partially implemented	Documentation of attributed savings still needs to be improved.
Policies (PREs)	Conduct a comparison of the project economics provided to Government under the PRE tender round with those currently assumed for each plant type in SADEM to help improve the realism of the data in the model.	Implemented	Generation technology economics in SADEM were reviewed and compared to project economics; however generation technologies are now modelled in GEM. If not already done so, then a similar comparison should be carried out for GEM.
Policies (PREs)	Conduct a comparison of the modelled (SADEM) savings per kWh with those assumed in the PRE evaluation to ensure these are broadly consistent.	Undetermined in this review	Reported that a comparison would be carried out.
Policies (NGAs)	Ensure an improved understanding of impacts of Negotiated Greenhouse Agreements is obtained from the ongoing work by the Ministry for Economic Development looking at energy demand within the heavy industry sector.	Implemented	Study on energy demand in heavy industry commissioned by the Ministry for Economic Development <sup>12</sup> Negotiated Greenhouse Agreements no longer relevant as proposal for a broad-based carbon tax has been dropped.
Compilation	Reinvigorate efforts to ensure the use of common datasets across all sectors.	Implemented	This has been implemented.

<sup>12</sup> <http://www.med.govt.nz/upload/38670/heavy-industry-energy-demand.pdf>

<b>Table 9: Assessment of Progress on Lower Priority Recommendations from 2005 Review</b>			
<b>Sector</b>	<b>Recommendation</b>	<b>Status</b>	<b>Comment</b>
Compilation	Consider aligning the definitions of projections used in the net position work to those used for international reporting to the UNFCCC.	Partially implemented	The 'most likely scenario' projections in the net position report are aligned to the UNFCCC 'with measures' projections; ie, it encompasses currently implemented and adopted policies and measures. The upper and lower scenarios are not aligned with any definition and, depending on the sector, are produced by considering both uncertainties in emissions factors, activity data and the outcome of policy. As discussed in the section on uncertainty, modelling the impact of uncertainty should be done separately from examining the effects of policies or other events. These are probably better treated by constructing different scenarios.

## 6 References

AEA, 2005. Review of New Zealand's Net Position, Final report to the Ministry for the Environment, AEAT/ED48447/R1, 24 October 2005.

BRANZ, 2006. Energy use in New Zealand Households, Report on the Year 10 Analysis for the Household Energy End-Use Project (HEEP).

Covec, 2005. Review of MED Modelling Capability, August 2005, Covec for the Ministry of Economic Development, (<http://www.med.govt.nz/energy/modelling/papers>)

Covec, 2006. Heavy Industry Energy Demand, Covec, Hale & Twomey and Exergi Consulting for the Ministry of Economic Development, June 2006. (<http://www.med.govt.nz/energy/modelling/papers>)

Horgan G, 2007. Financial returns and forest planting rates. Cited in MAF, 2007.

MAF, 2007. 2007 Projected removals and emissions by the land use, land use change and forestry sector over the first commitment period (2008 – 2012) of the Kyoto Protocol. Prepared by the Ministry of Agriculture and Forestry, 2007.

MAF 2007a. 2007 Projected emissions from the agriculture sector over the first commitment period (2008 – 2012) of the Kyoto Protocol. Prepared by the Ministry of Agriculture and Forestry, 2007.

MED, 2006. New Zealand's Energy Outlook to 2030, Ministry for the Environment, 2006. Available from <http://www.med.govt.nz/energy/eo/2006/>

MED, 2007. Projected balance of emissions for the energy (including transport) and industrial process sectors, May 2007. Report prepared by the Energy information and modelling group, Energy & Communications Branch, Ministry of Economic Development.

MfE, 2007. New Zealand's Greenhouse Gas Inventory 1990–2005: The National Inventory Report And Common Reporting Format, July 2007, Ministry for the Environment.

MfE 2007, Projected balance of emissions units during the 1<sup>st</sup> commitment period of the Kyoto Protocol, June 2007, Ministry for the Environment

Wakelin et al. 2007, 2007 Net carbon uptake projections (2008 – 2012) - Land use, land-use change and forestry. ENSIS, March 2007.