Forestry accounting options

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Authors: J Ford-Robertson, K Robertson

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Publisher

Ministry of Agriculture and Forestry
PO Box 2526
Pastoral House, 25 The Terrace
Wellington 6140
www.maf.govt.nz

Telephone: 0800 008 333

Facsimile: +64 4 894 0300

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Forestry Accounting Options

Justin Ford-Robertson
Kimberly Robertson

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FORCE CONSULTING LTD
444 Pukehangi Rd
Rotorua 3015, NZ
Tel: +64 7 343 9559
kimbelryrobertson@xtra.co.nz

Company Office
PO Box 37228
Christchurch 8245 NZ
T +64 3 329 6888
F +64 3 329 6880
E activate@catalystnz.co.nz
W www.catalystnz.co.nz

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Forestry Accounting Options

1 Executive Summary

This project explores the accounting systems for forests and their products. It examines guidance on forestry, national greenhouse gas inventories and accounting systems under the Kyoto Protocol and raises a number of issues. New Zealand data on forestry-related stocks and flows are used to create a simple national mass balance for 2005. Different accounting rules are applied to examine the accounted impacts, to inform negotiations on a post-2012 framework.

Greenhouse gas accounting systems include methods for both estimating emissions and removals, and ways to combine data for particular situations. National accounting is largely based on the change in emissions relative to a base year (1990), but also incorporates the change in forest stocks during the first commitment period. Accounting for projects focuses on emissions reductions, or stock changes, relative to a counterfactual baseline. The accounted impacts on the project scale are therefore not the same as the impacts on the national scale.

The current accounting system for forestry and related products describes neither when nor where emissions and removals occur. The focus is on forest carbon stock changes based on the assumption of emissions at the point of harvest. It is acknowledged that the instant oxidation default assumption is not accurate, and only recommended for initial calculations. It creates significant issues with accuracy, equity, policy and encouraging behaviour change. For example there is an incentive to maximise forest stocks, avoiding harvesting that is treated as an emission. Since both harvesting and deforestation are considered as emissions, consumers may tend to avoid wood products.

Since emissions are allocated to the the point of harvest, bioenergy emissions are not accounted for. Accounting for a zero-emission fuel in relation to a fossil fuel reference scenario creates the impression that burning biomass is reducing emissions. This gives it equal status to activities such as afforestation. Hence the introduction of baselines to the project accounting system creates further distance between what the atmosphere sees and what is accounted for.

Identification of the components of the forest-related carbon cycle indicates the potential for improving the accuracy of the national inventory rather than assuming instant oxidation of harvested carbon. This report investigates the impacts of activities on the atmosphere and the different ways such activities can be perceived by applying different accounting approaches.

This report evaluates three options to estimate the accounted forestry impacts:

Option 1. - Forest stock change;
Option 2. - Modelling stocks and flows to derive estimates of
a) stock changes in all stocks or
b) delayed emissions; and
Options 3 - Net removal from the atmosphere.

Based on carbon stocks and flows of NZ forests the net removals from the atmosphere for these options have been calculated. Under the Status Quo it appears that NZ has a forest sink of 26.8 MtCO_2e. If proposals to include stock changes in wood products (in use and waste disposal sites) are applied, there is a minor increase in the apparent sink (28.1 Mt CO_2e). If however, the focus is

applied to the atmospheric exchanges resulting from forestry activities (forest sink – bioenergy – SWDS), net removals increase by 37% to 36.8 $MtCO_2e$. This means NZ under-estimates annual net removals (and hence overstates the net atmospheric GHG emissions) by 10 $MtCO_2$/yr.

The options were also considered in terms of:

- Accuracy of emission and removal estimates
- Equity: the allocation of responsibilty for emissions and removals
- Policy: which policies each of the options favour and
- Behavioral change:what behaviours the accounting options and policies would enocurage/discourage.

Overall option 3 is the most accurate approach for estimating atmospheric impacts within national boundaries when they occur. It is based on scientific attribution of emissions and removals which reflects resource flows through the economy. This reduces complexity and associated concerns arising from other allocation options. If national policies recognise the ongoing sink in production forests there is a greater chance that land managers will be given the incentives to maintain and enhance forest sinks and reservoirs. This will lead to enhanced environmental services compared to other land use options. Option 3 will also lead to greater efficiency in the use of wood products, and encourage cascading biomass uses that will optimize atmospheric outcomes.

A key recommendation is the need to develop a process to improve the availability and understanding of information on carbon stocks and flows within and from New Zealand as a basis of developing an accounting system that better reflects atmospheric impacts. This would include key officials, researchers and industry representing forestry, energy, and waste. A range of specific actions to support this are listed and two specific projects are detailed.

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2 Introduction

This project explores the greenhouse gas accounting systems for forests and their products. It draws on Intergovernmental Panel on Climate Change (IPCC) guidance and related political decisions, and identifies key aspects of different accounting systems in place to measure emissions reductions and assess compliance with national commitments. New Zealand data on all plantations and wood products are used to evaluate the contributions of forestry and related products according to different accounting rules. Options for a post-2012 framework for all forests that will contribute to improved global atmospheric outcomes are identified. The impact of these options is assessed in terms of both atmospheric exchanges and stock changes.

This project does not reflect the accounts under the Kyoto Protocol (KP) which are focused on a subset of forests and activities, which are unlikely to result in many (if any) products during the first commitment period. The analysis therefore is intended to inform the negotiations on accounting in future periods.

2.1 Overview of GHG accounting

Greenhouse gas (GHG) accounting follows a process that commences with methods for estimating emissions by sources and removals by sinks. These estimates can be reported as the direct atmospheric impacts of activities (e.g. national GHG inventories), and can be manipulated to meet stated objectives such as to determine the change in impacts relative to an historic base year (e.g. KP), or to estimate changes relative to a future baseline (e.g. individual projects). Inconsistencies can be expected between methods and calculations to suit different objectives, but these can cause confusion. Hence a project meeting its objectives may not contribute to national commitments in terms of atmospheric outcomes.

The guidelines and methods for estimating emissions and removals from different sectors and activities have been compiled by the IPCC. IPCC guidance was originally developed to help prepare accurate inventories of greenhouse gas emissions and removals when and where they occur. Accurate data is required in order to produce accurate estimates of atmospheric impacts. Accuracy is important for several reasons including:

- Modelling. Accurate estimates of where and when emissions and removals occur is required for climate models in order to develop reliable estimates of the impacts on atmospheric GHG levels. This will influence the development of future climate scenarios.
- Equity. Accurate estimates about where and when emissions and removals occur is required to enable allocation of responsibility for reducing emissions or enhancing removals. In prinicple Parties are only responsible for emissions over which they have some control.
- Policy development. Accurate estimates of emissions and removals from different activities is required to enable the development of policy that can reduce emissions or enhance removals by encouraging favoured production or consumption behaviour.
- Behavioural change. Accurate estimates of emissions and removals from different activities reflect resource flows through the economy. Such a system is easy to understand and allows direct comparision of the impacts of one activity over another. Accounting based on incomplete data, counterfactual baselines and relative impacts can create different perceptions that may not encourage positive atmospheric outcomes.

The guidelines (IPCC, 1997, 2000, 2003) have also been adopted for accounting under the KP. Whereas the GHG inventories focus largely on the evaluating direct atmospheric impacts of activities, the KP focus is on encouraging change (reductions) in emissions. It allocates responsibility for emissions and removals and the introduction of legally binding commitments and penalties adds a financial dimension. Various national policies are being introduced to reduce emissions, but also to encourage emission reductions through collaborative projects.

2.2 Climate Change Responses

A range of national policies and mechanisms are being implemented in New Zealand and awareness is growing of the carbon costs of doing business. There are numerous examples of positive steps being undertaken to reduce and offset emissions but still New Zealand's greenhouse gas emissions for 2006 are reported to be 77.9 Mt CO_2-e, 26% higher than the 1990 level of 61.9 Mt CO_2e (MfE, 2008). The proposed New Zealand Emissions Trading System (ETS) aims to reduce emissions relative to business as usual (baseline) which, if successful, could at least reduce the rate of increase in emissions. This is a step forward, but is unlikely to return emissions to 1990 levels. Therefore it looks likely that New Zealand will be one of a number of countries purchasing emissions reductions from offshore to meet commitments returning emissions to 1990 levels.

Projects and associated carbon trading are often seen as an effective approach for reducing emissions at least cost. Carbon trading incorporates a number of different emission reduction units, depending on their source and the mechanism being employed. The accounting rules applying to each of these mechanisms directly affects the estimate of emissions avoided or reduced, and hence the quantity of emission reduction 'credits' generated. Inconsistencies in the rules and interpretations thereof, mean all emissions reductions are not necessarily equivalent. For example, reductions relative to a future baseline may not offer any reductions relative to an historic base year.

Despite all climate-related policies and responses, including increased trade in 'emissions reductions' (over 1,700 MtCO_2e in 2006 and almost 3,000 MtCO_2e in 2007 (Capoor and Ambrosi, 2008)), the rate of emissions growth and the atmospheric GHG concentrations continue to climb. The overall KP target for a 5% reduction below 1990 emissions by Annex I Parties appears in jeopardy. Questions are therefore being asked about the atmospheric effectiveness, as well as other impacts, of different trading mechanisms in place.

The first commitment period (CP1) 2008-12 of the KP has only just begun but as the financial implications become clearer, many governments, businesses and other interested parties are proposing alterations to the accounting framework, claiming particular circumstances warrant special attention, or pointing to the inconsistencies in the rules for different sectors or activities. Just as the KP has been subsequently adjusted with additional activities, caps and accounting rules, similar modifications are being considered at the national level. Many such factors are being taken into account during the ongoing negotiations for an international agreement for the post-2012 period.

New Zealand was well prepared for the negotiations around the KP and hence was able to influence the construction of the agreement based on sound scientific arguments and evidence. In particular, the adoption of a gross-net approach[1] provides greater recognition of the role of forests than a net-

[1] The gross-net approach proposed indicated that the total units of carbon accumulated by forests was a better indicator of its impact on atmospheric concentrations than the adoption of a net-net approach that would compare the annual rate

net approach. The climate agreement post-2012 is anticipated to require much greater emissions reduction than CP1, leading towards dramatic cuts in emissions below 1990 levels by 2050. The way forestry and other land use activities are incorporated will be a major influence on the national GHG accounts, as well as on the future of forestry in New Zealand.

2.3 Report structure

In this report the following sections are developed:

- Section 3 explores reporting and accounting systems with a focus on forestry and related products.
- Section 4 discusses the differences between these systems and some of the issues that arise from these.
- Section 5 identifies New Zealand data and estimates of carbon stocks and GHG flows related to the forest industry.
- Section 6 presents some accounting options.
- Section 7 quantifies the impacts and perceptions created by applying different rules and assumptions.
- Section 8 draws conclusions and makes recommendations for further work that will contribute to improved global atmospheric outcomes.

The results and issues raised are intended to assist with the negotiations for the post-2012 framework, and to the development of New Zealand domestic policy that is consistent with sustainability and carbon-neutral objectives.

of stock change during 2008-12 with the rate in the base year (1990). The net-net approach has been adopted for most sectors and activities other than forestry.

3 Current systems for carbon reporting and accounting

The provision of products and services, and the connection with climate change is illustrated in Figure 1. The world can simplistically be viewed as three nested spheres containing a finite quantity of carbon: the atmosphere as the outer shell, the geosphere as the centre, and the biosphere as a layer in between them. The climate change issue has arisen primarily because there is too much carbon being released from the geosphere (and biosphere to a lesser degree) to the atmosphere, creating the enhanced greenhouse effect. Bertram and Terry (2008) point out that the focus on individual country emission levels underplays the significance of historic emissions and total contribution to the atmospheric stocks, and suggest the "real measure of a nation's impact on the atmosphere is its cumulative share of emissions over time".

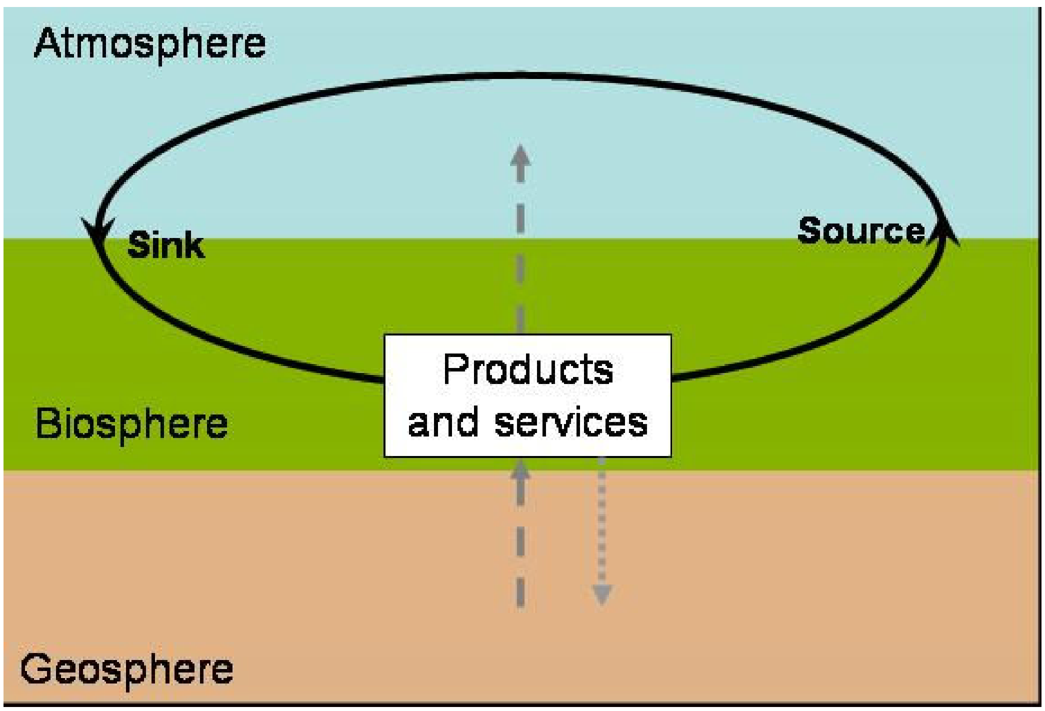

Figure 1. Atmospheric GHGs are increased by reducing carbon stocks in the biosphere and geosphere, in order to provide various products and services.

3.1 United Nations Framework Convention on Climate Change

The overarching objective contained within the United Nations Framework Convention on Climate Change (UNFCCC) is to prevent dangerous anthropogenic interference with the climate system. The IPCC provide a range of possible scenarios of future emissions and the anticipated impacts of stabilizing the atmospheric concentration at different levels. In the short term the objective is to reduce emissions relative to a future baseline scenario, or reducing the rate of increase in emissions. In the longer term the objective is to reduce absolute emissions relative to an historic base year e.g. reduce emissions to 50% of 1990 levels by 2050. This represents a reversal of the current emission trend. This is likely to involve not just a reduction in sources of emissions but also the maintenance and enhancement of sinks and reservoirs.

Sinks, sources and reservoirs are defined by the UNFCCC:

- A SINK is any process, activity or mechanism that removes a GHG, an aerosol or a precursor to a GHG from the atmosphere.
- A SOURCE is any process, activity or mechanism that releases a GHG, an aerosol or a precursor to a GHG into the atmosphere.
- A RESERVOIR means a component or components of the climate system where a greenhouse gas is stored.

Emission and removals of GHGs are documented by Parties to the UNFCCC in National Inventories which "contain estimates for the calendar year during which the emissions to (or removals from) the atmosphere occur" (IPCC, 2006). Data are presented, under guidance from the IPCC, in a common reporting format to enable consistency between Parties.

One of the features of the IPCC guidelines is the provision of Tiers that represent levels of methodological complexity. Three tiers are commonly provided with Tier 1 as the basic default, Tier 2 intermediate and Tier 3 the most demanding in terms of complexity and data requirements. Tier 1 methods for all categories are designed to use readily available statistics in combination with default emission factors provided, and therefore should be feasible for all countries. An inventory of land-use change and forestry emissions developed on default values only is unlikely to be considered credible for any country which has significant emissions or activities in these areas. Tiers 2 and 3 are sometimes referred to as *higher tier* methods and are generally considered to be more accurate. It is good practice to "produce inventories which contain neither over- nor under-estimates so far as can be judged, and in which uncertainties are reduced as far as practicable" (IPCC, 2003).

The Revised 1996 IPCC Guidelines (96GL) form the basis for reporting and all subsequent revisions should be consistent with this. New data and improved methods are included in successive guidelines. The forestry sector guidelines are described under Land Use Change and Forestry (LUCF) (IPCC, 1997), Land Use, Land Use Change and Forestry (LULUCF) (IPCC, 2003) and most recently in the combined guidelines for Agriculture, Forestry and Land Use (AFOLU) (IPCC, 2006).

The LUCF sector of the Guidelines (IPCC, 1997) states:

i. "Changes in forest and other woody biomass stocks may be either a source or a sink for carbon dioxide for a given year and country or region. The simplest way to determine which, is by comparing the annual biomass growth versus annual harvest, including the decay of forest products and slash left during harvest."
ii. "For the purposes of the basic calculations, the recommended default assumption is that all carbon removed in wood and other biomass from forests is oxidized in the year of removal. This is clearly not strictly accurate in the case of some forest products, but is considered a legitimate, conservative assumption for initial calculations."
iii. "Harvested wood releases its carbon at rates dependent upon its method of processing and its end-use: waste wood is usually burned immediately or within a couple of years, paper usually decays in up to 5 years (although landfilling of paper can result in longer-term storage of the carbon and eventual release as methane or CO), and lumber decays in up to 100 or more years."

Since the international process has moved beyond initial calculations, more accurate approaches appear to be required, and the guidelines provide an indication of what this could involve. This would seem even more relevant to accounting under the KP in which there are potentially considerable financial implications.

The 2006 Guidelines are intended to help the development of the post-2012 international agreement. Agriculture has traditionally been considered separately from forestry, and despite combining the sectors in the latest guidelines, the methods remain distinct. Carbon dioxide is the principal component of estimating impacts of the LULUCF sector, but is not a feature of the agriculture sector. Hence estimates of emissions are not directly comparable, and the impacts of changing land use may be more difficult to determine.

3.2 The Kyoto Protocol

It is important to acknowledge the difference between reporting emissions in national GHG inventories under the UNFCCC, and accounting for emissions under the KP. National inventories are prepared to provide complete, transparent and accurate record of emissions and removals resulting from anthropogenic activities. Under the KP, a subset of these -emissions resulting from specified Afforestation, Reforestation and Deforestation (ARD) activities since 1990 - is accounted for, using additional rules and procedures for allocating responsibility for sources and sinks.

The UNFCCC has a high level objective but no legally binding commitments. The KP requires Annex I Parties to collectively reduce their emissions during CP1 (2008-2012) to 5% below their emissions in 1990. National commitments are established based on a set of accounting rules, with New Zealand agreeing to return average annual emissions during CP1 to 1990 levels.

Any increase in gross emissions can be offset by the net changes in forest stocks during CP1 resulting from eligible forest activities. The KP also includes a number of mechanisms which a country can use to meet its emission reduction commitments.

A key principle for accounting under the Kyoto Protocol (UNFCCC, 2002) is that the reversal of any removal due to land use, land-use change and forestry activities be accounted for at the appropriate point in time. The removal occurs during photosysnthesis in the forest, and in most cases this is reversed by processes such as decay or combustion, frequently off-site.

3.2.1 Land use, land use change and forestry

The negotiation of LULUCF rules after reduction targets were set in the CP1 caused a number of difficulties and led to the adoption of a number of ‘fixes’ for issues that arose. For example, special rules are applicable to harvesting or deforestation of land afforested since 1990. Similarly, to avoid reducing the impact of the KP, limits were negotiated for sink credits available from forest management as one of the ‘additional activities’ not originally specified in the KP.

The accounting system for LULUCF describes neither when nor where emissions occur. Instead there is a widespread assumption that all emissions are accounted for when and where biomass is harvested. The IPCC (1997) recognise that this is not accurate, and it could contravene the accounting principle above regarding the timing of emissions (reversing removals) from forestry.

Another issue is that land use activities are not all treated in the same way. While forestry has a focus on stock change (growth minus harvest, representing sink and source) during CP1, other land uses are more focussed on emissions of non-CO_2 GHGs such as CH_4 and N_2O. Furthermore, the agriculture accounting system is not focussed on the change in stocks during CP1, but the change in emissions since 1990.

3.2.2 Joint Implementation (JI) and Clean Development mechanisms (CDM)

These are both ways of undertaking emission reduction projects in conjunction with other countries. JI allows trading with other Annex I countries and the CDM with non-Annex I countries. In both cases there is a need for projects to show additionality e.g. more emission reduction than could have been anticipated without the project. Emission reductions are therefore estimated relative to a counterfactual baseline, allowing for possible leakage i.e. activity by third parties in response to the project. The estimation of emission reductions by projects is thus more demanding than estimates based on verifiable activity data and emission factors. The credits available from the national allowance (Assigned Amount Units or AAUs) for such projects are therefore not always consistent with national targets.

A country that aims to stabilize emissions at an historic level but recognizes its energy demand is increasing could satisfy both objectives in a range of different ways. For example:

- Meet energy demands with natural gas, meaning emissions will rise. These could be offset with afforestation in New Zealand, meaning the extra emissions are matched by an equal removal from the atmosphere. They could equally be offset by purchasing emission reductions from overseas. Emission reduction units could be earned by, for example, afforestation projects that remove carbon from the atmosphere, renewable energy projects that avoids emissions increase, or efficient new energy generation projects that increase emissions less than would otherwise be anticipated. The net atmospheric impact of these will vary accordingly.
- Meet energy demands with wind generation meaning no additional emissions. However, if the wind projects are assessed relative to a business as usual baseline based on fossil fuel generation, they could be eligible for credits through avoided emissions. These credits can be sold as offsets for emissions overseas i.e. the transfer of AAUs to the emitting country. The atmosphere will therefore see net emissions from this trade. The country establishing wind generation has not increased its emissions but now has insufficient AAUs to cover its emissions.
- Meet energy demands with wood (bioenergy). Since emissions from biomass are allocated to the point of harvest, bioenergy is considered to be zero emissions to avoid double counting. The atmospheric impacts can be assessed in different ways such as:
    - Since biomass contains carbon, its combustion releases GHGs meaning emissions will rise. The emission intensity of bioenergy per unit of energy is higher than many fossil fuels hence emissions could be said to increase relative to a business as usual baseline.
    - The zero emissions status can be enhanced if bioenergy is credited with avoiding fossil fuel emissions. This could qualify for emission reductions relative to a baseline, but would not reduce emissions relative to the base year.
    - If the biomass is diverted from landfill to energy there may be additional benefits resulting from avoided methane emissions; however, this may not be positive if adding to landfill carbon stocks is considered to be a sink activity.
    - If harvesting residues are used this will mean accelerating the return of the carbon to the atmosphere, rather than leaving the residues in the forest to decay. This will have implications on stock changes in the forest.

The examples above provide a range of different options to meet the two objectives of stabilizing emissions and meeting increased energy demand. Each option provides a different perspective on the impacts of an activity, by focusing on different elements of the complete picture. All of these can be considered correct. Hence an accounting system needs to identify the appropriate elements and methods of combining these to reflect national contributions to atmospheric GHGs, and to enable countries to collaborate to achieve the required atmospheric outcomes. The challenge for countries is to adopt domestic policy to encourage desired behaviour and/or behavioural change.

3.3 New Zealand Emission Trading Scheme

The United Nations Framework Convention on Climate Change states that in tackling climate change countries should respond according to their "…common but differentiated responsibilities and respective capabilities and their social and economic conditions".

The New Zealand Government has proposed that New Zealand becomes a sustainable and carbon neutral nation. A number of policies have been introduced to facilitate New Zealand's transition to a sustainable future and to address climate change (Appendix 1).

The Emission Trading Scheme (ETS) is a major component of government policy intended to contribute to these goals. The stated objective of the ETS is to support and encourage global efforts to reduce greenhouse gas emissions by:

- Reducing New Zealand's net emissions below business as usual levels and
- Complying with New Zealand's international obligations including the Kyoto Protocol.

It is recognized that it would be preferable to include as many New Zealand emitters and major GHGs in the ETS as possible, and also that emissions performance (e.g. at the farm level) can be accurately measured and tie individual businesses' obligations to the national target (MfE, 2005). The first sector to enter into the ETS is forestry in 2008. Other sectors are intended to be brought in over time, with all sectors covered by 2013.

The ETS has undoubtedly raised awareness of climate change, and the 'cost of carbon' throughout New Zealand. Submissions and negotiations have enabled some sectors to achieve special treatment, which is intended to maintain international competitiveness. Proponents of the ETS claim it will enable New Zealand to meet the KP commitments at least cost, but this has been challenged by other analyses.

Disadvantages of the ETS include the following:

- The first objective will contribute to, but not meet, the second objective. At current emission rates, the ETS will not be able to deliver on the CP1 commitment of emissions levels at 1990 levels. Emissions are anticipated to be 30% above this goal in 2010.
- Exemptions and allowances in the ETS reduce its contribution to reducing emissions below business as usual, and shift costs from emitters to taxpayers.
- Since forestry is the only sector included for several years, there is a risk that the credits generated will be sold offshore and thus not be available to offset emissions increases in New Zealand.
- Pre-1990 and post-1989 forests are treated differently in the ETS. Land described as forest on 1 January 1990 is ineligible for carbon credits from forest growth but owners are held responsible for emissions from their forests if deforestation occurs. Forests established after 31 December 1989 can choose to participate in the ETS and will receive credits for stock changes during CP1 as the forest grows and will be liable for debits when the carbon stock decreases, regardless of the cause e.g. storm event, harvesting or deforestation.

The ETS has adopted many of the international rules and common interpretations, with some modification to suit New Zealand circumstances and objectives. Further enhancements could start with revisiting the instant oxidation assumption which is at the heart of the stock change approach.

Accounting for stock changes rather than emissions and removals is a fundamental difference between forestry and other land uses, which has impacts on how emissions are accounted in other sectors.

4 Accounting issues

This section explores accounting issues relating to forestry. It identifies issues around the focus on forest carbon stock changes and the use of base years and baselines as reference points. It concludes with some alternate accounting options.

Forestry is widely recognized as a key sector in terms of climate change responses, for its roles in both mitigation and adaptation. The range of acknowledged climate benefits includes:

- Higher carbon stocks than other land uses
- Lower net annual emissions (and/or higher net annual sink) than other land uses
- Fossil fuel substitution
    - Direct: wastes and 'used' products can still yield energy
    - Indirect: wood/fibre-based products less energy intensive than alternatives
- Increased resilience of land and protection of communities against erosion, flooding, wind.

This list demonstrates there are wide ranging impacts across land use sectors, industry, energy, building, and waste. The time period over which these benefits can occur makes the task of determining direct impacts challenging.

Minimising net emissions to the atmosphere requires consideration of more than forest stock changes. Figure 2 show the interrelationships between land use and carbon stocks and flows.

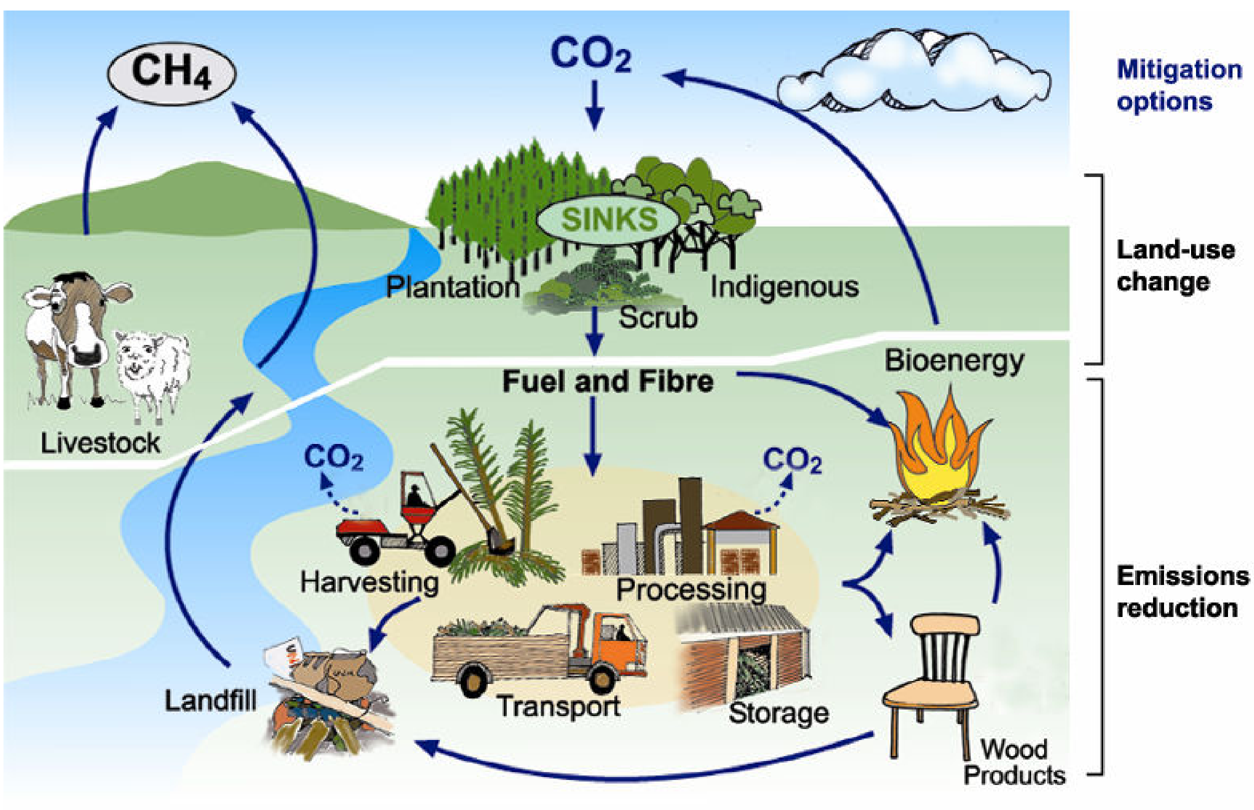

Figure 2. Land use stocks and flows.

Source: Gifford et al, 2002.

A distinction needs to be made between a stand and a forest, since they are frequently confused. A 'stand' refers to an area of trees of similar characteristics (e.g., species, age, stand structure or management regime) while 'forest' refers to a larger estate comprising many stands. An objective of sustainable forest management is often to have non-declining yields, which can be achieved by establishing and harvesting trees over successive years. In some situations these might be managed as individual stands, each clearfelled and restocked on a rotation. Other forests can be more diverse with some species suited to individual tree harvesting. Either way, as long as the harvest from the forest does not exceed the annual increment (growth) the total forest/carbon stock will not decline.

4.1 Limitations of the forest stock change approach

Issues associated with the focus on forest stock change alone include:

- The assumption that stock change equals a sink/source is an acknowledged inaccuracy that does not reflect atmospheric emissions when or where they occur. Forests remove carbon from the atmosphere during growth, and processes such as combustion and decay return the carbon to the atmosphere (IPCC, 1997). The instant oxidation assumption is neither accurate nor recommended for countries where there are significant LUCF activities.

- Harvesting and deforestation are both treated as activities causing emissions due to negative stock changes. Deforestation is caused not by removing trees but by preventing their return. However, if the area and age class structure of a forest doesn't change, the physical location of a forest is less relevant. The year of establishment makes little if any difference to the sink or maximum potential stock.

- The perception that harvesting causes an emission can lead consumers to avoid wood products. It also encourages bias towards 'protection' forests that are not going to be harvested in order to protect the forest stocks.

- The focus on forest stocks alone fails to maximize the emission reduction potential that forestry offers both as a land use and through off-site fossil fuel substitution. Forest products are less energy-intensive than other materials and can be used in place of fossil fuels.

- There is no incentive for efficient or multiple use of carbon e.g. for the consumer to conserve the carbon through reuse, remanufacture and recycling, because assuming instant oxidation means it doesn't exist. Conversely there may be incentives to use it directly for energy since it is considered to be at least emission-free, if not eligible for credit for avoided emissions through fossil fuel subsitution.

- The focus on forest stock change leads to the perception that the inaccuracy will be addressed or removed by adding stock changes in wood products. Hence producers are responsible for assumed emissions of harvested carbon and consumers of wood could benefit from the 'apparent sink' in wood products (in use and in soild waste disposal sites (SWDS)).

- There are equity issues with regard to the sink/source (producer/consumer). It is widely accepted that vegetation performs as a sink, and the source occurs when the resulting biomass (or derived products) is consumed during processes such as combustion and decay. Allocating emissions to the producer allows the consumer to ignore emissions from their use of biomass. While bioenergy enthusiasts and SWDS operators may enjoy the perception created, forest owners are being penalized.

- The limited connection between production and consumption could create supply/demand issues. For example, promotion of bioenergy as an offset (avoided fossil fuel emissions) gives it equivalent status to the sink created by afforestation. Yet there is a major difference in the timing of the benefits accruing, favouring investment in bioenergy rather than biomass growth. Furthermore, incentives for bioenergy can cause economic impacts that contribute to the diversion of biomass to energy from other uses (food, feed, fibre etc).

- The allocation of emissions to harvesting fails to capture the true value of forests and the forest sector. A sustained yield production forest may have constant carbon stocks, but continuing harvest indicates the forest continues to provide a sink. Not only can this lead to a trend towards no-harvest forestry, but it can also divert attention from real emissions sources such as bioenergy and SWDS.

- Accounting for stock changes inevitably creates difficulties in trying to consider land uses consistently. Carbon stock changes, and CO_2 in general, are ignored in agriculture, with the focus instead on emissions (particularly CH_4 and N_2O). For all land uses, emissions and removals should be estimated using scientifically credible and feasible methods that do not result in double counting.

4.2 Base year and baselines

One of the difficult issues in establishing targets has been the difference between net-net and gross-net accounting. In the energy sector for example, it is relatively easy to estimate emissions from combustion of fuels in different years, and make comparisons between them. The ultimate objective is to emit less than in a previous year.

A target based on a historic base year clearly favours those with high emissions in the base year, providing what has been termed a licence to pollute. Those that produced lower emissions in the base year also have reduced potential for further savings, which would penalize early adopters.

Land use activities can be responsible for removals from as well as emissions to the atmosphere. This means the scale of impacts does not only extend from high to zero emissions (as for fossil fuels), but also includes 'negative' emissions. Hence there is a 'good' impact (net removals) and a 'bad' impact (net emissions). Establishing a net-net target based on emissions or removals in an historic base year may provide false perceptions. If a target for emissions reduction is based on a historic rate of deforestation, reducing emissions creates the perception of 'good' when on the land use scale it is 'less bad'. A high sink rate in the base year may result from earlier high afforestation rates which cannot endure indefinitely. Reducing the sink rate creates the perception of 'bad' when it may be more accurately viewed as 'less good'.

Establishing targets based on counterfactual baselines is even more fraught with issues (Pielke *et al*., 2008). While it is useful to compare the impacts from the provision of a service via different routes, it can be challenging to establish credible baselines. What would have happened in the absence of an activity is hard to know, as is how others behave once the activity begins. Additionality and leakage are complicated aspects of accounting, which could also be irrelevant if the accounting system had global and more comprehensive coverage.

Businesses often favour baselines based on GHG intensity targets. These can be seen as a measure of the cost per unit, which can be compared with any other similar product. It is often promoted as a way of identifying the 'best' locations for production, generally reflecting the country or region-specific energy resources available but also the efficiency of production. While such outcomes are good from the global perspective, intensity targets may need to be combined with a cap on total GHG emissions in order to contribute to national GHG objectives.

If national commitments are based on historic base year and the responsibility is passed on to sub-national entities based on a future baseline this will create problems. Providing credits to projects for reducing emissions relative to a baseline means offering part of the national Assigned Amount, established from the base year emissions level. If these AAUs are sold overseas without a reduction in emissions relative to the historic base year, the national target for emissions reduction becomes more difficult.

The accounting system lies at the heart of the issues above – both identifying and quantifying atmospheric exchanges and allocating responsibility which facilitates appropriate responses. While the consumer-based accounting systems for fossil fuels are relatively well accepted, the land use and primary-based sectors continue to be beset by problems. The difficulties associated with including agriculture and forestry in the New Zealand ETS have been noted (MfE 2005).

4.3 Alternate accounting options

The accounting framework establishes the boundaries for consideration and allocation of responsibilities, and hence affects the perception of different activities. Few studies address the fundamental aspects of emissions accounting underpinning policies and mechanisms. Addressing the inaccuracies in the accounting system by adopting a consistent focus on the atmospheric exchanges, would enable the development of policy that improves atmospheric outcomes.

While there are undoubtedly other aspects to consider, it is the impacts on the atmospheric GHG concentration that is likely to be a fundamental driver of any climate-focused agreement, and hence policies for climate change mitigation. The IPCC recognize that "In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon C stocks, while producing an annual yield of timber, fibre, or energy from the forest, will generate the largest sustained mitigation benefit" (IPCC, 2007).

The design of forest strategies and policies should consider the trade-offs between increasing forest carbon stocks and increasing the sustainable rate of harvest and transfer of carbon to provide products and services (Figure 3). This can be compared with the impacts of different options of land use or of providing the same service. For example, afforestation could reduce agricultural land area and lead to more emissions-intensive farming practices (e.g., more fertiliser use), deforestation for agricultural expansion elsewhere, and/or increased imports of agricultural products (McCarl and Schneider, 2001). Equally, stopping all forest harvest could increase forest carbon stocks, but energy-intensive materials, such as concrete, aluminium, steel, and plastics, would be required to replace wood products, resulting in higher GHG emissions (Gustavsson *et al.,* 2006).

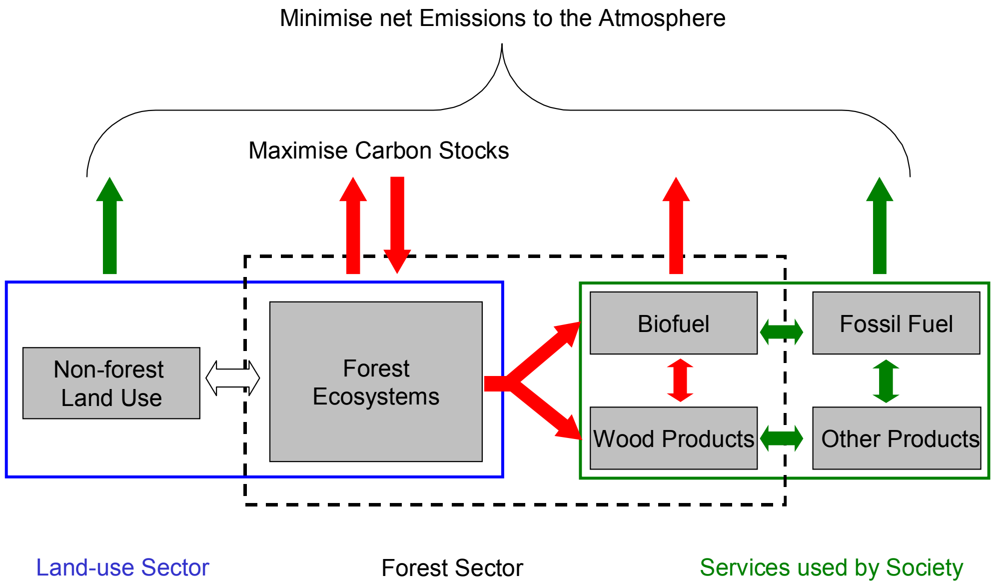

Figure 3. Minimising net emissions: more than maximising forest stock changes.
(Source: IPCC, 2007)

4.3.1 Accounting Options

In light of such issues with the current accounting system it is possible to evaluate a range of options to maintain or enhance the accuracy of emissions estimates:

	Option	What	Why selected
1	Forest stock change (Assumed forest 'sink')	Status Quo: carbon assumed to be emitted at harvest	Simple continuation of existing practices that have been adopted by governments and markets.
2	Modelling stocks and flows 2a) Stock change in all stocks 2b) Delayed emissions	Estimate the longevity of carbon in products (including waste) and hence derive estimates of either a) stock changes or b) emissions	Better reflects the forestry life-cycle impacts. Equivalent to current international proposals.
3	Net removal from the atmosphere	Estimate emissions directly from known sources such as landfills and bioenergy plants	Provides a simple alternative to a complex modelling exercise that is assumed in Option 2.

The challenge for all options is to ensure that the accounting system is consistent with national commitments. For example, if a country accepts responsibility for emissions related to (or contained within) exported products, the emission reduction targets could be adjusted to reflect this.

Each of these options can be compared with the atmospheric impacts of forestry and related wood products. Section 5 identifies data on the stocks and flows resulting from forestry activities and uses these to create a mass balance for New Zealand. This enables quantification of the atmospheric impacts. Section 6 then discusses each of the options above in relation to the atmospheric impact.

5 Forestry stocks and flows data

This section provides information on the New Zealand carbon stocks and flows resulting from forestry activities. This data is compiled to help identify what data are available and how the GHG impacts of different activities are currently estimated. This provides a simple carbon mass balance for 2005 which provides an indication of the overall atmospheric impacts of forestry and wood products. Components of the data identified can also be used to estimate impacts under different accounting options, either alone or in comparison to other products and services.

The majority of the data used is sourced from New Zealand National Inventory Report (NIR) and associated data tables (MfE, 2007a) but other national statistics are also used. Reference is also made to the latest national projections of the New Zealand balance under the first commitment period of the KP (MfE, 2007b).

Figure 4 below summarises current information on the carbon stocks and flow resulting from forestry activities in New Zealand. Unless otherwise indicated, all stocks and flows are given in million tonnes of carbon (MtC) to avoid confounding effects of using Global Warming Potentials (GWP). The direct atmospheric exchanges (net sink in trees and sources from bioenergy and waste) are also given in terms of $MtCO_2e$ (including GWP impacts) to facilitate calculation of net atmospheric impacts.

In the following sub-sections each of the elements in Figure 4 will be examined in more detail. However this overview is useful to show the relationships between the different elements. For example:

- The atmospheric impact of forestry and related products in New Zealand is a net removal of 36.8 Mt CO_2e (= 42.54 – 4.56 – 1.19 = 10.22 MtC), whereas the accounted impact (stock change) would be 7.3 x 44/12 = 26.8 Mt CO_2e.
- The direct atmospheric exchanges (11.6 - 1.26 - 0.12 = 10.22 MtC) equals the change in stocks plus exports (7.3 + 0.15 +0.2 + 2.51 = 10.16 MtC).
- Harvested carbon (4.3 MtC) is approximately equal to the transfers to exports and domestic products (3.8 MtC), and would balance by assuming a contribution (0.5 MtC) to energy.
- Almost two-thirds of carbon removed from the atmosphere is being accumulated in forest stocks. Less than 5% is accumulating in products in use and in SWDS.
- Exports are a key component of the flows accounting for over 20% of the carbon sequestered.

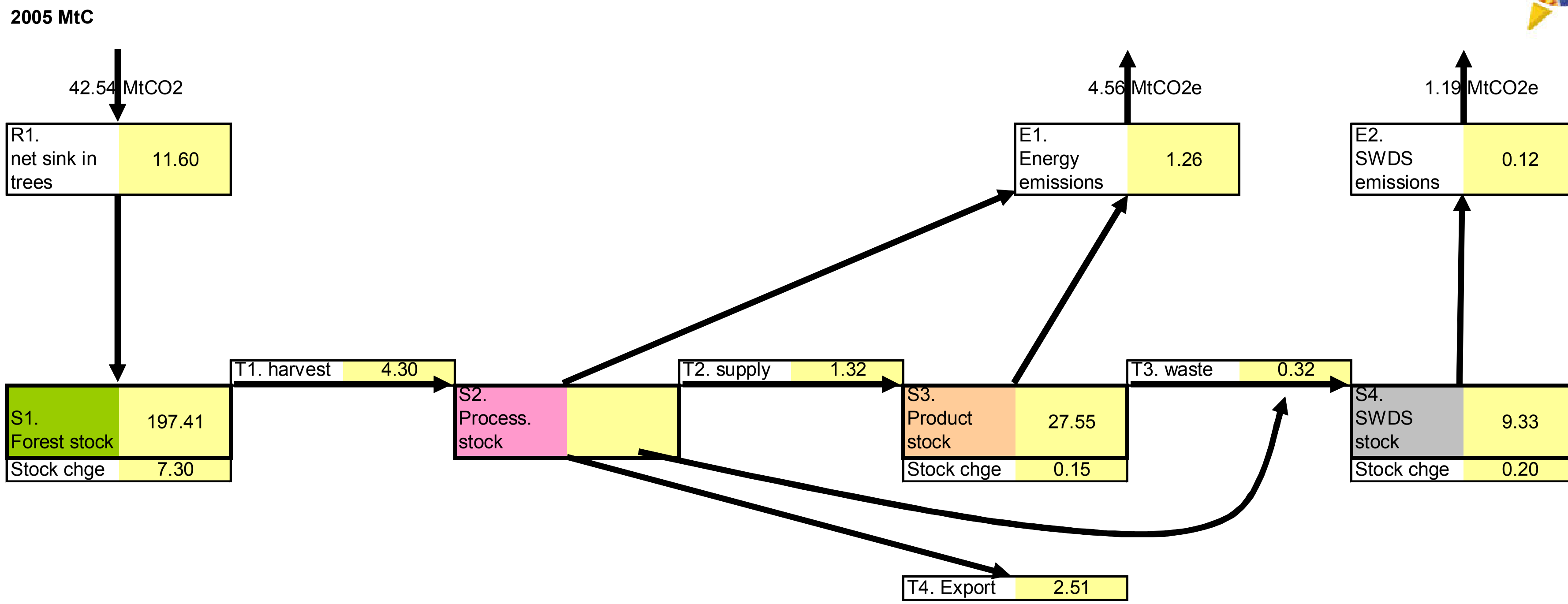

Figure 4. New Zealand Carbon stocks and flows (2005) resulting from forestry activities.

Removals by sinks		**Transfers**		**Reservoirs**	
R1.	Net sink in plantation forests.	T1.	Harvested carbon	S1	All plantations (excl soil)
		T2.	Products to market domestic	S2	Process plant - assumed minor
Emissions by sources		T3.	Wood/paper waste to SWDS	S3	Products in use
E1.	Energy from wood (not biogas)	T4.	Exports: logs, chips, products	S4	Waste/used products
E2.	SWDS (Incl landfill energy)				

5.1 Forest growth and harvesting data

The New Zealand NIR (MfE, 2007a) reports increases for plantation forests from 1990 to 2005 in

- forest area (1.18 to 1.85 Mha),
- carbon stock (112 to 197 MtC),
- annual sequestration before harvest (8.3 to 11.6 MtC/yr),
- annual planted forest harvest (2.5 to 4.3 MtC/yr) , and
- annual sequestration net of harvest (= stock change) (5.8 to 7.3 MtC/yr).

These values indicate that plantation forestry in New Zealand is an increasing reservoir of carbon and is removing more carbon from the atmosphere at a faster rate than in 1990. This trend has been anticipated due to historic planting patterns and the young age-class structure of the forest estate, but will diminish or even reverse as the harvest level increases and the age-class structure becomes more balanced.

Figure 5 shows that in the last few years the forest area has changed little, yet the forest carbon stocks continue to accumulate. On a unit area basis, the gross sequestration rate has fallen from 7.0 to 6.3 tC/ha/yr, and sequestration net of harvest (stock change) from 4.9 to 4.0 tC/ha/yr.

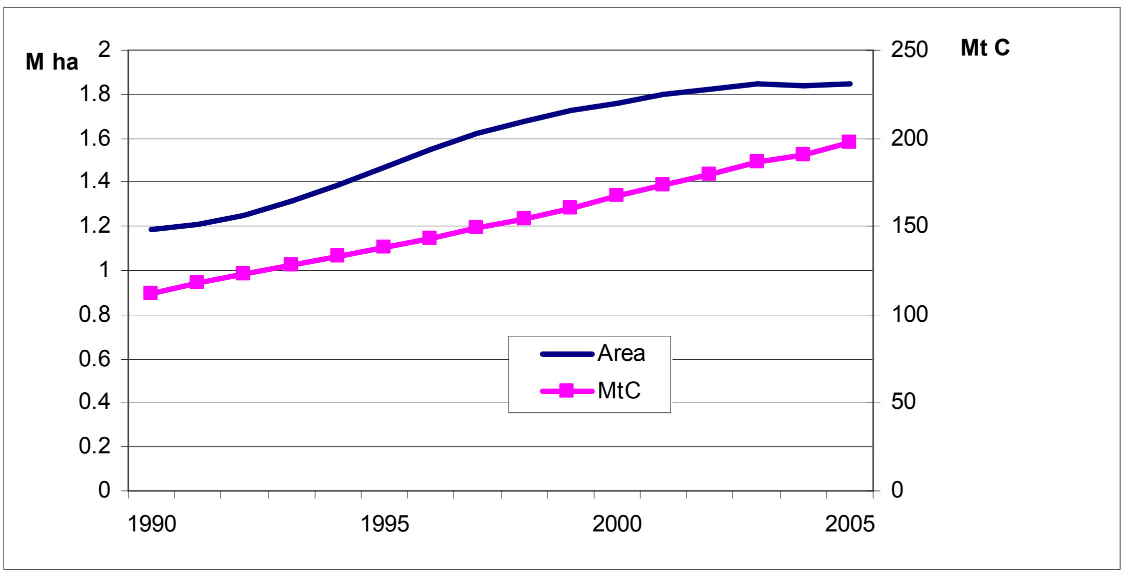

Figure 5. Plantation forest area and carbon stocks in New Zealand.

5.2 Harvesting and wood products data

Figure 5 indicates that 4.3 MtC was harvested in 2005. The data on wood products in Table 1 illustrates that almost 90% (3.8 MtC) of this harvested carbon is incorporated into wood products or exported as logs/chips. Since a large portion of the remainder is used as fuel within the forest industry, this represents an efficient use of the raw material.

The Table also illustrates that two-thirds of the harvested carbon (2.5 MtC) is exported (excluding products in use such as pallets or packaging). This indicates that although the carbon is reported as an emission by New Zealand it is more likely to be released somewhere other than in New Zealand.

Table 1. Wood products manufacture and export (2005).

		Production			Exported		
	Units	(units)[1]	Carbon (Mt C)	Carbon (Mt CO_2)	(units)[1]	Carbon (Mt C)	Carbon (Mt CO_2)
logs/chips	M m^3	5.65	1.13	3.11	5.65	1.13	3.11
timber	M m^3	4.41	0.88	2.42	1.84	0.37	1.01
panels	M m^3	2.18	0.76	2.10	1.13	0.40	1.09
pulp	M tonnes	1.59	0.63	1.73	0.84	0.33	0.91
paper	M tonnes	0.92	0.41	1.14	0.63	0.28	0.77
Total			3.82	10.51		2.51	6.89

[1] Source: MAF statistics (MAF, 2005)

If the exported carbon were not considered to be an emission in New Zealand, the national sink reported in plantations would rise. Reporting only domestic consumption of harvested carbon would reduce emissions reported by 2.5 MtC/yr (9.2 $MtCO_2$). The same impact would not be seen in CP1 accounts since it is restricted to activities since 1990, and hence it is assumed there will be few post-1989 forests likely to be harvested within that time.

Data are available on roundwood harvested and there are production and trade statistics for many wood-based products. There are also data on domestic consumption of wood products, but there is much less data available on the amount of wood in use, how long different products remain in use, or what happens to them once they have served a useful life. While there is a growing acceptance that the role of wood products needs to be recognized, there remains considerable doubt over how to accomplish this. Four different approaches proposed can be summarised in a matrix based on two separate criteria (Table 2).

Table 2. Matrix of approaches for determining emissions from harvesting and wood products.

Estimates of:	**When and where**	**When**
Changes in stocks	Stock change (SC)	Production (PR)
Emissions	Atmospheric flow (AF)	Simple decay (SD)

These four approaches can be described as follows:

- Stock Change (SC) approach - This estimates net changes in carbon stocks in the forest and wood-products pool. Changes in carbon stock in forests are accounted for in the country in which the wood is grown, referred to as the producing country. Changes in the products pool are accounted for in the country where the products are used, referred to as the consuming country. These stock changes are counted within national boundaries, *where* and *when* they occur.
- Production (PR) approach - This also estimates the net changes in carbon stocks in the forests and the wood products pool, but attributes both to the producing country. This approach inventories domestically produced stocks only and does not provide a complete inventory of national stocks. Stock changes are counted *when*, but not *where* they occur if wood products are traded.
- Atmospheric flow (AF) approach - This accounts for net emissions or removals of carbon to/from the atmosphere within national boundaries, *where* and *when* emissions and removals occur. Removals of carbon from the atmosphere due to forest growth are accounted for in the producing country, while emissions of carbon to the atmosphere from oxidation of harvested wood products are accounted for in the consuming country.

- Simple Decay (SD) approach - This also estimates the net emissions or removals of carbon to/from the atmosphere *when*, but not *where* they occur if wood products are traded. Removals of carbon from the atmosphere due to forest growth, and emissions resulting from oxidation of harvested wood products are accounted for in the producing country.

The approaches based on changes in stocks retain the instant oxidation assumption at the forest gate, and focus on determining the change in product stocks. In both the SC and PR approaches the change in product stocks is a proxy for the emissions or removals, by assuming the transfers into the product stocks are atmospheric removals. In contrast, the approaches estimating atmospheric emissions aim to provide higher Tiers that reflect a more realistic decay profile than instant oxidation.

There are several examples in IPCC guidelines where instant emission is the Tier 1 default, and the Tier 2 enhancement is to calculate a more realistic delayed emissions profile. The waste sector is an obvious example, with New Zealand estimating emissions under both Tier 1 (instant) and Tier 2 (delay) methods (see Section 5.3). Deforestation to crop or grassland incorporates a default instant oxidation assumption, with the Tier 2 option to apportion losses on and off-site to decay and combustion processes - except for wood products (IPCC, 2003). The default assumption for all harvested forest carbon is instant oxidation, but many countries apply a decay factor to residues remaining on site. The same does not apply to biomass harvested and transported off-site.

The net sink in forests can more easily be determined from the stock change in the forest plus harvested carbon, than attempting to quantify all source and sink processes occurring in the forest. A stock change calculation is not so easy for wood products given the extensive international trade in them. While there are forest inventory and trade data, there are few data on stocks of wood products.

The approaches that recognise both when and where stock changes or emissions occur can look to other national data and statistics to help verify their estimates. The SC approach offers potential for estimation from statistics affecting major wood stocks e.g. building consents. The AF approach can be related to data on biomass combustion and waste.

Estimating the timing of emissions from a diverse range of products providing an equally varied array of services is challenging. If the accounting system also has to identify only the impacts of a subset of products e.g. resulting from specified ARD activities since 1990, the challenge is increased. Approaches proposed for either require considerable aggregation of product categories and broad generalizations and assumptions.

The IPCC (2003) suggest default half-lives of 2 years for paper, 20 years for non-structural panels, and 35 years for sawn timber. Applying these values to New Zealand products (excluding landfill impacts) suggests the wood product stocks in New Zealand increased by less than 0.2 MtC in 2005. Adding the overseas product stock changes resulting from New Zealand harvest will more than double the benefit to New Zealand, assuming importers continue to use the wood for products rather than as an emission-free energy source. The same data and model suggest delayed emissions are around 1.4 MtC, which can be compared with the direct estimates of emissions from bioenergy (1.3 MtC) and SWDS (0.1 MtC).

The most recent analysis of wood products in New Zealand (Wakelin *et al*., 2008) is not directly comparable to the estimates in this paper due to the use of different datasets, assumptions and models. Their results (for 2005) indicate an accumulated stock since 1900 of 19.5 MtC in wood products and 0.9 MtC in paper, as well as a stock of 7.1 MtC in domestic SWDS. This represents around 10% of the accumulated stock in plantation forests. The stock change in New Zealand is estimated to be 0.5 MtC (1.7 $MtCO_2$) in products in use and 0.2 MtC (0.6 $MtCO_2$) in SWDS. Both stocks exhibit increases and hence are perceived to be sinks.

Wakelin *et al*. (2008) also estimated the annual release of carbon to the atmosphere from domestic HWP consumption to be 1.3 MtC (4.6 $MtCO_2$). These data are calculated from changes in stocks (difference between HWP inflows and outflows), rather than reporting only the emissions from the products. The estimate is reported to include emissions from fuelwood and products in use and products in SWDS, but the linkages to these other data in the inventory are unclear.

It is not possible to assess whether one set of data on wood products stocks and stock changes is more accurate than another. Data requirements are similarly demanding, although aspects such as the decay profile adopted have a significant impact on historic data requirements. While it may be possible to improve the accuracy of input data, verification of the results could be extremely challenging.

The data on wood products used in the analysis below will focus on the stock change in products in New Zealand (SC approach, 0.2 MtC) and the emissions from products in New Zealand (AF approach, 1.4 MtC). These approaches are chosen to reflect the impacts on choices within New Zealand boundaries, rather than attempt to estimate what happens to New Zealand-grown timber once it is exported.

5.3 Waste data

The IPCC (1996, 2000) provide guidance for the waste sector that includes two methods to estimate CH_4 emissions from solid waste disposal sites (SWDS):

- the default method (Tier 1) and the
- First Order Decay (FOD) method (Tier 2).

The main difference between the two methods is that the default method is based on the assumption that all potential CH_4 is released in the year the waste is disposed of, whereas the FOD method produces a time-dependent emission profile that better reflects the true pattern of the degradation process over time. The IPCC (2000) state it is *good practice* to use the FOD method, if possible, because it more accurately reflects the emissions trend.

New Zealand currently uses both the default and FOD approach. In summary, for every unit of carbon entering an SWDS, half remains buried, and roughly 25% each is converted by decay to methane and carbon dioxide. However, some of the methane is recovered (assumed combusted to CO_2) and some is oxidised in the surface layers of the SWDS.

Data from the 2006 IPCC Waste model (Gulliver, 2008) indicate that in New Zealand 0.32 MtC in wood and paper was deposited in solid waste disposal sites in 2005. This contributed to a stock change in SWDS of 0.2 MtC and total emissions of 0.12 MtC. Taking GWP into account, the deposited carbon is equivalent to 1.16 $MtCO_2e$ and the emissions to 1.19 $MtCO_2e$. The total stock of carbon in wood and paper products accumulated since 1950 is estimated from the same data to be 9.3 MtC.

The amount of methane recovered in New Zealand has been increasing (see Table 3) since flaring was first installed in 1992, and now includes recovery for energy generation. The amount oxidised is assumed to be 10%. Both of these activities reduce the quantity of methane emitted, and concurrently increase the quantity of CO_2 emitted.

The quantity and timing of carbon emissions can be estimated from the waste model that is used to estimate the proportion of this that is released as CH_4. The amount released as CO_2 can be derived through simple subtraction.

Despite half of the carbon deposited being fixed, and an increasing quantity of methane being recovered, the CO_2 equivalent balance of the SWDS is negative. In other words, the CO_2 equivalent emissions are higher than the CO_2 removals by the biomass that is deposited in the landfill. This is due to the emission of 0.01 Mt CH_4 which has a higher global warming potential than CO_2, so as more CH_4 is recovered the balance improves.

Table 3. Total waste deposited and methane generation

Year	Total MSW disposed to SWDs (Gg MSW)	Gross annual methane generation (model)	Recovered methane per year (Gg CH_4)	Net methane generation (Gg CH_4)	Methane oxidised (Gg CH_4)	Net methane emissions (Gg CH_4)	Net methane emissions (Gg CO_2e)
1990	2,925	112.3	0.00	115.3	11.5	103.8	2179.2
1991	3,016	113.7	0.00	116.8	11.7	105.1	2208.0
1992	3,055	114.9	3.53	111.4	11.1	100.2	2104.6
1993	3,088	116.1	3.95	112.1	11.2	100.9	2119.6
1994	3,129	117.3	6.59	110.8	11.1	99.7	2093.3
1995	3,182	118.7	18.46	100.2	10.0	90.2	1893.9
1996	3,159	119.9	19.16	100.7	10.1	90.6	1903.2
1997	3,136	120.9	21.11	99.8	10.0	89.8	1886.7
1998	3,113	121.9	25.32	96.6	9.7	86.9	1825.6
1999	3,091	122.8	32.88	89.9	9.0	80.9	1699.2
2000	3,068	123.6	32.56	91.0	9.1	81.9	1719.9
2001	3,045	124.2	35.87	88.4	8.8	79.5	1670.3
2002	3,022	124.8	39.13	85.7	8.6	77.1	1619.9
2003	3,104	125.6	41.21	84.4	8.4	76.0	1595.4
2004	3,186	126.6	46.00	80.6	8.1	72.5	1523.3
2005	3,206	127.6	50.30	77.3	7.7	69.6	1460.7

Note: 1 Gg = 1,000 tonnes

It is clear that if biomass is deposited in SWDS, methane recovery is essential to improve the atmospheric carbon balance. The NIR shows a total of 0.4 Mt DOC entering SWDS in 1990 which is equivalent to 1.5 $MtCO_2$. The emissions from direct CO_2 and CH_4 emissions, and combustion and oxidation of CH_4 to CO_2, is equivalent to 2.7 $MtCO_2e$. The emissions are 75% higher than the original sink. The equivalent data for 2005 are 1.7 and 2.1 $MtCO_2e$, an increase of only 25%, demonstrating the beneficial impact of increased methane recovery.

If energy recovery is the objective, it is likely that the mitigation impact could be improved if the biomass was used for energy directly. The NIR reports 0.05 Mt CH_4 was recovered in 2005 from total generation of 0.13 Mt CH_4. If all the methane generated or captured were used for energy (net calorific value 50.1 MJ/kg) this would equate to 6.4 and 2.5 PJ respectively. For comparison, the Energy Data File (MED, 2007a) reports total primary energy supply in 2005 was 740 PJ.

The annual deposit of 0.32 MtC is equivalent to approximately 0.6 Mt of dry biomass or an energy content of 12 PJ. If the same energy was produced from coal with emissions of 0.8 tCO_2e/GJ this would have released 9.6 $MtCO_2e$.

5.4 Bioenergy data

The CO_2 emissions from biomass used for energy or emitted from waste disposal sites are noted as memo items in the NIR. This is because emissions from harvested biomass (if reported at all) are allocated to the biomass producer, not the consumer. Reporting emissions at the forest/farm gate and also at the point of oxidation would result in double counting. This problem would be overcome if the emissions were reported only when and where they occur.

Some forms of biomass e.g. food may be grown and consumed within an inventory period (one year) and hence have little impact on atmospheric carbon levels. While the atmospheric impacts may be minimal, the sinks and sources may occur in different countries. Global trade suggest there is a flow of carbon into biomass in some countries and the emission occurs through consumption in other (often more developed) countries. The producer countries have little influence over the use of, or the timing of emission of the carbon for which they have accepted responsibility.

The use of wood for energy in New Zealand was reported (MfE, 2007a) to have emitted 1.3 MtC (in CO_2, CH_4 and CO) with a global warming impact of 4.6 $MtCO_2e$ (Table 4). Biogas contributes a small addition leading to a total bioenergy impact of 4.7 $MtCO_2e$.

Table 4. Emissions from using wood biomass for energy (2005)

	t CO_2	t CH_4	t N_2O	t NO_X	t CO	t NMVOC
Energy						
Manufacturing	3,600,587	493	131	2,135	19,377	1,642
Commercial						
Residential	847,234	2,318	31	850	85,007	4,637
Total by GHG	4,447,821	2,811	162	2,985	104,384	6,279
Total C content	1,213,042	2,108			44,736	
GWP	1	21	310			
CO2 equiv	4,447,821	59,031	50,307			

Source: MfE, 2007a

6 Evaluation of alternative accounting systems

This section combines the data presented in the previous section to quantify the impacts resulting from forestry activities. The analysis is based on the entire plantation forest estate and all products regardless of their age, source activity or country. The avoided impacts that are more relevant to project accounting are discussed in order to give an indication of the possible impacts of counterfactual situations. The range of baselines that could be included is considerable and hence the impacts from using project mechanisms are not estimated at the national level.

The analysis and results presented here are not intended to reflect the KP accounts. It is intended to examine the ways that data can be used in order to estimate emissions and removals, in order to inform decisions about future accounting systems.

This section will use the data from Section 5 to consider the options outlined previously:

1. Forest stock change;
   - Apply the instant oxidation default to equate forest stock change with net emissions/removals, ignoring carbon retention in some products
   - Stock change in the forest
     - In Figure 4 this relates to the change in forest stock (S1)

2. Modelling stocks and flows;
   - Use data on product manufacture, use and trade to estimate emissions and removals
   - a) Stock change in the forest, products and landfill
     - In Figure 4 this relates to the change in all stocks (S1 to S4)
   - b) Sink minus estimated sources (delayed emissions)
     - In Figure 4 this relates to the forest sink (= stock change + harvest) minus the estimated annual emissions from domestic consumption i.e. harvest minus exports (T1 - T4). Given the delay factor, current year emissions include those from domestic consumption in previous years.

3. Net removal from the atmosphere.
   - Estimates removals and emissions directly from source activities
   - Sink - bioenergy - landfill (with methane recovery)
     - In Figure 4 this relates to the forest sink (R1) and sources (E1 and E2).

These options assume that the focus on gross-net accounting will remain for forestry. If net-net accounting was applied to the data in Table 5 to compare annual stock change in 2005 with the base year (1990) the accounted removals would drop from 7.3 to 1.5 MtC, due to the high base year stock change of 5.8 MtC. This represents the change in stock change, which is assumed to reflect the change in removals when applying the instant oxidation assumption. A focus on the change in stocks from 1990 (112 MtC) to 2005 (197 MtC) would create a very different impression with an accounted removal of 85 MtC over the period. A number of other options including comparison with various baselines, is also possible. If net-net accounting is to be considered for future periods such options will need to be revisited.

Table 5. GHG impacts of forests.

	Units	1990	2005
Forest area	M ha	1.18	1.85
Carbon stock	Mt C	112.0	197.4
Stock change	Mt C	5.81	7.30
Annual sequestration preharvest	Mt C	8.30	11.60
Annual planted forest harvest	Mt C	2.49	4.30
Average stock	tC/ha	96	107
Atmospheric impact (sink)	tC/ha/yr	7.01	6.28
Stock change	tC/ha/yr	4.90	3.95

6.1 Forest stock change

The sink in New Zealand plantations is reported to be 11.6 MtC (42.5 $MtCO_2$, Table 5) and the carbon in planted forest harvest in 2005 amounted to 4.3 MtC (15.8 $MtCO_2$). If the IPCC default assumption is applied, the harvested carbon is accounted as an emission at the point of harvesting. This would lead to forests being accounted as a net sink of 7.3 MtC (26.8 $MtCO_2$).

The latest projection of the balance over CP1 for New Zealand (MfE, 2007b) presents a different picture. The KP focuses on impacts resulting from selected activities since 1990, which means the forest area considered shrinks to below 0.7 Mha, and the associated removals (net of harvest) from 7.3 MtC down to around 5 MtC. It is anticipated that the KP accounts will also register emissions from deforestation, which for New Zealand is capped by government at 1.15 MtC/yr during CP1 (21 $MtCO_2$ over 2008-12).

The average plantation sink is 6.3 tC/ha/yr (23 tCO_2/ha/yr), which is approximately the carbon content of 30 m^3 of timber. In a typical site the stem represents half of the onsite carbon, with the remaining half in the crown and roots. If a forest produces a sustained timber harvest it must be removing carbon from the atmosphere. When the harvested carbon is assumed to be oxidized on site, the perception of a lower net sink is created. The stock change net of harvest therefore gives the impression of a sink rate of only 4.0 tC/ha/yr (14.5 tCO_2/ha/yr). If New Zealand plantations reach a steady state with constant stocks, the reported 'sink' rate will fall to zero, even if they are producing a sustained yield.

When the loss of carbon stock is assumed to be an emission where and when the harvest takes place, the Kyoto accounts do not include emissions from woody biomass when they occur via processes such as decay or combustion. The forest stock change is the only relevant value under this approach, hence New Zealand could account for a **net removal of 7.3 MtC (26.8 $MtCO_2$).**

6.2 Modelling stocks and flows

A model can be used to estimate stocks and stock changes in, or emissions from, wood products. The stocks in SWDS can be incorporated with products in use, or derived separately. The data can include all products or a specified subset of these, but for this analysis all products will be used to provide a consistent focus on the atmosphere. There are two broad options under this approach.

6.2.1 Stock change in all stocks

One option is to focus on stock changes in (semi-)finished products, as in the IPCC wood products model, using these as a proxy for emissions. The estimated impact is therefore the sum of the stock change in the forest (7.3 MtC) and stock change in products (in use and in SWDS, total 0.4 MtC).

This approach would therefore account for 'sinks' in all stocks, amounting to a total **net removal of 7.7 MtC**. The 'sink' would be considerably higher if stock changes overseas (from New Zealand-grown timber) are also included.

6.2.2 Delayed emissions

Another option is to provide higher Tiers to accompany the instant oxidation default assumption, i.e. derive a more accurate estimate of the timing of emissions from harvested carbon. Rather than assuming oxidation of harvested carbon, this option applies a decay profile to the harvested carbon (domestic consumption) to account for emissions over a number of years. Delayed emissions for each year are the sum of emissions from previous years' harvests. With the focus on emissions, there is an incentive to reuse and recycle domestic products to avoid emissions, and when finally released there is an incentive to capture energy at the same time, to avoid the need for other energy sources.

This approach would therefore report a sink in forests (11.6 MtC) and sources from products in New Zealand (1.4 MtC), for a total **net removal of 10.2 MtC**. The sources from products would rise to 3.9 MtC if New Zealand were responsible for emissions from all wood harvested in New Zealand, including exports.

6.3 Net removal from the atmosphere

Figure 4 demonstrates that while there are a range of transfers around the biosphere, there are three activities which reflect the atmospheric exchanges within national borders, all of which New Zealand can manage to some extent. These are the sink in forests, and the sources from bioenergy and SWDS.

The current inventory reports an emission of 4.3 MtC, based on applying the instant oxidation default to the harvested plantation carbon. Improving the accuracy of the inventory could lead to reporting the emissions from bioenergy and SWDS instead of attempting to track all carbon flows and derive stock changes or emissions. These values only represent 1.4 MtC, which is clearly considerably lower than the harvested carbon quantity and could therefore raise questions over its validity. It would not be unexpected to see some difference in the values, since there is a time lag between harvesting and final emissions, but this would be unlikely to explain such a large discrepancy. However, the harvest also contributes to stock changes in products and SWDS (0.4 MtC) and to exports (2.5 MtC), giving a total of 4.3 MtC. This appears to be a more accurate reflection of atmospheric impacts than allocating all the emissions to the point of harvest.

Under this approach the accounts would show a sink in forests of 11.6 MtC and emissions from bioenergy (1.3 MtC) and SWDS (0.1 MtC), giving a total **net removal of 10.2 MtC**. A direct conversion from carbon to CO_2 would suggest a removal of 37.5 MtCO_2 but taking the higher GWP of CH_4 emissions from SWDS into account decreases the estimated net removal to 36.8 MtCO_2e.

6.4 Avoided impacts

Avoided impacts can be estimated relative to a baseline that describes a scenario that might have occurred in the absence of a project. Such projects may be eligible for Assigned Amount units and hence can affect the national accounts. This section will therefore quantify some aspects of alternate choices related to forests and related products. These choices relate to:

- Land use – forest vs other land use
- Wood/fibre products vs other materials
- Bioenergy (heat/electricity/transport) vs fossil fuels

As with the direct impacts, the analysis of avoided impacts is affected by the focus of the evaluation (see example in Section 3.2.2). While this study has not undertaken a complete analysis of this, the following sections provide sufficient information to demonstrate that forestry and forest products are considerably more atmospherically benign than the alternatives. The one exception to this is the use of biomass for energy, which is more emissions intensive than other direct energy sources. However, even in this case, counterfactual scenarios can be constructed to provide a favourable comparison, e.g. assume the use of wood instead of marginal (thermal) electricity.

6.4.1 Land use

The average carbon stock in plantations (see Table 5) is over 100 tC/ha (366 tCO_2/ha). Pasture stocks (Table 6) are typically much lower, averaging around 1 tC/ha (3 – 5 tCO_2/ha) (MfE, 2007a). These data do not include soil carbon. Soils can contain high carbon stocks, but changes tend to be slow and difficult to identify as a significant change in a large quantity; furthermore these changes tend to be dwarfed by changes in biomass stocks in forest sites.

Table 6. Grassland biomass stocks and sink.

	biomass stocks	sink
	t CO_2e/ha	t CO_2e /ha/yr
high prod grassland	5.0	24.8
low prod grassland	2.9	11.2

Source: MfE 2007a

The New Zealand NIR (MfE, 2007a) reports 2005 emissions from the agriculture sector is 37.4 Mt CO_2e which is 4.9 Mt CO_2e (15%) above the 1990 level. The total grassland area recorded in the NIR (derived from the 2002 land cover data base) is 14.4 Mha. This equates to an annual average emission of approximately 2.6 tCO_2e/ha. Further differentiation can be achieved using land area data for different production systems as shown in Table 7.

Table 7. Annual agricultural CH_4 emissions per unit of land area

	livestock nos[1] (millions)	Methane[1] Mt CH_4	Mt CO_2e
Dairy cattle	5.15	0.42	8.87
Non-dairy cattle	4.44	0.26	5.42
Sheep	4.00	0.44	9.29
		1.12	23.58

	Area[2] M ha	Emissions[3] tCO_2e/ha
dairy	1.88	4.72
sheep and beef	7.91	1.86
	9.79	

[1] MfE 2007a. Methane includes enteric fermentation and manure management
[2] MfE 2008c. Data for 2004.
[3] MfE 2007a. Aggregated data for sheep and beef production.

Sequestration values do not differ greatly between pines and pastures according to MfE (2008b). However, the pasture sink is not included in reporting and accounting in agricultural systems as it is assumed that the stock change is zero and therefore no net CO_2 emissions occur. Only non-CO_2 emissions are estimated. Hence little attention is paid to the annual pasture sink of 11 – 25 t CO_2/ha (see Table 6). CO_2 emissions are assumed to balance removals by pasture sinks, and carbon exported in products is also excluded.

Hence in contrast to the 'average' annual[2] forest sink of 23 tCO_2/ha/yr, dairy is a source of 4.7 tCO_2/ha/yr and sheep/beef a source of 1.9 tCO_2/ha/yr. The relative land use impact of forestry (sink and avoided emissions) would therefore lead to a benefit of 25-28 tCO_2e/ha. Conversely, deforestation to pasture both reduces the stock and turns the land use from a sink to an ongoing source of emissions. More detailed studies could incorporate other factors such as methane absorption by forest soils, soil carbon changes, volatile organic compounds and the albedo effect, as well as other non-GHG impacts such as evapotranspiration rates and biodiversity impacts.

There are numerous counterfactual scenarios that could be devised to identify avoided emissions. Avoided deforestation is one which, while currently being considered primarily for developing countries, could also be applied to at least some New Zealand locations. The UNFCCC specifically mentions maintaining and enhancing forest sinks and reservoirs as important goals, but they have very different impacts on the atmosphere. An existing forest retains carbon on site whereas afforestation of pasture turns a land use source to a sink and accumulates additional carbon from the atmosphere. Giving these activities equivalent status as offsets will tend to favour avoided deforestation due the immediate accounting benefits, despite little impact on the atmosphere. Afforestation is a much slower sink in comparison.

Finally, just as the carbon stock can fluctuate little in a productive sustained yield forest, the same usually applies to protection forests. In the latter situation carbon is not harvested for offsite uses but merely decomposes on site. This avoids any opportunity for ongoing off-site fossil fuel substitution either directly or indirectly.

6.4.2 Materials

While wood products themselves may be fairly minor component of global carbon stocks, their impact is enhanced by substituting for more energy and/or greenhouse gas intensive materials. Buchanan and Levine (1999) estimated that the magnitude of the emissions decrease from increasing the wood content of New Zealand buildings was more than 4 times the increase in carbon stocks. Any such competitive advantage of wood over other materials will however depend largely on the relative treatment of materials. If energy intensive industries are given special treatment to help their international competitiveness, this will reduce the natural advantages of wood products.

Not only is wood less energy intensive than most other materials (Table 8), but the wood processing industry is also 66% self-sufficient in energy (MED 2006). Clearly processing timber is not emission free, although where biomass is used for energy the emissions are derived from a by product that may otherwise have been emitted elsewhere e.g. via decay either as CO_2 or possibly a more potent GHG such as CH_4.

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[2] Considerable caution is advised over the adoption of any such 'average' data. While it is used here for illustrative purposes, the sigmoid growth pattern of most trees, and uneven age-class structure of many forests, should be recognised and accommodated in more detailed studies.

Table 8. Energy use for material production (GJ/tonne)

	Electricity	Petroleum	Coal	Nat gas	Biofuel	Total	Total Excl Biofuel
Lumber	0.41	2.26	0	0	1.88	4.55	2.67
Particle board (virgin wood)	1.08	2.79	0	0	2.5	6.37	3.87
Particle board (recovered wood)	1.18	1.33	0	0	1.05	3.56	2.51
Concrete	0.07	0.21	0.37	0	0	0.65	0.65
Steel (50% scrap, 50% ore)	2.4	1.2	6.2	2.5	0	12.3	12.3

Source: Sathre and Gustavsson, 2007

Table 8 needs to be interpreted carefully as it indicates that concrete has the lowest energy intensity, but it may not have the lowest greenhouse gas emissions per functional unit. One tonne of wood, concrete and steel do not necessarily perform the same task. Steel and concrete also use coal in their production which has the highest greenhouse gas emissions of all energy carriers. The actual emissions will vary by country depending on the electricity mix. New Zealand has relatively low emissions associated with electricity production due to the large contribution from renewable energy. The data above for concrete do not include emissions from calcination of limestone which is reported to be over 0.5 tCO2/t cement.

6.4.3 Fuels

Emission factors from various energy sources and fuels are shown in Table 9. The electricity emission factor can vary depending on the source data used and boundaries applied, for example:

- National energy statistics (MED, 2007b) show emissions from 40.8 TWh electricity generation were 8.7 Mt CO_2e in 2005. This equates to an average emission over all sources of 0.23 tCO_2e/MWh or (at 3.6 GJ/MWh) 0.06 tCO_2e/GJ consumed. This is similar to the MfE (2008b) purchased electricity emission factor of 0.21 tCO_2e/MWh.
- Thermal (fossil fuel) generation emissions alone are reported to be 8.4 MtCO_2e from producing 14.3 TWh. Thermal electricity therefore produces emissions of 0.60 tCO_2e/MWh or 0.15 tCO_2e/GJ consumed.

Table 9. Emission factors for energy and transport fuels

	t CO_2e		Energy content		tCO_2e/GJ
Electricity (thermal)	589	per GWh	3.6	GJ/MWh	0.164
Electricity (all)	209	per GWh	3.6	GJ/MWh	0.058
Natural gas (com)	0.053	per GJ	0.039	GJ/m3	0.053
Coal	2.016	per tonne	25.10	GJ/t	0.080
Fuel oil (heavy)	0.003	per litre	40.30	MJ/l	0.074
Diesel	0.0027	per litre	38.10	MJ/l	0.070
Petrol	0.0023	per litre	35.34	MJ/l	0.066
LPG	0.0016	per litre	26.50	MJ/l	0.061
Biomass (wood)	0.1042	per GJ	10.30	GJ/t	0.104

The NIR emission factors (MfE, 2007a) indicate that biomass for energy emits 0.1 tCO_2e/GJ, which is more per unit of energy than other fuels (Figure 6). Unfortunately, carbohydrates have a lower energy density than hydrocarbons. If the biomass is processed or upgraded the energy density can be improved, but the energy yield per unit of biomass and hence per unit area will reduce as a result. Not only is less carbon available for energy, but more carbon may be released from additional processing energy.

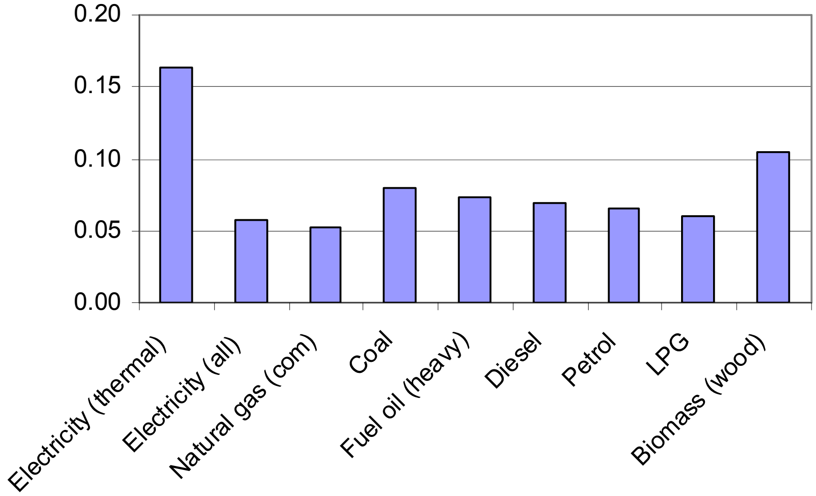

Figure 6. Emissions per unit of energy (tCO_2e/GJ)

7 Discussion of alternative accounting systems

In this section the results for each of the accounting options presented in the previous section are discussed in terms of the criteria identified in the introduction:

- Modelling: consistency of emission and removal estimates with atmospheric impacts,
- Equity: the allocation of responsibilty for emissions and removals,
- Policy: which policies each of the options favour, and
- Behaviour: what behaviour (change) do the options encourage.

7.1 Modeling

Table 10 shows the net removals accounted for under each of the carbon accounting options, as described in the previous section. If the accounting system includes only stock changes (option 1), it would appear that New Zealand has a forest sink of 26.8 MtCO_2e. If proposals to include stock changes in wood products (in use and SWDS) are applied (Option 2), there is a minor increase in the apparent sink (28.1 Mt CO_2e). The extra carbon stock in New Zealand would be minor (particularly compared to forests stocks) and it could be hard to justify the additional modeling and data capture effort for such a small gain.

Accounting for the delay in emissions resulting from the retention of carbon in products increases net removals to 37.3 MtCO_2e. This reflects the considerable exports of carbon that will be emitted overseas. If the focus is applied to the atmospheric exchanges resulting from forestry activities (forest sink – bioenergy – SWDS), net removals increase by 37% to 36.8 MtCO_2e. This means New Zealand under-estimates annual net removals (and hence overstates the net atmospheric GHG emissions) by 10 MtCO_2/yr.

Table 10. Forest-related carbon removals in New Zealand (2005)

Option		MtC	MtCO_2e
1	Forest stock change	7.30	26.78
2a	Stock change in all stocks	7.65	28.05
2b	Delayed emissions	10.18	37.33
3	Net removal from atmosphere	**10.22**	36.80

The location of emissions is less relevant for atmospheric modeling than the timing of emissions. This suggests that the increased accuracy in Options 2b and 3 in terms of when emissions occur would improve the accuracy of modeling exercises, and hence improve the development of future climate scenarios.

If the accounting system reflects the atmospheric sinks and sources it is easy to comprehend and easy for consumers to see the impacts of their activities and choices (assuming no distortions through allowances/exemptions etc). Option 3 accounts for direct atmospheric exchanges rather than being derived from a complex modeling approach (option 2b) requiring considerable historic data and assumptions relating to broad categories of products. Data for Option 3 is already reported in national inventories (bioenergy memo items) or could be derived from the IPCC Waste model, and is therefore likely to be a much less complex approach that can be applied at both national and project scales.

7.2 Equity

Emissions from the use of fossil fuels are allocated to the consumer of the energy. Higher consumption therefore leads to higher emissions, and a price on emissions can encourage lower consumption. Allocating LULUCF emissions to biomass producers does nothing to encourage consumers to conserve resources. The producer has little if any control over the use of their biomass once it has left the farm or forest. Allocation to the activity emitting GHGs is more transparent and allows the emitter to manage emissions.

If the current accounting system remains (Option 1) then biomass exporters (forest products, food etc) will continue to be penalized for emissions that will tend to occur overseas at some future point in time. Analysis of atmospheric impacts may provide support for some form of 'allowance' in national emission reduction commitments for biomass exporting countries. There could even be compensation for biomass producers for their atmospheric services e.g. forest management (avoided deforestation).

Option 2a would do little to improve the equity issues, at least for biomass exporting countries. The change in stock in products is assumed to be a sink which is allocated to the consumer country. Emissions from biomass imported for energy will not feature on the accounts of the importer, since they have already been reported by the producer/exporter. Hence if New Zealand exports logs, the importer can use part of the log as energy to convert logs to wood products. The energy is 'emission-free' and the carbon in wood products is accounted by the importer as if it had been removed from the atmosphere.

Options 2b and 3 both focus on accounting for emissions and removals where they occur i.e. they apply a 'polluter pays' principle. This might be an important element in encouraging developing countries into a future agreement, since many of them are exporters of biomass-derived products. These options would allow countries to focus on reducing emissions associated with domestic consumption. They could also encourage reductions in domestic emissions associated with production of exported goods, so that they will better compete with overseas producers in export markets. With UK supermarkets already making moves to show consumers the GHG impacts of their consumption, it is not a big stretch to see this visual indicator turning into a price signal.

Globally there are over 5.3 Gt of CO_2 embodied in trade (Peters and Hertwich, 2008). Countries like the U.S. have increasingly outsourced emissions to their trading partners, especially China. Accounting for this in emission inventories gives a more consistent description of a country's environmental pressures and avoids many trade related issues. If nothing else, a better understanding of the role of trade in a country's economic and environmental development can help design a more effective climate agreement.

New Zealand stands to gain from the large volumes of carbon contained within exported products, as well as from the low emission intensity of many food and bio-material products compared to other producers. The high proportion of renewable electricity also provides a competitive advantage to many products, to counter the long distances to market. However, the costs of imported manufactured goods such as cars and computers would undoubtedly increase.

7.3 Policy

If the accounting system in Option 1 is retained, the forests contribution to accounted removals would diminish over time as stocks stabilize, without policies and measures to ensure afforestation is continued. National policy would aim to maximize the quantity of New Zealand-grown biomass used for products and energy within national boundaries. The emissions from harvested biomass are accounted for at the point of harvest, so the more products or services derived from this biomass the better. Exporting biomass means accepting responsibility for emissions without capturing the benefits of a product or service. This option can also leads to a policy of importing biomass as an emission-free energy source instead of fossil fuels.

Accounting for forest and product stocks (option 2a) is unlikely to make a significant difference to net removals. The proposed IPCC model has domestic consumption as inputs and hence policies to encourage higher net imports would increase the apparent sink.

Accounting for emissions according to a decay pattern (option 2b) would favour policies that encourage the production of long-life products, and/or extended cycles (from sink to source) via reuse and recycling. Both of these appear consistent with other New Zealand sustainability policies. Similarly, accounting for only the emissions that occur within national boundaries ensures that policies can be developed to affect the timing of emissions.

Accounting for emissions under options 2b and 3 is consistent with the 'polluter pays' principle of other New Zealand policies. Policy to encourage the use of biomass for energy would not increase emissions accounted if New Zealand-grown biomass is used, since all New Zealand-grown carbon is currently assumed to be emitted at harvest. However, this would not encourage the import of biomass for energy since this would carry an associated emission liability. This could encourage greater production and use of biomass within national boundaries and hence global atmospheric benefits by avoiding additional international transport.

While policies and measures are important aspects of national responses to climate change, it is the activities undertaken that affect emissions and removals.

7.4 Behaviour

National policies can include mechanisms to encourage behaviour or behavioural change to reduce emissions or maintain and enhance sinks and reservoirs. For example this could encourage the most appropriate use of resources such as:

- Encourage use of clean biomass for products aiming to maximise product life before carbon is released;
- Encourage manufacture of products that facilitate (and/or do not represent barriers to) subsequent reuse, recycling or use for energy;
- Encourage use of biomass for energy at appropriate points of lifecycle (processing plants, collection points) where opportunities for reuse, recycling are not readily available;
- Discourage disposal of biomass in dumps (with little or no containment or management);
- Discourage biomass disposal in SWDS/landfills.

The GHG impacts are not the only factor affecting behaviour. There is no reason why the national accounting system has to be mirrored in domestic policies. As noted previously, projects undertaken for climate change mitigation can be assessed against completely different reference scenarios from the national accounts.

If Option 1 is adopted, the focus is entirely on forest stock changes. This would therefore encourage land uses with rapid growth and the potential for high carbon stocks. There may well be a signal to establish non-harvest forests to avoid accounting for emissions at harvesting. Consumers may avoid wood products entirely since harvesting is perceived to be an emission.

Since options 2a and 2b are derived from a modeling approach, it is distanced from consumer behaviour. It is not clear how consumers would gain benefit from increasing their consumption of wood products (option 2a), or how the emissions from discarding the products (option 2b) would be captured.

The focus on emissions under options 2b and 3 could be perceived as an inherent liability for emissions at a future point in time. This is similar to the concern noted under option 1 and could be a barrier to biomass trade, with consumers favouring non-wood products. However, if the embodied emissions from the manufacture of different products is taken into account and translated into a carbon price signal, this would affect consumer choices.

Consumer choices can already be 'offset' through various activities. Rather than changing their own behaviour to directly reduce emissions, entities and individuals can buy emissions reductions from elsewhere. While this would appear to be an effective way of reducing emissions at least cost, there are concerns over the accounting systems in place for projects.

Most project activities can be described as reducing emissions below a 'business as usual' baseline, since there are a variety of valid baselines that can apply to different situations. However, the accounted impacts may differ from the atmospheric impacts. For example, an efficient gas fired power plant might have much lower emissions than a conventional coal plant, but it still adds to the atmospheric concentrations. Similarly, a landfill gas energy system converts methane to carbon dioxide and therefore reduces the CO_2 equivalent emissions, but still releases GHGs. A wind farm on the other hand does not emit GHGs, but nor does it remove carbon from the atmosphere. Afforestation removes carbon from the atmosphere. In each case the direct atmospheric impacts are very clear, and they are not equivalent.

If if the sink from establishing forests and avoided fossil fuel emissions resulting from bioenergy are eligible for equivalent 'credits' there is a greater incentive for investors to support projects to burn biomass than establish forests. This imbalance between supply and demand could increase pressure on existing forests. Furthermore, without recognition of the GHG impacts of wood products, there is an incentive to burn biomass rather than convert it to products, hence increasing demand for products manufactured from other materials.

This raises the possibility of some kind of rating system for impacts, in order to retain the credibility of carbon offsets. This could at least recognize atmospheric impacts of different activities and inform buyers of the differences between reduced and avoided emissions. This could be as simple as recognising the direct atmospheric impacts e.g. a sink > neutral impact > source.

8 Summary

GHG accounting systems include methods for both estimating emissions and removals, and ways to combine data for particular situations. National accounting is largely based on the change in emissions relative to a base year (1990), but also incorporates the change in forest stocks during CP1. Accounting for projects focuses on emissions reductions, or stock changes, relative to a counterfactual baseline. The accounted impacts on the project scale are therefore not always the same as the impacts on the national scale.

The IPCC guidelines are based on a principle of continuous improvement to update factors and calculations in order to help parties improve the accuracy of estimates of emissions/removals. There is also the explicit principle that parties will use the most accurate data and methods available. The default option (Tier 1) is a basic entry level assessment, and parties should improve upon this wherever possible. Often Tier 2 data and methods assist this process, but parties are encouraged to go further and develop their own 'Tier 3' methods based on factors such as local conditions, use of country/region specific models.

Accounting issues arise when the Tier 1 defaults are adopted to estimate emissions for accounting purposes. Once such methods are widely adopted it will be a much more difficult task to change to methods that more accurately account for emissions and removals. In the absence of the ability to distinguish between different meanings of 'reducing emissions' activities adopted will tend towards those that are easier/quicker or less risky options e.g.

- reducing emissions relative to an increasing future baseline rather than a stable historic base year,
- using biomass for 'avoided' emissions rather than reducing emisions *per se*,
- using biomass for avoided emissions rather than sequestering carbon from the atmosphere (increasing C density of land use).

Forestry is widely recognized as a key sector in terms of climate change responses, for its roles in both mitigation and adaptation. However, perceptions based on an accounting system that does not accurately reflect GHG emissions and removals can lead to perverse outcomes, particularly when activities can result in either sinks or sources. For example a decline in forest sink rate rather than direct impacts (sink as opposed to source) creates the perception of 'bad' when it may be more accurately viewed as 'less good'.

The default instant oxidation at harvest assumption is neither accurate nor recommended for countries where there are significant LUCF activities (such as New Zealand). The focus on forest stocks alone fails to maximize the emission reduction potential that forestry offers both as a land use and through off-site direct and indirect fossil fuel substitution. The accounting systems therefore lie at the heart of the issues – both quantifying impacts and allocating responsibility to encourage appropriate responses. While the consumer-based accounting systems for fossil fuels are relatively well accepted, the land use and primary-based sectors continue to be beset by problems.

Continuing with the current accounting system results in accounting "challenges" such as:

- Emissions or removal estimates varying depending on which components are included and how. These estimates can be manipulated in relation to historic base years, future baselines or other factors to estimate emissions reductions. The accounted impacts will vary depending on the reference scenario applied.

- The outcomes of an accounting system creating perceptions that lead to the development of policy or the adoption of certain behaviour. For example, the perception that harvesting causes an emission can lead consumers to avoid wood products. Similarly, ignoring the CO_2 emissions from SWDS could create the impression that this sector is 'under control' which could lead to sub-optimal bioenergy outcomes.

- Inaccurate accounting can also create issues between countries. Exporting biomass tends to mean the carbon will be emitted overseas. Biomass producers may be prepared to accept responsibility for emissions from exported biomass, but there may be a need to adjust national commitments to reflect embodied emissions. Allowances and exemptions for particular materials or processes (internationally or within domestic policy) increase distortions that reduce the perceived benefits of one choice over another.

- The accounting systems applied to sectors that only produce emissions may not be appropriate when applied to sectors that include the potential for negative emissions i.e. removals by sinks. It leads to a focus on reducing emissions and hence change. While reducing annual emissions is positive, reducing annual removal by sinks (if measured by stock changes) is inevitable. It is not feasible to continue to expand the forest area or to increase carbon density per unit of land. Reducing the sink rate creates the perception of 'bad' when it may be more accurately viewed as 'less good'.

This report evaluates three options to estimate the accounted forestry impacts:

Option 1. - Forest stock change;
Option 2. - Modelling stocks and flows to derive estimates of
a) stock changes in all stocks or
b) delayed emissions; and
Options 3 - Net removal from the atmosphere.

The net removals accounted under these options have been calculated based on carbon stocks and flows of NZ forests. Under the forest stock change option it appears that NZ has a forest sink of 26.8 $MtCO_2e$. If proposals to include stock changes in wood products (in use and SWDS) are applied, there is a minor increase in the apparent sink (28.1 Mt CO_2e). If however, the focus is applied to the atmospheric exchanges resulting from forestry activities (forest sink – bioenergy – SWDS), net removals increase by 37% to 36.8 $MtCO_2e$. This means NZ under-estimates annual net removals (and hence overstates the net atmospheric GHG emissions) by 10 $MtCO_2$/yr.

These options have been considered in terms of their accuracy and hence their contribution to:
- Modelling: consistency of emission and removal estimates with atmospheric impacts
- Equity: the allocation of responsibilty for emissions and removals
- Policy: which policies each of the options favour and
- Behavioural: what behaviour the accounting options and policies would encourage/discourage

Overall option 3 is the most accurate approach for estimating atmospheric impacts within national boundaries when they occur. It is based on scientific attribution of emissions and removals which reflects resource flows through the economy. This reduces complexity and associated concerns arising from other allocation options. If national policies recognise the ongoing sink in production forests there is a greater chance that land managers will maintain and enhance forest sinks and reservoirs. This will lead to enhanced environmental services compared to other land use options.

Option 3 will also lead to greater efficiency in the use of wood products, and encourage cascading biomass uses that will optimize atmospheric outcomes.

8.1 Recommendations for further work

To develop a process to improve the availability and understanding of information on carbon stocks and flows within and from New Zealand as a basis of developing an equitable accounting system that better reflects atmospheric impacts. This would include key officials, researchers and industry representing forestry, energy, and waste.

To support this process the following work is recommended:

a) To have available a recognized national database of 'official data' as the basis for ongoing and comparable analysis. This will reduce the risk of inconsistencies between sectors or analyses.
b) That a study be undertaken to estimate emissions of harvested carbon from end use activities. This would increase the accuracy of GHG inventories by focusing on where and when emissions occur. This option is simple (not data intensive such as the proposed IPCC wood products model), easy to understand as it reflects atmospheric sinks and sources, and enhances transparency.
c) That an accounting system be created that is linked directly to a central inventory system of activity data and emission factors used to determine atmospheric exchanges. This would enable multiple accounting scenarios to be directly linked to and compared with the atmospheric impacts of different options.
d) That a biomass map for NZ be developed including points of production, processing and trade, and consumption. This would be used to assist in the identification of any inefficiency and potential points of intervention to enhance sinks or reduce/delay sources.
e) That an analysis of the carbon trade balance for NZ be undertaken by quantifying imports and exports and estimating the carbon impacts/content of each. This would assist in the identification of emission-intensive products (and related services) that might be avoided through substitution of a (local) less-intensive alternative.
f) Undertake an analysis to determine the potential trade impacts if exports of carbon in biomass (wood, leather, wool, meat etc) meant a transfer of associated emission responsibility.
g) Evaluate the potential for different categories of emissions reductions (offsets) to reflect their direct impact on the atmosphere. This will also enable policymakers to identify projects with positive national outcomes, and could avoid a potential biomass supply:demand imbalance resulting from investors favouring immediate returns..

Specific projects that are suggested are:

Project 1

Work with MAF/MfE officials to produce an improved model incorporating the most appropriate activity data and emission factors for all NZ land use. This would incorporate appropriate data to reflect future activity scenarios and provide direct and transparent links from activity data to produce estimates for the national GHG inventory and various accounting approaches and reference scenarios.

The aim is to produce a tool that will facilitate the assessment of accounting proposals and assist in developing appropriate emission reduction polices and measures. The tool could for example:

- help identify biomass stocks and flows and hence potential points of intervention to improve climate mitigation outcomes;
- provide support for proposals for future accounting rules (international or domestic);
- help evaluate proposals from others for post-2012; and
- assist with negotiation of national commitments to account for national circumstances.

Project 2

This project extends the analysis in this report by focussing on the application of accounting rules to particular land uses and evaluates the impacts of these on the national carbon accounts. Financial implications of different activities can be evaluated in terms of cost of emission reductions and impacts on property costs/revenues. This will help evaluate the incentive for land managers to continue or change their behaviour.

Undertake and evaluation of property level (farm forestry) case studies based on different accounting rules. This would include:

- the estimation of carbon stocks and flows since 1990, and extrapolated to 2020;
- compiling ‘relevant’ reference scenarios;
- comparing GHG impacts under different rules; and
- financial analysis to compare the impacts of policy options.

9 Glossary

96GL	Revised 1996 IPCC Guidelines
AAU	Assigned Amount Units
AFOLU	Agriculture, Forestry and Other Land Use
Baseline	A scenario against which emissions can be compared
Base year	Historic reference point e.g. 1990 for Kyoto Protocol
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent (accommodating GWP)
CH_4	methane
DOC	degradable organic carbon
Emission avoidance	avoiding an increase in emissions, sometime referred to as reducing emissions relative to a future baseline (often increasing)
Emission reduction	absolute reduction in emission relative to historic base year
ETS	NZ Emissions trading scheme
GHG	Greenhouse gas
GL06	2006 IPCC Guidelines
GWP	Global warming potential
KP	Kyoto Protocol
LUCF	Land Use Change and Forestry
LULUCF	Land Use, Land use change and forestry
Mt	million tonnes
N_2O	Nitrous oxide
NIR	National Inventory Report (reports GHG under UNFCCC)
Reservoir	a component or components of the climate system where a greenhouse gas is stored.
Sink	any process, activity or mechanism that removes a GHG, an aerosol or a precursor to a GHG from the atmosphere.
Source	any process, activity or mechanism that releases a GHG, an aerosol or a precursor to a GHG into the atmosphere.
SWDS	solid waste disposal site
t	tonne (metric). 1 tonne = 1,000kg)
UNFCCC	United Nations Framework Convention on Climate Change

Unit	Abbreviation	Magnitude
Megajoule	MJ	1,000,000 J
Gigajoule	GJ	1,000,000,000 J
Terajoule	TJ	1,000,000,000,000 J
Petajoule	PJ	1,000,000,000,000,000 J

1 MWh	3.6 GJ
1 GJ	0.278 MWh
1 PJ	278 GWh
1 Gg	1,000 tonnes (1 kt)
1 Mg	1 tonne
1 Mt	1,000 Gg
1 t Carbon (1 tC)	12/44 t CO_2

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11 Appendix 1: New Zealand sustainability targets

The New Zealand government targets for a sustainable future

Targets

- By 2025, 90% of electricity generation is from renewable sources.
- By 2040, per capita transport greenhouse gas emissions are reduced by half of those in 2007.
- NZ will be one of the first countries in the world to widely deploy electric vehicles.
- NEW ZEALAND to remain a world leader in agricultural emissions reduction research, and in the early adoption and application of new technologies and processes that reduce agricultural greenhouse gas emissions.
- By 2020, NEW ZEALAND to achieve a net increase in forest area of 250,000 hectares from 2007 levels.

Achieving these targets will allow New Zealand to be effectively:

- Carbon neutral in the electricity sector by 2025
- Carbon neutral in the stationary energy sector by 2030
- Carbon neutral in the transport sector by 2040
- Carbon neutral in the total energy sector by 2040