NORWAY

21 March 2011

**Submission to the Ad-Hoc Working Group on Further Commitments for
Annex I Parties under the Kyoto Protocol (AWG-KP)**

Information on forest management reference level

Summary

According to decision 2/CMP.6 each Party included in Annex I to the Convention is requested to submit to the secretariat, by 28 February 2011, information on the data, methodologies and procedures used in the construction of their forest management reference level inscribed in appendix I of the decision, including any update to replace the value. Norway maintains 1990 as its historic reference level for forest management. We hereby submit updated information on this reference level in accordance with the guidelines outlined in part I of appendix II to the decision.

In a submission to the Ad-Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP) in September 2009, Norway presented projections for the years 2010, 2015 and 2020 for emissions and removals related to the activities under Article 3.3 and 3.4 of the Kyoto Protocol. Since then, the method used to estimate future removals from forest management under Article 3.4 has been improved.

For Norway the historic forest management reference level, as well as the estimated removals from future forest management under Business As Usual conditions, are expected to have impact on how our reduction levels will be set in future commitments. For the relevance and the purpose of transparency we therefore in this submission also present updated projections for expected forest management removals under Business As Usual conditions up to 2020.

Update on historic reference level (1990)
The annual estimates of carbon stock in living biomass from 1990 to 1997 have so far been based on the values for 1989 and 1998, using linear interpolation between these years. The calculated annual change in carbon stock has therefore been the same for all years in this period, not reflecting annual variations in increment and drain. In accordance with our efforts to continuously improve our methods, we have decided to revise our methodology for estimating historic removals to better reflect annual fluctuations. To make the estimates for annual carbon stock change more realistic, a correction factor has been constructed, taking into account the relationship between annual increment and annual drain used for every year in this period. Based on this correction factor a new and more realistic estimate for our 1990 removal has been calculated. The new reference level also includes estimated net removals from Finnmark County, mountain birch area and small trees which have previously not been reported.

The reference level inscribed in appendix I to decision 2/CMP.6, was -14.2 Mt CO_2-eq/yr, whereas the new reference level based on the correction factor mentioned is estimated to -11.4 Mt CO_2-eq/yr.

Projected future removals from forest management up to 2020
The removals scenarios presented in the Norwegian September 2009 submission were based on a business as usual approach reflecting the past 10 years of development in our forests.

Our updated and improved scenario uses the former scenario as a foundation, but incorporates expected effects of policies and programs decided no later than December 2009, in accordance with paragraph 11 in annex II to the Cancun-decision.

In order to improve the former projection scenarios, a new model approach has also been developed for producing short-term reference scenarios for forest management. This includes two new sub-models which better reflect age class distribution effects and the probability of final felling, with high harvest probability for plots close to maturity and in flat terrain.

Consistent with the improved basis for our historic reference level, the projections also include estimated net removals from Finnmark County, mountain birch area and small trees.

The annual removal from forest management in 2020 was estimated to 19.2 million tones of CO_2 per year in our September 2009 submission. Based on our improved projection models our updated removal estimate is around 23.2 million tones of CO_2 per year in 2020. The expected increase in annual removal based on the improved projection models is due to more realistic near future assumptions, giving higher carbon increment and higher build up of dead organic matter and soil carbon up to 2020. There will always exist uncertainty related to forward-looking projections. The new models applied have significantly reduced this uncertainty and provided a more realistic estimate for Norway´s forest management removals in 2020, based on the best knowledge today.

The figure below compares the old historical data and projections and the new numbers presented in this submission.
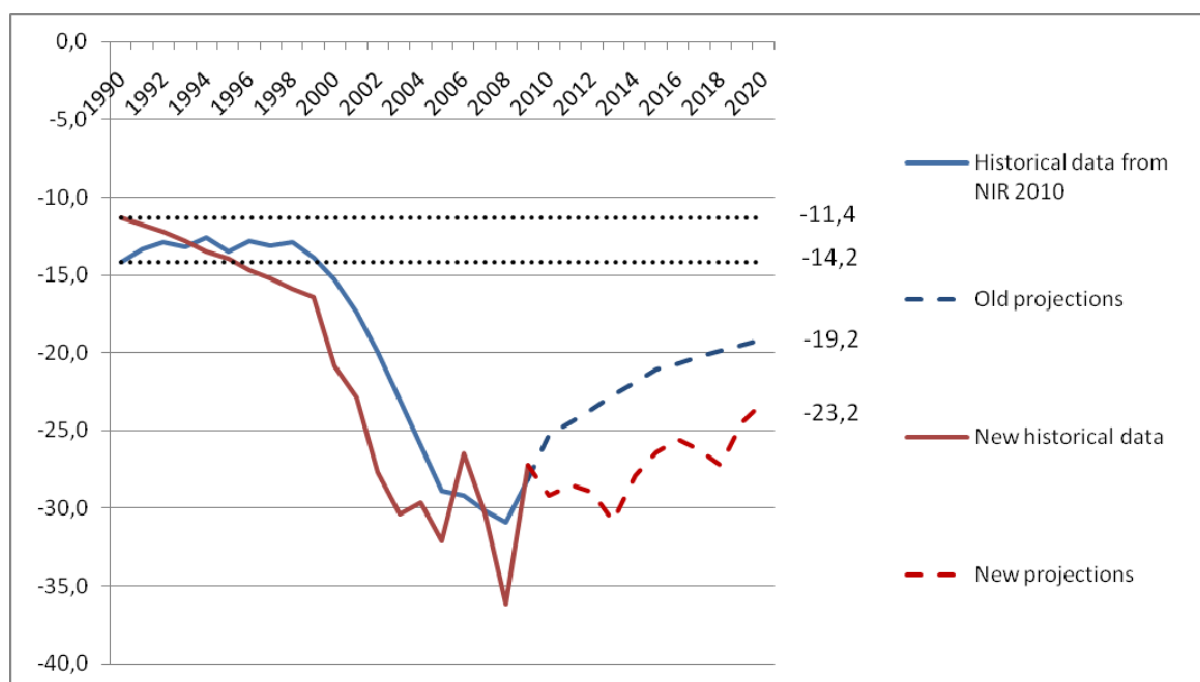
1.   Forest management reference level

1.1   General description

Norway has proposed to use 1990 as reference level for a net-net accounting for forest management. Such an approach would be in accordance with how other activities under Article 3.4, as well as non-LULUCF categories, are accounted for. Using 1990 as a reference level is simple and a transparent basis for accounting.

The forest management reference level inscribed in appendix I to the decision was set transparently, taking into account point (a) in footnote 1 in paragraph 4 of the decision. That is, the reference level is taking into account the removals from forest management in 1990, as submitted to the UNFCCC in the Norwegian national inventory report (NIR 2010). Harvested wood products, force majeure, removals resulting from elevated carbon dioxide concentrations above preindustrial level and indirect nitrogen deposition are hence not accounted for in the estimate.

As part of the methodological review in preparing the next national inventory report, the estimate for 1990 has been improved compared to the value inscribed in appendix I.

The calculations of carbon stock changes in living biomass are based on data obtained from the National Forestry Inventory (NFI). The NFI utilizes a 5-year cycle based on a re-sampling method with permanent plots. Each year 1/5 of the plots are inventoried with the sample plots randomly distributed across the country in order to reduce the periodic variation between years. The same plots are inventoried again after 5 years. The current system with permanent plots was put in place between 1986 and 1993, and made fully operational for the cycle covering 1994 through 1998. Because the re-sampling method was not fully implemented in 1990, the method used to calculate annual emissions and removals is not the same throughout the time-period, and the methods have been bridged.

The data obtained between 1986 and 1993 form the basis for the estimated carbon stock in living biomass per 31.12.1989. There are no annual biomass data available in the NFI for the years between 1989 and 1998. The annual estimates of carbon stock in living biomass for the years from 1990 to 1997, inclusive, are therefore based on the values for 1989 and 1998 using linear interpolation between these years. Because of the linear interpolation the calculated annual change in carbon stock is the same for all years in this period. To make the estimates for the annual carbon stock change more realistic, taking into account the relationship between annual increment and annual drain, we have constructed a correction factor which has been used for every year in this period. The formula for the correction factor is:

$$C_t = [(X_t - Y_t) / (\sum_{t=1990}^{1998} X_t - \sum_{t=1990}^{1998} Y_t)] \sum_{t=1990}^{1998} Z_t$$

where:

t = 1990, 1991…... 1998
C_t = correction factor for year t
X_t = annual increment in year t
Y_t = drain in year t
Z_t = removals of CO_2 from the atmosphere in year t

In addition to this correction factor, the new reference level also includes net removals from Finnmark County, the mountain birch area and small trees.

The previous reference level, inscribed in appendix I to decision 2/CMP.6, is -14.2 Mt CO_2-eq/yr, whereas the new reference level is -11.4 Mt CO_2-eq/yr. The revised estimate is expected to give a more precise description of the actual net removals from forest management in 1990, and is the estimate that will be reported to the UNFCCC in the Norwegian national inventory report in 2011 (NIR 2011).

1.2 Inclusion of areas, pools and gases

Forest land is defined according to the Global Forest Resources Assessment (FRA 2004). Forest land is land with tree crown cover of more than 10 per cent and area more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. No minimum width for Forest land is considered in the Norwegian inventory causing small discrepancy according to the definition in FRA 2004. Young natural stand and all plantations established for forestry purposes, as well as temporarily unstocked forest area as a result of human intervention or natural causes, are included under Forest land.

Table 1, Parameters for defining Forest land

Parameter	Range	Selected value
Minimum land area	0.05–1 ha	0.5 ha
Minimum crown cover	10–30 %	>10 %
Minimum height	2–5 m	5 m

Forest management is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological, economic and social functions of the forest in a sustainable manner. All forests in Norway are used either for wood harvesting, hunting, picking berries, hiking etc., and are hence considered managed. National parks fulfill ecological functions (including biodiversity) and unproductive forests are largely used for recreation (social functions) and hunting (economic and social functions). Consequently, we propose to include all forests that do not meet the requirements to be included under article 3.3 as Forest management, i.e. forest land remaining forest land. Hence, drainage (cultivation) of wetlands, fertilizing and fires are also included.

The reference level contains the following pools and gases:

- Living biomass – above-ground and below-ground
- Dead organic matter and soil organic matter
- N_2O from fertilization under forest management
- CO_2 and N_2O from drainage of soils under forest management
- N_2O and CH_4 from biomass burning (wild forest fires)

1.3 Approaches, methods and models used

Living biomass

As mentioned, the estimates for living biomass are based on data obtained from permanent plots assessed by the NFI, with permanent plots put in place between 1986 and 1993, county by county. The sampling design is based on a systematic grid of geo-referenced sample plots

with 3x3 km spacing under the coniferous tree limits. The areas of mountain birch above the coniferous limit and Finnmark, the northernmost County, were not included in the NIR 2010. The reported carbon refers to biomass of all living trees with a height of at least 1.3 m. Thus, small trees, shrubs and other vegetation, such as herbs, were not included in the figures either.

All areas are, however, included in the updated estimate for 1990. The removals from living biomass in total for 1990 are estimated to -6.42 Mt CO_2-eq. This estimate is considered to be better than previous estimates, because it includes all forest areas in the country. The estimates of the removals from the new forest areas are based on extrapolation, assuming that the proportion of standing volume in the different areas compared to total standing volume below the coniferous limit has stayed constant throughout the period. The estimates for areas above the coniferous limit and Finnmark County, may be recalculated in future greenhouse gas inventories, as more information, e.g. from the NFI, maps, old and new aerial photos, may be used to improve the estimates back to 1990.

Trees with diameter larger than 50 mm at breast height
The biomass for all trees larger than 50 mm diameter at breast height was calculated from their diameter and height measurements. Both above-ground and below-ground biomass is reported. Above-ground biomass is defined as living biomass above stump height (1 per cent of tree height). The Swedish single tree allometric regression function developed by Marklund (1987,1988) is applied to data from the NFI for prediction of the various tree biomass components – stem, stem bark, living branches, dead branches, needles (not leaves) for Norway Spruce (Picea abies), Scots pine (Pinus sylvestris) and birch (Betula pendula and Betula pubecens). These species (including other coniferous about 1 per cent) constitute about 92 per cent of the standing volume (Larsson et al. 2007). Other, broad-leaved species constitute most of the remaining 8 per cent and the birch functions are applied to all broad-leaved species.

Below-ground biomass is defined as living biomass below stump height down to a root diameter of 2 mm, and is estimated by Petersson and Ståhl's (2006) single tree allometric regression functions for the same tree species as for above-ground biomass. The living biomass is estimated consistently based on the same monitoring design, by using the same functions for the same tree species from the base year 1990 and onward.

Norway has selected to use the stock change method to estimate emissions/removals for forest land remaining forest land. The removals from living biomass in 1990 are estimated to -5.99 Mt CO_2-eq, when using the correction factor as described above.

Trees with diameter less than 50 mm at breast height
In 2005, the NFI started to assess trees with diameter less than 50 mm at all plots. The full cycle of measurements of small trees is expected to be completed for the whole country in the national inventory report in 2014.

In the period 2005-2009, the standing volume in small trees was 3 per cent of the total volume. Assuming that this proportion has remained constant over the last twenty years, the removals from small trees (above and below the coniferous limit – except Finnmark) in 1990 are estimated to -0.18 Mt CO_2-eq.

The mountain birch area
Until 2004 the mountain areas and the birch above coniferous limit, were not included in the NFI. During the inventory cycle 2005–2009, the mountain birch areas were assessed in the same way as the rest of the country, but in 3x9 km grid. In addition to the land-use classification from the NFI during 1986–1993, old and new aerial photographs will be used to establish land-use of each plot in 1990. The plan is that the time-series of land use and biomass for the mountainous areas are completed in 2012. The assessments of these areas will end in 2012, and are planned to be included in the national inventory report in 2014.

In the period 2005–2009, the standing volume in the mountain birch area was 2.7 per cent of the total volume below the coniferous limit. Assuming that this proportion has remained constant over the last twenty years, the removals from the mountain birch areas in 1990 are estimated to -0.16 Mt CO_2-eq.

The coniferous and birch area of Finnmark County
During the inventory cycle 2005–2009, the coniferous areas were assessed in the same way as the areas under the coniferous limit in 3x3 km grid. NFI started in 2008 to establish a less dense plot grid for forest land and other wooded land that are mainly stocked with birch, in 9x9 km grid. It is planned to complete the whole time-series of land use and biomass for Finnmark during 2012, and the estimates are planned to be included in the national inventory report in 2014.

The standing volume in the coniferous and birch area of Finnmark County was in the period 2005–2009 1.3 per cent of total volume below the coniferous limit. Assuming this proportion has remained constant over the last twenty years, the removals from the coniferous and birch area of Finnmark County in 1990 are estimated to -0.08 Mt CO_2-eq.

Dead organic matter and soil organic matter
The dynamic soil model Yasso, as described in detail by Liski et al. (2005), and for Norwegian conditions by de Wit et al. (2006), is used to calculate changes in carbon stock in dead organic matter and in soil. The calculations are hence done in according to a Tier 3 method. The current implementation of the Yasso model is not designed for obtaining estimates of dead organic matter and soil organic carbon for disaggregated areas or land use classes other than forest land remaining forest land.

The Yasso model describes the accumulation of dead organic matter and soil organic matter in upland forest soils and is designed to process data from forest inventories (Liski et al. 2005). The model requires estimates of litter production as input to the soil and basic weather data. The model has two litter compartments that relate to physical fractions of litter. It has five soil components that differ in their rate of decomposition. A gradual formation of more complex compounds (humification) is possible through limited transfer among soil compartments. The litter and soil compartments can be viewed as "dead wood" and "soil organic matter". The estimated values of both "dead wood" and "soil organic matter" are reported. With the current parameterization (Liski et al. 2005), the model gives an estimate of the soil organic matter down to a depth of 1 m in the mineral soil. The parameter values used reflect the climate of Southern Finland and Middle Sweden (annual mean temperature of 3.3 degrees Celsius and a May-to-September precipitation deficit of -32 mm). These reference conditions were used in all steps of simulations, hence no annual changes in climate/weather. We assume that the model is relevant for Norwegian conditions.

Due to the lack of repeated soil carbon assessments, the initial soil carbon content was calculated assuming a steady state between soil organic matter and litter input at the first year of simulation. It is known (de Wit et al. 2006) that the initial soil C pools influence the following estimates of annual changes. This influence diminishes with time, thus to minimize errors due to an unrealistic start value, the steady state was calculated for the first year in a time-series started in 1960. Simulation output is only used from 1990, thus allowing for an equilibration period of 30 years.

Further description of the YASSO model is given in NIR 2010, page 226.

The removals from dead organic matter and from soil below coniferous limit are in 1990 estimated to -2.04 Mt CO_2-eq and -3.06 Mt CO_2-eq, respectively. These estimates do not include dead organic matter of dead wood and soil in mountain birch area and Finnmark County, due to lack of qualified data.

The estimates of removals from dead organic matter and from soil will be recalculated, with the aim to include all forest areas in the reporting in 2014.

N_2O from fertilization under forest management

Statistics on consumption of fertilizers are based on data from the National Agricultural Inspection Service. Fertilization of forest is of little importance in Norway. Because national emission factors for fertilization of forest soil are unavailable, the estimate is based on Tier 1 and default emission factors.

N_2O-directfertlizer = $(F_{Statistics\ Norway} + F_{ON}) * EF_1 * 44/28$

where

$F_{Statistics\ Norway}$ = the amount of synthetic fertilizer applied to forest soil adjusted for volatilization as NH_3 and NOx. Gg N.

F_{ON} = the amount of organic fertilizer applied to forest soil adjusted for volatilization as NH_3 and NOx. Gg N.

EF_1 = Emission factor for emissions from N input, kg N_2O-N/kg N input.

There are national statistics on the area with fertilizer applied. This area was only 26 km^2 in 1990 (Statistics Norway, Forestry Statistics). The statistics do not specify whether this is synthetic or organic fertilizer. Furthermore, it does not say anything about the amount applied. Statistics Norway has supplied unpublished data on application on synthetic fertilizer for the period 1995–2005. The average ratio between the amount applied and the area fertilized was used to estimate the amount applied for 1990–1994. It is assumed that organic fertilizer is not applied to forest in Norway. To the extent that it is applied, the associated emissions are reported under agriculture (this assumption is according to IPCC 2003).

The amount of fertilizer applied is given as total weight. The nitrogen content is depending on the type used. According to Statistics Norway, 95 per cent NPK-fertilizer (nitrogen (N), phosphorus (P), and potassium (K)) is used on wetlands. On dry land about half is NPK and the rest N-fertilizer. The N-content of these were taken from YARA (www.hydroagri.com).

The default emission factor is 1.25 per cent of applied N. There are no national data to improve this. 1 per cent of the N-applied is volatilized as NH_3 (the ammonia model of Statistics Norway).

The resulting emissions are about 2–4 Mg N_2O per year, which is very small compared to the emissions from agriculture. The emission factor is highly uncertain. According to IPCC (2003), the range in emission factor can be from 0.25 per cent to 6 per cent. The amount of fertilizer applied to forest is subtracted from the input to the calculation of emissions from agriculture, because that figure is based on the total fertilizer sale. See NIR 2010 for more information.

The emissions from fertilization in 1990 are estimated to 0.001 Mt CO_2-eq.

N_2O from drainage of soils under forest management

The area of drained organic soil has been drastically reduced since the 1960s (Figure 1). This is due to economic conditions and an increased focus on preserving mires. There is no national data on the CO_2 emissions from drainage, and hence the method used corresponds to IPCC (2003) Tier 1 method.
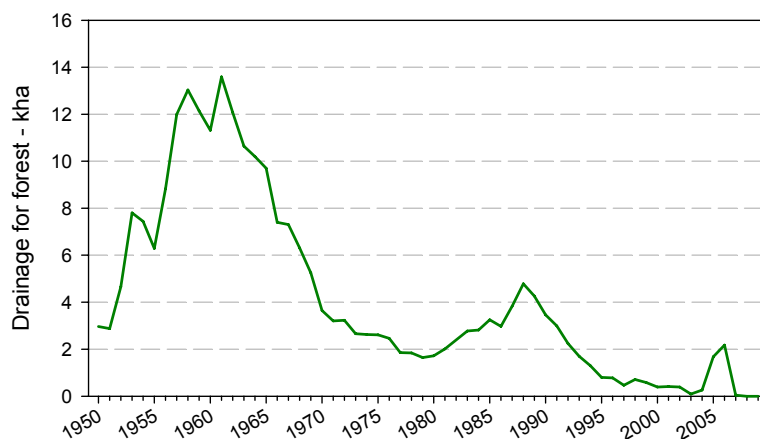
Figure 1, Drainage of forest 1950–2009. Source: Statistics Norway.

Due to lack of national emission factor, the IPCC default factor for drained organic soils in managed forest (boreal), 0.16 Mg C/ha/year, is used.

Drainage of organic soils generates emissions of N_2O, in addition to CO_2. Drainage will also reduce emissions of methane and even generate a sink (IPCC, 2003). However, data are unavailable to estimate this effect (IPCC, 2003) and there are no national data to estimate this. Given that the area drained in Norway currently is low, no estimate is given for methane. This is in accordance with the methodology given in an appendix in IPCC (2003) (for further methodology development). Because no national data are available, the methodology used to estimate N_2O is based on IPCC (2003). It is assumed that all drainage is related to organic soils.

N_2O emissions = Area of drained forest soil * emission factor

The emission factor is taken from IPCC (2003). It is assumed that all soil is nutrient poor, the corresponding emission factor is 0.1 kg N_2O-N/ha/year (0.6 for nutrient rich). The range of

emission factor is from 0.02 to 0.3, which is an indication of the large uncertainty of the estimate. It is assumed that there is no rewetting of drained forest soils.

According to Statistics Norway the area of drained organic soils (total accumulated) was 231.8 kha in1990. The estimated emissions (CO_2 and N_2O) are about 0.15 Mt CO_2-eq.

See NIR 2010 for the whole time-series from 1990–2008.

N_2O and CH_4 from biomass burning (forest fires)

No prescribed burning of forest takes place in Norway and all forest fires are due to accidents in dry periods (wildfires). According to IPCC (2003) the emissions of CO_2 from fires should be estimated, because the re-growth and subsequent sequestration are taken into account when it takes place. However, both the emissions and removals of CO_2 will be covered by the growing stock change based CO_2 calculations.

Data on area burned in forest fires are available from the Directorate for Civil Protection and Emergency Planning for 1993–2009 (Table 4). For 1990–1992 only data on the number of fires were available and these data were used to estimate the area burned based on the ratio for subsequent years. This method may be very inaccurate because the size of fires is very variable. Because the number of fires was higher in 1990–1992 than later, it is possible that the estimate for the base year is too high.

Table 2, Forest fires in Norway 1990-2009.

Activity data	Number of fires	Unproductive forest (ha)	Productive forest (ha)	Total area Burnt (ha)
1990	578	679.6*	256.4*	935.9*
1991	972	1 142.8*	431.2*	1 574.0*
1992	892	1 048.8*	395.7*	1 444.4*
1993	253	135.5	88.3	223.8*
1994	471	123.6	108.1	231.7
1995	181	77.6	35.5	113.1
1996	246	169.7	343.8	513.5
1997	533	605.8	260.6	866.4
1998	99	164.7	110.3	275
1999	148	734.0	12.7	86.1
2000	99	142.6	29.3	171.9
2001	117	84.3	5.2	89.5
2002	213	124.7	95.8	220.5
2003	198	905.6	36.8	942.4
2004	119	84.6	32.3	116.9
2005	122	252.7	92.6	345.3
2006	205	3222.1	660.7	3 882.7
2007	65	22.2	106.1	128.3
2008	174	1210.2	1963.6	3173.8
2009	109	1257.7	70.8	1328.5

Source: Directorate for Civil Protection and Emergency Planning
*Area estimated by the Norwegian Forest and Landscape Institute (2005).

Emissions in all forests are reported. The area burned varies considerably from year to year due to natural factors (for example variations in precipitation). Assuming that the carbon

content of biomass is 50 per cent, half of the biomass burned will end up as CO_2. There are no exact data on the amount of biomass burned per area. Normally, only the needles/leaves, parts of the humus and smaller branches are burned. We have assumed that there are 20 m^3 biomass per ha and that the mass of trees burned constitute 25 per cent of this (this is consistent with IPCC (2003). It is also likely that there is about 1 m^3 dead-wood per ha that will be affected by the fire due to its dryness. It is difficult to assess how much of the humus is burned, and this is much dependent on forest type. There is about 7 500 kg humus per ha, we assume that 10 per cent of this is burned. This factor is, however, very dependent on the vegetation type. Most of the forest fires in Norway take place in pine forest with a very shallow humus layer.

There are no national data on emission factors for non-CO_2 gases from forest fires. Estimates of non-CO_2 gases emissions are therefore based on the C released as described in IPCC (2003). The following equations are used:

CH_4 emissions = C * Emission ratio * 16/12
N_2O emissions = C * N/C ratio * Emission ratio * 44/28

where C is the carbon released.

IPCC (2003) suggests a default N/C ratio of 0.01. The methane emission ratio is 0.012 and for nitrous oxide 0.007.

The emissions of CH_4 and N_2O in 1990 are 0.002 Mt CO_2-eq.

1.4   Summary

The table below is summarizing the estimates from all the categories above.

Table 3, Forest management reference level – 1990

	1990 Mt CO2-eq.
Living biomass	-6.42
- below coniferous limit	*-5.99*
- small living trees (below and above coniferous limit – except Finnmark)	*-0.18*
- mountain birch area	*-0.16*
- Finnmark County	*-0.08*
Dead organic matter below coniferous limit	-2.04
Soil organic matter below coniferous limit	-3.06
Biomass burning (Wild fires – N_2O and CH_4)	0.002
Fertilization	0.001
Drainage of soils under Forest management (CO_2 and N_2O)	0.15
Total	**-11.37**

2.   Projections for forest management

In September 2009, Norway presented projections for 2010, 2015 and 2020 for, inter alia, the activity forest management, in a submission to the Ad-Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP). The aim of the projections was to describe the expected development in emissions and removals based on existing forest and climate change policy, i.e. business as usual projections (BAU). The projections were further discussed in a submission in November 2009, where Parties were invited to submit information on forest management.

Since then, the methodology used to develop the projections has been improved. In this submission, we present new projections based on these methodological improvements. As the former projections, these are based on data from the Norwegian Forest and Landscape Institute. The new projections incorporate expected effects of policies and programs decided no later than December 2009 in accordance with paragraph 11 in annex II to the Cancun-decision.

2.1 Model approach
In order to improve a number of shortcomings of the projection scenarios developed by Astrup et al. (2010) and presented in the Norwegian submission to AWG-KP in September 2009, a new model approach has been developed for producing short-term reference scenarios for forest management. The new model approach was developed to be (1) in accordance with the stock change method employed in the current Norwegian LULUCF reporting, (2) transparent and simple, and (3) to utilize the NFI data employed in the current reporting as foundation for the driving functions.

Living biomass of each NFI plot is forecasted individually. Each year, 1/5 of the NFI plots (corresponding to the NFI plots that are scheduled for re-measurement) are forecasted. Finally, the stock change between moving 5-year averages are computed and assigned to the appropriate year. As in the historic reporting, dead organic and soil carbon are modeled with the Yasso model (Liski et al 2005) utilizing the forecasted litter inputs from the NFI plots.

The forecasting of an individual sample plot consists of two sub-models: (1) the biomass increment sub-model and (2) the probability of final felling and harvest sub-model.

The biomass increment sub-model
The biomass increment sub-model is designed to account for age-class distribution effects. In order to most realistically represent current growth conditions in relation to climate, CO_2 concentration and nitrogen deposition, only data less than 10 years old is utilized. The sub-model is designed to be simple and transparent and consists of average annual CO_2 uptakes for different forest types stratified according to site index, age and species.

In a given strata the carbon increment estimate is expressed as the average observed change on the NFI plots with land-use class Forest between Norway's 8th (2000 - 2004) and 9th (2005- 2009) national forest inventory. The carbon increment estimates include plots with pre-commercial thinning and single tree removals (firewood cutting) but exclude plots with volunteer final felling or commercial thinning.

The harvest sub-model

The probability of the harvest sub-model has two components, one that predicts the probability of volunteer final felling, and another that predicts the probability of commercial thinning. Both components are modelled using logistic regression. Stands that have suffered an involuntary felling (e.g. storms) are not considered as final felled. The status of a plot is defined as 1 if it has been harvested since the last measurement and 0 otherwise. Hence, the basic form of the model is:

$$P_i = \frac{1}{1 + e^{-\beta X}}$$

where P_i is the probability of the ith plot to be thinned or felled in the next five years, βX is a linear combination of parameters β and explanatory variables X. The candidate explanatory variables considered include: *S*: a set of dummy variables for each species present, *V*: volume in m^3/ha, *D*: distance to road in 100 m, *S*: slope in %, Y_V: time until maturity (years), *SI*: site index at a base age of 40 years, and *R*: region.

Data used are from the last three complete measurements of the Norwegian NFI, that is, 1995–1999, 2000–2004, 2005–2009. Hence the model represents the harvesting practices in Norway during the last 15 years. Details of the model will be made available in Antón-Fernández, C. and Astrup, R. (in prep.).

In general the harvest sub-model predicts high harvest probabilities for plots close to maturity, dominated by spruce, and in flat terrain. On the other hand, the probability of harvest for a low volume birch stand in steep terrain far from a road will be approximately zero. As the forest structure changes over time, the predicted final felling will change – if more forest desirable for harvest (e.g. high volume, close to maturity, close to roads, in easy terrain, and spruce dominated) becomes available, the predicted harvest will increase. Similarly, harvest will decrease if less of the desirable forest types are available.

Uncertainty estimates

Uncertainty for the change estimates were estimated using a Monte Carlo approach, as recommended by the IPCC Good Practice Guidance for LULUCF (IPCC 2003), with 4000 iterations. Several sources of uncertainty and their key dependencies were considered. Model uncertainty associated with the final felling and thinning models, as well as with the volume increment and biomass increment models, was accounted for. Uncertainties stemming from sampling (sampling uncertainty), the soil carbon model (yasso), measurement error on input variables such as tree diameter and error originating from the biomass equations, were not accounted for. Similarly, uncertainty estimates related to Finnmark, small trees or mountain forest were not included.

2.2 The new projections

From historic data, it is expected that the annual harvest will increase slowly due to the age structure in the Norwegian forest, where the areas with mature desirable forest types will increase over the period. Based on this, it is expected that the annual harvest will increase from approximately 10 million m^3 today to around 12 million m^3 in 2020.

Furthermore, the Norwegian governmental strategy for increased bio-energy production and use, and the strategies and means in forest- and agricultural policies provided in a White

Paper on agriculture, forestry and climate change (St. meld. nr. 39 (2008-2009)), adopted by the Norwegian Parliament in 2009, are strategies that will have impact on the determination of future harvest levels. Also new economic means implemented to enhance bio-energy production, wood construction and use and chip production, are expected to have an effect on the future harvest level. We assume that the total effect of the new strategies and means, adopted by December 2009, will be a further increase in mean annual harvest level from 12 million m^3 to 13 million m^3 in 2020. The harvest level is not assumed to increase between 2010 and 2015, as the development of infrastructure is rather slow. The average harvest level from 2010 to 2020 is assumed to be 12 million m^3 per year.

Based on these assumptions, and the estimated near term annual growth in Norwegian forests based on the new sub-models applied, the removals from forest management in 2020 are estimated to 23.2 Mt CO_2-eq.. Figure 2 illustrates the estimated removals from 2010 to 2020, with uncertainties represented by 95 per cent confidence intervals.
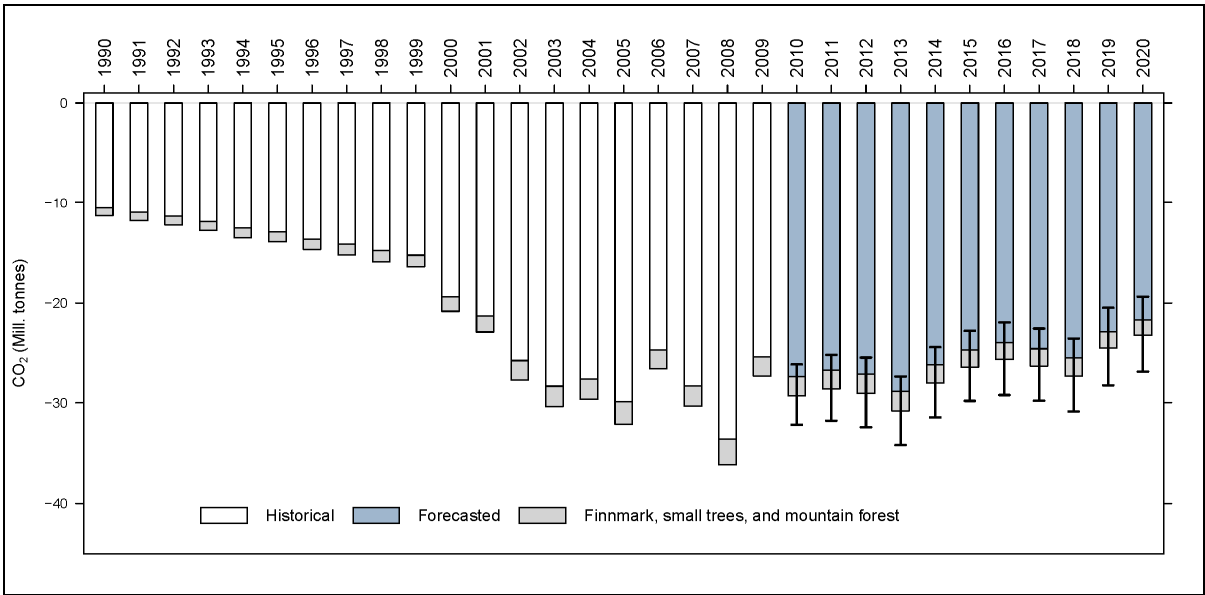

Figure 2, Estimated annual growth in Norwegian forests 2010-2020 with 95% confidence intervals

Table 4 gives the results from the old and new projections for 2010, 2015 and 2020.

Table 4, Projections for forest management – 2010, 2015 and 2020.

	Old projections	New projections
2010	-25.3	-29.2
2015	-21.1	-26.4
2020	-19.2	-23.2

Both the new and the old projections assume a harvest level of 13 million m^3 in 2020. The old projection from September 2009 gave an expected annual removal from forest management of 19.2 million tones of CO_2 per year in 2020 (See table 4). The improved projections give a better description of the probable near term development of annual removals in Norwegian forests. Based on the best knowledge of today, the improved estimate gives a removal from forest management of around 23.2 million tones of CO_2 in 2020. Thus, the new estimated annual removals from forest management are higher than the previously presented

projections. This is due to more realistic assumptions about carbon increment and build-up of dead organic matter and soil carbon up to 2020.

Figure 3 compares the old historical data and projections and the new numbers presented in this submission.

Figure 3. Old data compared with new data.