Norwegian Ministry
of Climate and Environment

National forestry accounting plan for Norway for the first commitment period 2021-2025

21 March 2019

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1 General introduction

1.1 General description of the forest reference level for Norway

The forest reference level (FRL) for Norway for the period 2021-2025 is in average -25.46 million tons CO_2-equivalents per year when including emissions and removals from harvested wood products (HWP) using the first order decay function and default half-lives. When instantaneous oxidation of HWP is assumed, the FRL is -24.08 million tons CO_2-equivalents per year.

See table 1 for information on average annual emissions and removals from the carbon pools included in the FRL for Norway.

Table 1. Average annual emissions and removals from the carbon pools included in the Norwegian forest reference level for the first commitment period 2021-2025

Emissions and removals	2021-2025 (Mt CO_2 eq. yr^{-1})
Living biomass (CO_2)	**-16.878**
Mineral soils, including dead wood and litter (CO_2)	**-7.3084**
Below ground	*0.1389*
Dead wood	*1.2059*
Litter	*5.9637*
Drained organic soils (CO_2, N_2O, CH_4)	**1.0356**
CO_2	*0.6948*
N_2O	*0.2903*
CH_4	*0.0506*
Biomass burning (wildfires) (N2O, CH4)	**0.0014**
N_2O	*0.0008*
CH_4	*0.0005*
N-fertilization (N_2O)	**0.0001**
Harvested wood products (CO_2)	**-1.3810**
Sawn wood	*-0,8374*
Wood based panels	*-0,2922*
Paper and paperboard	*-0,2516*
Total without HWP	**-24.0813**
Total with HWP	**-25.4623**

The forest reference level includes the following carbon pools; living biomass (above and below ground), dead organic matter (dead wood and litter) and mineral soils, drained and undrained organic soils. In addition, the carbon pool of harvested wood products is included. The forest reference level also includes emissions of CH_4 and N_2O from forest fertilization, drained organic soils, and biomass burning (wildfires).

The overall approach used to construct the forest reference level for Norway is in accordance with the LULUCF Regulation and follows the Guidance on developing and reporting Forest Reference Levels in accordance with Regulation (EU) 2018/841. The forest reference level is constructed based on the continuation of the management practices in the Norwegian managed forests, as observed in the reference period 2000 – 2009. The simulation starts from the year 2010.

The definitions, methodologies and data used to calculate the forest reference level are consistent with the methods used to estimate emissions and removals related to the different carbon pools in the national greenhouse gas inventory report (NIR), where the main source of activity data is the National Forest Inventory (NFI).

We have used SiTree, an individual growth simulator, and imputation methods to project the future growth, mortality, ingrowth, and natural regeneration. The emissions and removals of total soil organic C (dead wood, litter, and soil pools) from forest land on mineral soil are estimated using the decomposition model Yasso07. For non-CO_2 sources, we have assumed that the emissions in the period 2021-2025 will be the average of the emissions from the sources in the reference period 2000-2009.

1.2 Consideration to the criteria as set in Annex IV of the LULUCF Regulation

1.2.1 Annex IV section A

Annex IV section A of the LULUCF Regulation defines criteria for determining the Forest Reference Level (FRL). Below we give some considerations to how these criteria are addressed in the construction of the FRL, and where more information could be found, where relevant.

a) The reference level shall be consistent with the goal of achieving a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, including enhancing the potential removals by ageing forest stocks that may otherwise show progressively declining sinks

This criterion encourages the Member States to reflect on the Paris Agreement and the long-term development of the carbon sink, also beyond 2030.

The carbon stocks in living biomass on forest land has historically increased due to planting of trees 60-70 years ago, and active forest management policy in the decades that followed. These trees are now in their most productive age and contribute to the increase in living biomass. At the same time, annual fellings are much lower than the annual increment. Hence, 43 percent of the productive forest area in Norway consist of mature forest. The area harvested the last ten years has been about 0.45 % of the forest area. Therefore, Norway has a skewed age structure with a lot of old forests with declining annual increment. Figure 1 shows the forest area distributed on maturity classes.

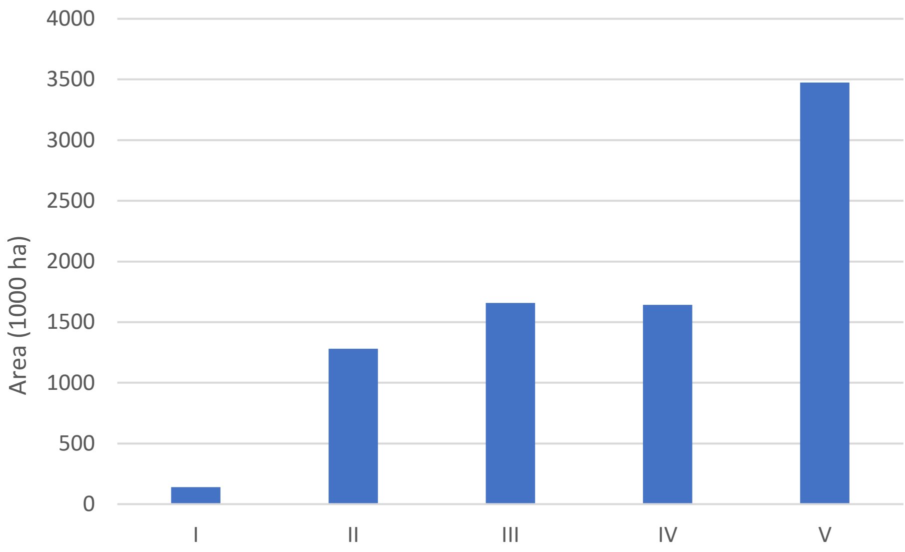

Figure 1. Forest area distributed on maturity classes in hectars. I – Under regeneration; II – Juvenile stands; III – Young production stands; IV – Older production stands; V – Old/mature stands. Source: The Norwegian Institute of Bioeconomy Research.

If we continue the same low harvest intensity as we have had historically, the area of old forest will increase the next decades. The projections indicate that the annual increment in the forest has peaked, and we hence expect that the annual CO_2 removals will be declining in the future. The forest will however continue to be a sink.

To achieve the goal in the Paris agreement of balancing between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, including enhancing the potential removals by ageing forest stocks that would otherwise show progressively declining sinks, the harvest intensity could temporarily be increased to, or to a certain level above, the sustained yield in productive forest, while maintaining eco-system services and biodiversity (i.e. sustainable harvest).

b) The reference level shall ensure that the mere presence of carbon stocks is excluded from accounting

This criterion is in accordance with the Kyoto Protocol Decision 16/CMP.1 (KP 2005), where the same principle was affirmed. It reflects the objective of enhancing the carbon stocks and the net carbon sinks where possible, instead of only preserving existing carbon stocks, since only annual removals will reduce the atmospheric carbon. By using a forward-looking reference level as the basis for accounting, as constructed in accordance with the LULUCF Regulation, there will be incentives to implement new measures to enhance the carbon stocks in the forests, since only removals above the reference level will be accounted for as credits. Existing carbon stocks in the forests will not be accounted for.

c) The reference level should ensure a robust and credible accounting system that ensures that emissions and removals from biomass use are properly accounted for

It is important to have a credible accounting system to ensure that emissions and removals from biomass used are properly accounted for, especially since combustion of wood is excluded for accounting in the energy sector. The Norwegian forest reference level is constructed in accordance with the LULUCF Regulation. Hence, all carbon pools in the forest are included, and all carbon stock changes in the forest carbon pools will be accounted for. The criterion is therefore fulfilled.

d) The reference level shall include the carbon pool of harvested wood products, thereby providing a comparison between assuming instantaneous oxidation and applying the first-order decay function and half-life values

In this document, Norway provides two reference levels, one assuming instantaneous oxidation of the carbon pool of harvested wood products, and one applying the first-order decay function and default half-life values.

The forest reference level for Norway is -25.46 million tons CO_2-equivalents, in which the HWP pool constitute -1.38 million tons CO_2-equivalents. If instantaneous oxidation of HWP was assumed, the FRL would be -24.08 million tons CO_2-equivalents.

e) A constant ratio between solid and energy use of forest biomass as documented in the period from 2000 to 2009 shall be assumed

In the reference period from 2000 to 2009, the ratio between annual harvest and annual data on national consumption and export was calculated for each of the three HWP categories sawn wood, wood based panels and paper and paperboard. The average ratio for each category was then used to calculate the national consumption and export in the commitment period 2021-2025. The rest of the harvested volume is assumed used for energy. Table 2 gives an overview of the annual harvest level in the reference period, and the ratio used for national consumption and export for the three HWP categories. These ratios are held constant when constructing the forest reference level.

Table 2. Annual harvest level in the reference period, and the ratio used for national consumption and export for the three HWP categories.							
Year	**Harvest**	**Sawn wood**		**Wood based panels**		**Paper and paperboard**	
		National	**Export**	**National**	**Export**	**National**	**Export**
	m³	**Ratio**	**Ratio**	**Ratio**	**Ratio**	**Ratio**	**Ratio**
2000	8 757 215	0.185	0.075	0.026	0.046	0.061	0.381
2001	11 221 989	0.149	0.052	0.025	0.030	0.027	0.307
2002	8 758 382	0.183	0.071	0.030	0.034	0.048	0.359
2003	9 208 585	0.177	0.061	0.027	0.032	0.058	0.342
2004	10 010 610	0.175	0.048	0.038	0.031	0.049	0.337
2005	8 995 722	0.209	0.049	0.043	0.033	0.058	0.358
2006	12 349 643	0.155	0.038	0.041	0.018	0.039	0.249
2007	10 106 411	0.199	0.038	0.040	0.028	0.049	0.286
2008	10 049 393	0.180	0.041	0.033	0.025	0.043	0.276
2009	11 621 634	0.122	0.039	0.030	0.019	0.041	0.188
Average	10 107 958	0.173	0.051	0.033	0.029	0.047	0.309

f) The reference level should be consistent with the objective of contributing to the conservation of biodiversity and the sustainable use of natural resources, as set out in the EU forest strategy, Member States' national forest policies, and the EU biodiversity strategy

Biodiversity and forest policy are not covered by the EEA agreement, and the EU Forest Strategy and biodiversity strategy are therefore not implemented by Norway. Norway is, however, following the same principles as set out in these strategies. European countries have, through the ministerial process FOREST EUROPE, developed a framework which defines sustainable forest management. "Sustainable forest management" means the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems. As signatory to FOREST EUROPE, Norway is committed to promote and to apply this framework in national policies.

The central objective of Norway's Forestry Act (2006) is to promote local and national economic development, and to secure biological diversity, considerations for the landscape, outdoor recreation and the cultural values associated with the forest. The Forestry Act also contributes to the conservation of biodiversity and the sustainable use of natural resources.

The Government has a goal to protect 10 % of the forest area. As of January 2019, 4.8 % of the total forest area, including 3.6 % of the productive forest area, has been protected.

No forest harvesting is allowed in areas protected for biodiversity purposes, and hence these areas are kept aside of the construction of the FRL.

For more information on the sustainable forest management practices and the Government's increased focus on environmental concerns, see chapter 2.3.

g) The reference level shall be consistent with the national projections of anthropogenic greenhouse gas emissions by sources and removals by sinks reported under Regulation (EU) No 525/2013

Since Norway is not a Member State of the EU, we are not obligated to report national projections of anthropogenic greenhouse gas emissions by sources and removals by sinks under Regulation (EU) No 525/2013. We have however, on a voluntary basis, reported projections, including on LULUCF, to the European Environment Agency (EEA), in accordance with Regulation (EU) No 525/2013.

The forest reference level is consistent with the reported national projections in the sense that both the forest reference level and the projections reported to the EEA are based on activity data from the National Forest Inventory (NFI) and methodologies used in the national greenhouse gas inventory. Both approaches also include the carbon pools living biomass, dead wood, litter and soil carbon.

h) The reference level shall be consistent with greenhouse gas inventories and relevant historical data and shall be based on transparent, complete, consistent, comparable and accurate information. In particular, the model used to construct the reference level shall be able to reproduce historical data from the National Greenhouse Gas Inventory.

The reference level is based on the same definitions, carbon pools, methodologies and historical data as applied in the national greenhouse gas inventory. It is hence based on transparent, complete, consistent, comparable and accurate information that undergo revision by an expert team according to the guidelines in 24/CP.19. For the same reasons, the model used to construct the reference level can reproduce historical data from the national greenhouse gas inventory.

In chapter 4.2 we demonstrate that the FRL is consistent with the national greenhouse gas inventory.

1.2.2 Annex IV section B

Annex IV section B of the LULUCF Regulation sets out the key elements that the national forestry accounting plan (NFAP) shall contain. Norway has developed the NFAP according to the proposed common table of content, to make sure we document each step of the suggested approach to implement the FRL requirements in line with the LULUCF Regulation.

2 Preamble for the forest reference level

2.1 Carbon pools and greenhouse gases included in the forest reference level

The forest reference level includes the following carbon pools; living biomass (above and below ground), dead organic matter (dead wood and litter) and mineral soils, drained and undrained organic soils. In addition, the carbon pool of harvested wood products is included. Hence, no carbon pools are omitted.

The forest reference level also includes emissions of CH_4 and N_2O from forest fertilization, drained organic soils, and biomass burning (wildfires).

2.2 Demonstration of consistency between the carbon pools included in the forest reference level

The definitions, methodologies and data used to estimate carbon stock changes in the national greenhouse gas inventory are the same as applied in the calculations of the forest reference level.

The main source for activity data is the National Forest Inventory (NFI). The NFI utilizes a 5-year cycle based on re-sampling of permanent plots. The same plots are distributed across the country in order to reduce the periodic variation between years, and each year 1/5 of the plots are inventoried. The current system with permanent plots was put in place between 1986 and 1993, and made fully operational for the cycle covering the years 1994 to 1998.

Below we give a short introduction to the definitions of the included carbon pools and associated methodologies used to estimate carbon stock changes. The methodologies are used both in the national greenhouse gas inventory (for more information, see NIR 2018) (Norwegian Environment Agency 2018) and applied in the calculation of the reference level.

2.2.1 Living biomass

Living biomass is defined as the biomass of living trees with a breast height diameter > 50 mm. For the biomass of all living trees observed on an NFI sample plot with a stem diameter larger than 50 mm at breast height (DBH) the carbon stock change is calculated. Thus, shrubs and non-woody vegetation are not included. Since tree coordinates are measured on NFI plots, each tree can be attributed to a land use category. Single tree allometric regression models developed by Smith et al. (2016; 2014), Marklund (1988), and Petersson and Ståhl (2006) are applied to DBH and height measurements from the NFI for estimating the tree biomass. The aboveground biomass of a tree is the sum of the estimates of the fractions of stem, stump, bark, living branches, and dead branches. The belowground biomass is the estimate of the fraction of stump and roots minus the estimate of the fraction of stump. The stock change method is used to calculate carbon stock changes (CSC) in living biomass. The method used corresponds to Tier 3, which uses a combination of NFI data and models to estimate changes in biomass. See the NIR 2018 for more information on the models used to estimate the biomass of the different tree fractions.

The biomass models are defined for Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), and birch (*Betula pendula and Betula pubescens*). These species constitute approximately 92 % of the standing forest volume (Larsson & Hylen 2007). Other broad-leaved species constitute most of the remaining eight percent. The birch biomass models are applied to all broad-leaved species.

Living biomass is estimated consistently based on the same biomass models from 1990 and onwards.

2.2.2 Dead organic matter (dead wood and litter) and mineral soils

For forest land remaining forest land, the changes in the dead organic matter pool are the changes resulting from the input and decomposition of all dead organic material (woody and non-woody, aboveground and belowground; C input) regardless of size and stage of decomposition. Only the most recalcitrant material (humus) originating from root decomposition is allocated to the soil pool.

The model used to estimate C stock changes in soils provides a change estimate for total soil organic carbon (SOC), which includes the dead wood, litter, and soil pools. This methodology is used for the forest area on mineral soil only. The estimate of total SOC entails all stages of decomposition and all C input elements regardless of size and origin (input aboveground or belowground). The total SOC change estimate was allocated to the dead wood, litter, and soil pools, respectively.

The emissions and removals of total soil organic C (dead wood, litter, and soil pools) from forest land on mineral soil are estimated using the decomposition model Yasso07 (Tuomi et al., 2008; Tuomi et al., 2009; Tuomi et al., 2011a; Tuomi et al., 2011b). This corresponds to Tier 3.

The same model is used from 1990 and onwards.

See Dalsgaard et al. (2016) and the national greenhouse gas inventory for more information on the Yasso07-model and the Norwegian application of the model.

2.2.3 Drained organic soils

On forest land organic soils are defined as having an organic layer deeper than 0.4 m. CO_2, N_2O and CH_4 emissions from drained organic forest soils were included following the methodology of the national greenhouse gas inventory of Norway (NIR 2018).

Norway uses a Tier 1 methodology with default emission factors. We have assumed that the emissions in 2021-2025 will be the average of the emissions from this source in the reference period 2000 - 2009.

2.2.4 Undrained organic soils

Organic soils on forest land, defined as soils with an organic layer deeper that 0.4 m, not subject to drainage are assumed to be in equilibrium. No methods are available for the estimation of the carbon emissions or removals on these areas. The forestry activity in areas with undrained organic soils is relatively low.

The same methodology is used in the national greenhouse gas inventory, see NIR 2018 for further justification. The methodology is used consistently throughout the reporting- and estimating period.

2.2.5 Non-CO_2 sources

Projections of emissions from the greenhouse gas sources N-fertilization and biomass burning (wildfires) were estimated based on the emissions reported in the national greenhouse gas inventory for the activity Forest management under article 3.4 of the Kyoto Protocol.

N_2O emissions from nitrogen mineralization were taken into account, but do not occur as mineral soils act as a sink of carbon. Liming on forest lands do not occur in Norway, therefore the emissions were not estimated. Emissions (CH_4 and N_2O) from biomass burning cover emissions from wildfires. Controlled burnings occur to a very little extent in Norway and is reported as NE in the national greenhouse gas inventory report. Direct and indirect emissions from N fertilization is included.

N-fertilization

The N_2O emissions from N fertilization were included in the reference level. The methodology of the national greenhouse gas inventory was used (NIR 2018). The N_2O-emissions for the years 2021-2025 is assumed to be the average of the emissions from the source in the reference period 2000 - 2009.

Biomass burning - wildfires

CO_2, CH_4 and N_2O emissions from wildfires were included in the reference level. CO_2 is part of the total estimates (reported in CRF as IE). For wildfires the emissions for 2021 to 2025 were estimated as a constant value being the average of the emissions in the reference period 2000 - 2009 (NIR 2018).

2.2.6 Harvested wood products

We present one forest reference level where we assume instantaneous oxidation (Tier 1) and one where we use the first-order decay function and the default half-life values for the three default HWP categories sawn wood, wood-based panels and paper and paperboard, as specified in Annex V of the LULUCF Regulation (Tier 2). We do not include imported harvested products; hence, we use the so called "Production approach". Harvested wood products in solid waste disposal sites and harvested wood products that were harvested for energy purposes are accounted for on the basis of instantaneous oxidation.

This is the same approach and methodology as we use when reporting emissions and removals from harvested wood products in the national greenhouse gas inventory. For more information see NIR 2018.

2.3 Description of the long-term forest strategy

2.3.1 Overall description of the forests and forest management in Norway and the adopted national policies

Norway has an active forest policy, which aims to increase the forest carbon stocks. The forest also represents an important source of renewable energy, and contributes to production of wooden materials that can replace materials with a stronger carbon footprint. The forest as a renewable resource is strengthened through research, value creation, and long term sustainable management of the forest.

As mentioned, the projections indicate that the Norwegian forest capacity as a carbon sink has reached a peak and that annual increment is likely to decline over the next decades unless new measures are implemented. However, the carbon stocks are still increasing in Norwegian forests. The Government has implemented support schemes for regeneration, afforestation, increased seedling density on regeneration sites, enhanced breeding of forest seedlings and fertilization of forest stands to increase the forest sink capacity in the future. Norway has in the latest years increased support for these measures significantly.

Overall description of the forests

Forest land is defined in the National Forest inventory (NFI) as land with tree crown cover > 10%. The trees have to be able to reach a minimum height of 5 meters at maturity in situ. Minimum area and width for forest land considered in the Norwegian inventory is 0.1 hectares (ha) and 4 meters, respectively. The values used in the NFI are in accordance with the range of parameters in the definition from the Global Forest Resources Assessment (FRA) 2005.

Forest land cover 12 million hectares and constitute 37.4 per cent of the land area in Norway. The most important species are Norway spruce (47 per cent), Scots pine (33 per cent) and birch (18 per cent). Forest ownership in Norway is dominated by private ownership with many small properties. Due to the ownership structure and specific terrain conditions, Norwegian forestry is diversified and characterized by small-scale activity.

All forests in Norway are considered managed, either for wood harvesting, protection and protective purposes, recreation, and/or to a greater or lesser extent, hunting and berry picking. On more marginal and less productive land the various management practices may be less intense, but still present.

In 2016, forest land contributed to net removals of 28.8 million CO_2-equivalents. Figure 2 shows emissions and removals of CO_2 on forest land from the carbon pools living biomass, dead wood, litter, mineral soil and organic soil from 1990 to 2016.

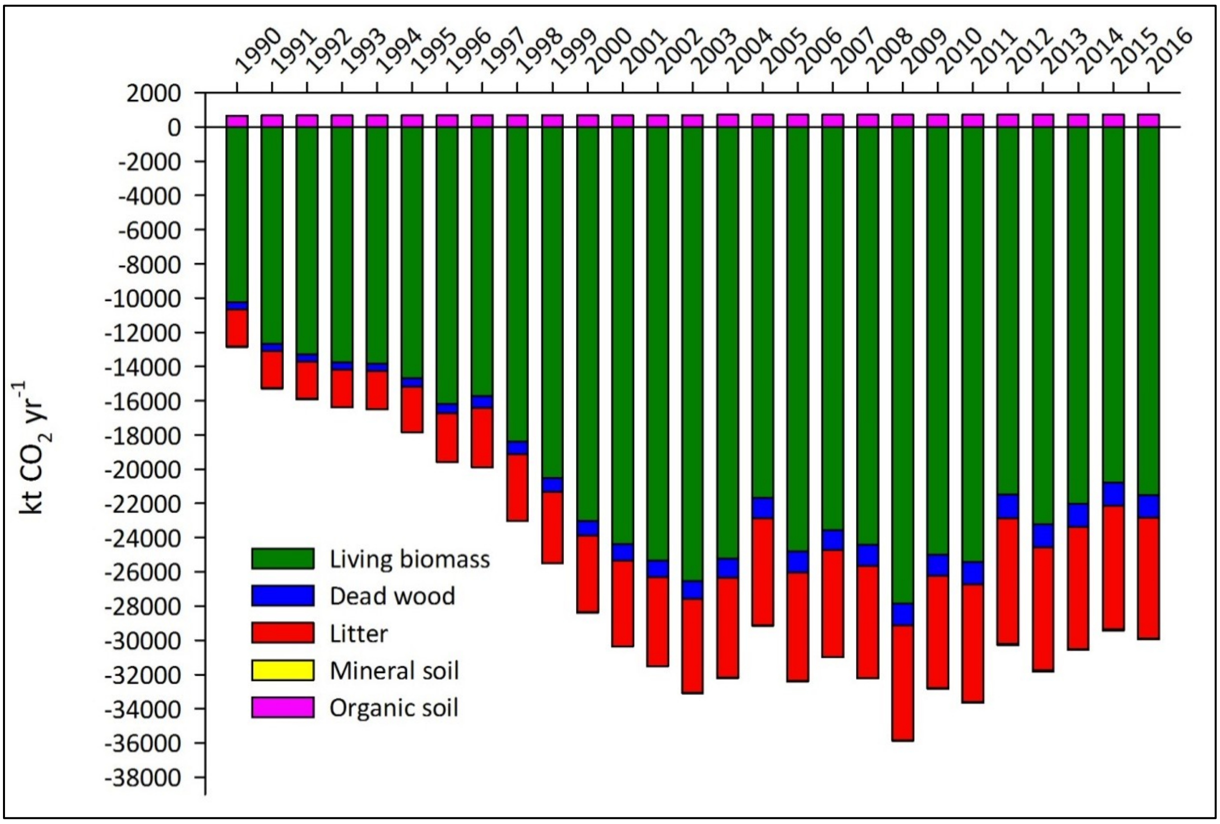

Figure 2. Emissions and removals of CO_2 on forest land from living biomass, dead wood, litter, mineral soil and organic soil from 1990 to 2016. Source: NIR 2018, Norwegian Institute of Bioeconomy Research.

Since 1990, the Norwegian growing stock has increased by around 30 per cent (figure 3). The steady increase in the growing stock is the result of an active forest management policy over the last 60-70 years. The combination of the policy to re-build the country after World War II and the demand for timber, led to a great effort to invest in forest tree planting in new areas, mainly on the west coast of Norway, and replanting after harvest on existing forest land. In the period 1955-1992, more than 60 million trees were planted annually with a peak of more than 100 million planted annually in the 1960s. These trees are now in their most productive age and contribute to the increase in the living biomass, and hence the carbon stock. Furthermore, the annual fellings are much lower than the annual increment, causing an accumulation of available timber resources. The number of planted trees has been decreasing since 1992, with a bottom in 2003 when only 16 million trees was planted. Since then, the number of planted trees has more than doubled, to 38 million trees annually in 2018.

Due to a relatively low harvest rate (approximately 40 per cent of the annual increment) and decreasing number of planted trees since 1992, the Norwegian forest has a very skewed age class structure that will lead to a long term reduction of the Norwegian forest sink. The projections also confirm that the Norwegian forest capacity as a carbon sink has reached a peak and that annual increment is likely to decline over the next century due to aging forests and reduced investments in regeneration during the last decades.

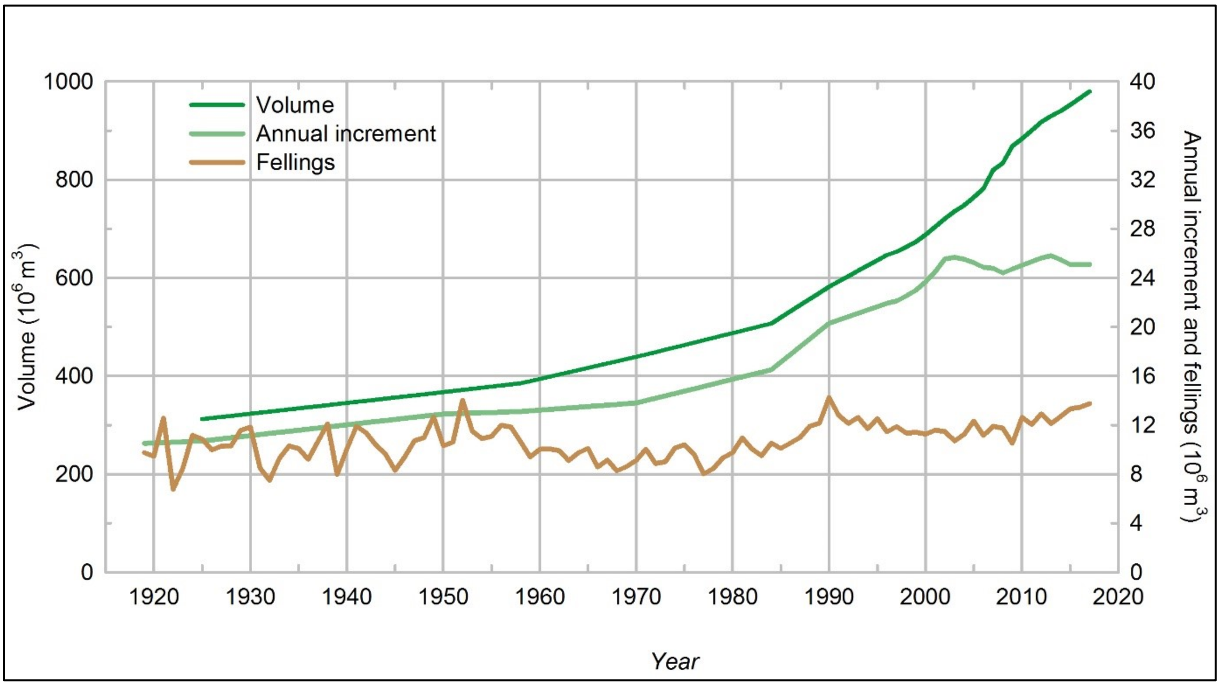

Figure 3. Forest fellings, annual increment and volume, 1919–2016. The 2014 value is the middle year in the National Forest Inventory cycle (2012-2016) for volume (without bark) and annual increment. The values for the two last years are extrapolated. Source: NIR 2018, Norwegian Institute of Bioeconomy Research and Statistics Norway.

Net land use changes in Norway from 1990 to 2016 have been very small. Only the area of settlements has increased slightly, while the other land-use categories have decreased or remained constant. From figure 4, we see that forest land was 37.6 % in 1990 and 37.4 % in 2016. There have been land-use changes from all categories to forest land (afforestation). At the same time there have also been forest land converted to other land uses (deforestation), resulting in a small net decrease in the area of forest land.

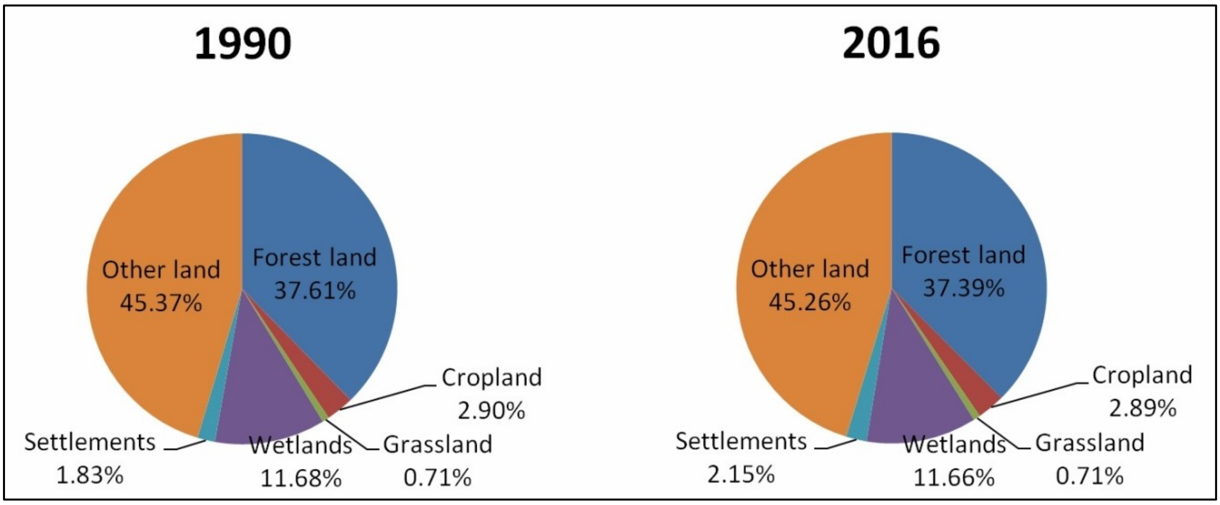

Figure 4. Area distribution of the IPCC land-use categories for 1990 and 2016. Source: NIR 2018, Norwegian Institute of Bioeconomy Research.

Forest management in Norway and the adopted national policies

A wide range of measures, including legislation, taxation, economic support schemes, research, extension services and administrative procedures, support the implementation of forest policy and mitigation actions. The current Forestry Act from 2006 has a main objective to promote sustainable management of forest resources with a view to promote local and national economic development, and to secure biological diversity. The forestry Act also contributes to the conservation of biodiversity and the sustainable use of forest biomass. However, the measures implemented will also influence CO_2 sequestration.

As a part of the climate policy, the Government has introduced measures designed to maintain or increase the carbon stocks in forest and facilitate extended use of biomass as a substitute for fossil energy sources and building materials with a larger greenhouse gas footprint and convert to use of renewable biomass for several industrial processes. Several measures have been initiated with a view to increasing greenhouse gas removals. These measures also encourage commercial activity and help to maintain a good resource base for the forest and wood industry. The Government will further develop and consider whether to strengthen these measures, and will also review and further develop other measures for reducing emissions and increasing removals in the LULUCF sector.

For more information about adopted forest policies in Norway and their estimated effect, see Norway's Seventh National Communication.

2.3.2 Description of future harvesting rates under different policy scenarios

In the reference period from 2000 to 2009, the average total (including top and waste) annual harvest level from managed forests as recorded by the NFI was 10.1 million m^3 (see table 2). In the most recent years we have seen a change in the Norwegian market, including an increasing demand for wood-based products, and the former decreasing trend of timber prices has reversed. This has led to an increased harvest rate the last years. After the reference period, the harvest level has increased to a level reaching 12,5 million m^3 in 2017 (mercahanble timber including deforestation and firewood).

The Norwegian Parliament is aiming to increase harvest and has strengthen the forest industry since the beginning of this century. In the Policy platform the Government also states that it intends to take steps to increase the timber harvest. Increased focus on forestry should be followed by increased environmental considerations, latest expressed by the ***Parliament's treatment of the White Paper to the Storting, Meld St. 6 (2015-2016), on the forest policy***. According to the ***Governments Political platform*** the Government will facilitate increased harvest. The Government set a goal in 2008 to ensure targeted and coordinated policy instruments for increased ***expansion of bioenergy*** *up to 14 TWh by 2020*. ***The Norwegian supply obligation for renewable fuels in road transport*** has increased the use of liquid biofuels strongly in recent years. This will affect the biomass demand and thereby the harvest rates. The Governments pledge to increase the biofuel quota obligation (the required proportion of biofuels in annual sales of road traffic fuels) to 40 per cent in 2030. In the latest National Transport Plan, the Government announced a target of 30 per cent sustainable biofuel in aviation by 2030. The Government is also considering biofuel requirements in shipping and for non-transitory vehicles and machines. These targets correspond to a volume of approximately 10-12 million m^3 timber. The government is concerned about the ILUC-effect of conventional biofuels, and therefore highlights the importance of increasing the production of advanced biofuels. At the same time, biomass demand from processing industries expect to multiply the next decades, according to the industry's own roadmap for low carbon development. In total, this could raise a significant future demand for liquid biofuels and biomass.

The government's bioeconomy policy (2016) includes sustainable, efficient and profitable production, extraction and use of renewable biological resources for food, feed, ingredients, health products, energy, materials, chemicals, paper, textiles and other products. The bioenergy policy has pledged to utilise the potential for increased, profitable and more efficient production, extraction and use of renewable biomass from agriculture, forestry, fisheries and aquaculture within sustainable boundaries.

The government presented a ***National Strategy for Green Competitiveness*** in October 2017. The aim of the strategy is to provide more predictable framework conditions for a green transition in Norway, while maintaining economic growth and creating new jobs. The strategy recognises the mitigation potential associated with increased use of the Norwegian forest resources and points out some prioritized measures like; increased use of wood in the building sector, increased use of chemicals from bio-refineries, use of timber based products as feed for the fish industry, increased use of bio-char, biofuel and bioplastic.

Studies and policy papers (***Climate Cure 2020, White-paper 39, Climate Challenges – Agriculture part of the Solution 2008-2009***) show that an increased harvest rate will reduce removals in the short term (2021-2030), but increase long term (second half of the century) removals due to forest regrowth if new measures are implemented. Renewable timber resources can simultaneously contribute to displacement of fossil emissions and prolonged carbon storage in the pool of harvested wood product. Access to sustainable forest biomass is also an important premise for carbon dioxide removal (CDR) technologies like bio-char and bio-energy with carbon capture and storage (BECCS).

The ***Office of the Auditor General of Norway*** (2016) has reprimanded that the trend of timber harvesting in Norway is not in line with the goals set by the Parliament. However, the Norwegian Government intends to take steps to increase the sustainable timber harvest level, to support national goals for bio economy and emission reductions in other sectors.

The Norwegian forest industry has expressed a target to increase the timber harvest to around 15 mill m^3 in the future (***SKOG 22 – National strategy for the Forest and Wood Industry, January 2015***). The goal set by the industry is based on an analysis from the Norwegian Institute of Bioeconomy Research on available forest resources, confirming that 15 mill m^3 is both environmentally and economically sustainable. The 15 mill m^3 is for industrial purposes and fire wood. Increased sustainable use of residues (slash) is not included and may increase the utilised volumes of biomass in the future.

These reports, strategies and policies are the basis for the Governments decision about taking steps to increase the timber harvest in a sustainable manner and in line with the long-term goals of the Paris agreement.

The increased focus on forestry is followed by ***increased environmental consideration***s. It's currently under consideration what increased environmental considerations implies. The Government has set a goal to protect 10 % of the forest area. By January 2019, 4.8 % of all forest area is protected, including 3.6 % of the productive forest area. It is not decided which further areas that will be protected to achieve the goal. If 10 % of the productive forest area should be protected, there will still be a large and increasing volume available for harvest. The Government will give greater weight to environmental concerns in forestry. The Government will, together with the forest owners organizations, outline appropriate measures for increased safeguarding of key biotopes.

Studies of the long-term sustainable and realistic harvest level in Norway vary between 14-18 million m3 dependent on the expectation of both demand (prices) and how additional environmental protection is implemented. The estimate is based on available mature forest, a continuation of the existing management practices and 10 % protection of the forest area (doubling of the current protected area).

3 Description of the modelling approach

3.1 Description of the general approach as applied for estimating the forest reference level

The overall approach used to construct the forest reference level is in accordance with the LULUCF Regulation and follows the Guidance on developing and reporting Forest Reference Levels in accordance with Regulation (EU) 2018/841. The forest reference level is constructed based on the management practices and - intensities in managed forests in Norway in the reference period 2000 – 2009. The definitions, methodologies and data used to calculate the forest reference level are consistent with the methods used to estimate emissions and removals related to the different carbon pools in the national greenhouse gas inventory, see chapter 2.2.

The main data source of the national greenhouse gas inventory for managed forest is the National Forest Inventory (NFI). The general approach for constructing the forest reference level is to forecast the development and management of the NFI plots and then apply the same methods for estimating emissions of the different pools as in the national greenhouse gas inventory.

The main steps in the modelling approach are:

(1) **Stratification of the managed forest area (see section 3.2.1)**: Norway has a large forested area with a large variation in tree species, topography, accessibility, productivity and cost of forest operations. Consequently, the management practices and intensity vary greatly within the forested area. In general, there is a high management intensity in areas of high productivity dominated by spruce and pine. These areas often have low cost of operations (flat terrain and good road access). Generally, there is a very low management intensity in low productive forests, hardwood forests and areas with poor infrastructure (road network). To account for this general variation in management practices seven strata are defined (see section 3.2.1) and applied to both the reference period and the forecast, ensuring the same area in both the reference period and the forecast.

(2) **Calculation of management intensity in the reference period (see section 3.2.2)**: In Norway, the forest management practices applied varies with the same factors as used in the stratification of the forest area. Highly productive spruce forests are most often clear cut and planted with high density. Lower productivity spruce forest are also clear cut, but are - regenerated with a lower number of trees. Pine forests are naturally regenerated with seed trees, while hardwood forest are naturally regenerated. Hence, five different management practices were defined and their area-based intensity is estimated with data from the reference period (see section 3.2.2).

(3) **Simulating the growth, mortality and ingrowth in the NFI plots (see section 3.3)**: The NFI consists of permanent plots where individual trees are re-measured at five-year time intervals. The key processes that affect the different carbon pools are growth, mortality and ingrowth. In order to forecast the NFI plots, an individual tree model (SiTree) is applied to the NFI plots which results in a data structure that is completely consistent with the data structure in the historic NFI (a table with individual trees and a table with plots variables) which makes it possible to directly use the methods from the national greenhouse gas inventory report to the forecasted data (see section 3.3).

(4) **Implementing management in the simulations:** In the simulations of the NFI plots, the management intensities (section 3.2.2) for the different strata (section 3.2.1) have to be implemented consistently with the management in the reference period. In practice, this implies selecting which plots should be harvested and thinned in each stratum. To do this task, we apply a regression model (see Anton-Fernadez and Astrup, 2012) that ranks the probability of harvest or thinning for all plots. The model (see Antón-Fernádez and Astrup, 2012) was re-fitted to observed harvest and thinning data from the reference period. At each maturity/stratum combination the plots are first ranked according to their probability of harvest. The plots with the highest probability get scheduled for harvest until the target area of the stratum/maturity combination (Table 8) is reached (see section 3.2). The remaining plots, not scheduled for harvest, are then ranked according to their thinning probability. The plots with the highest probability of thinning are scheduled for thinning until the target area for each stratum/maturity combination is met. Details of the implementation can be found in section 3.3.

(5) **Estimating emissions and removals based on the forecasted NFI plots**: Once the simulation is completed, the methods for estimating emissions and removals from the national greenhouse gas inventory (see section 2.2) is applied to the simulated data and the forest reference level is complete.

3.2 Documentation of data sources as applied for estimating the forest reference level

Below we give an overview of the main sources of data used to construct the forest reference level:

- The main source for activity data in the national greenhouse gas inventory is the National Forest Inventory (NFI) which is documented and described in detail in the national greenhouse gas inventory. The NFI utilizes a 5-year cycle based on re-sampling of permanent plots. The same plots are distributed across the country in order to reduce the periodic variation between years, and each year 1/5 of the plots are inventoried. The current system with permanent plots was put in place between 1986 and 1993, and made fully operational for the cycle covering the years 1994 to 1998.
- Climate data: Climate data is used in forecasting both the individual tree development, as well as in modelling of dead organic matter (DOM) and soil organic matter (SOM) with Yasso07. Climate data for the simulations follow the IPCC scenario RCP 4.5 downscaled to a 1 by 1 km grid for Norway. The utilized downscaled climate data is freely available at http://www.senorge.no/aboutSeNorge.html?show=on.
- Harvested Wood Products: For HWP the ratios between the different product categories are calculated based on data from FAOSTAT.

3.2.1 Documentation of stratification of the managed forest land

The managed forest land (MFL) was stratified into seven different strata (Table 3). The stratification of the managed forest land is based on stand species composition, productivity (site index), and harvest cost which can be seen as an integrated measure of terrain and road accessibility. Harvest costs are estimated according to standard approaches in Norway which is described in detail by Granhus et al. (2011). See table 5 for information on the different forest management practices (FMP) applied in the reference period.

Table 3. Stratification of the managed forest into seven strata with associated management practices.								
Stratification of MFL				**% distribution of forest management practices**				
Availability for wood supply	**Main species**	**Site index**	**Cost**	**FMP 1**	**FMP 2**	**FMP 3**	**FMP 4**	**FMP 5**
Not protected	Spruce	>= 17	< 300	100%				
		>= 14 and < 17	< 300		100%			
	Pine	>= 14	< 300			100%		
	Hardwoods	>= 14	< 300				100%	
	All	>= 6 and <12	No limit				100%	
		< 6	No limit				100%	
Protected	All	No limit	No limit					100%

The area in each strata was calculated from the NFI plots in the reference period (Table 4) and the area in each stratum was kept constant throughout the simulations for the forest reference level.

Table 4. Area (kha) in each strata in the reference period.				
Stratification of MFL				**Area (kha)**
Availability for wood supply	**Main species**	**Site index**	**Cost**	
Not protected	Spruce	>= 17	< 300	628
		>= 14 and < 17	< 300	493
	Pine	>= 14	< 300	286
	Hardwoods	>= 14	< 300	572
	Any	>= 6 and <12	Any	6026
		< 6	Any	3665
Protected	Any	Any	Any	416

3.2.2 Documentation of sustainable forest management practices as applied in the estimation of the forest reference level

In high latitude forests, growth rates and forest development is generally slow. This result in long rotation ages. Hence, only a small part of the forest area is treated each year. At the same time, the only management actions that have any significant effect on the stock changes in the period 2010-2030 is the amount of harvest and thinning carried out. Planting and tending intensities will have a large impact in the long run, but will only have minor effects on the short term stock changes. In the reference level, we apply five main forest management practices (FMP) (Table 5).

Table 5. Forest management practices.		
Index	**Name of practice**	**Short description of practice**
FMP1	Spruce intensive	Clear cutting and artificial regeneration with 2500 trees/ha.
FMP2	Spruce	Clear cutting and artificial regeneration with 1500 trees/ha.
FMP3	Pine intensive	Seed tree with natural regeneration.
FMP4	Low intensity	Clear cutting (seed tree for pines) with natural regeneration. For spruce stands planting with 1500 trees/ha.
FMP5	Protected	No management

When thinning, 32 per cent of the above-ground biomass is removed, and in final felling 88 per cent of the above-ground biomass is removed (Table 6). The removal intensities are based on the observed removal intensities in the reference period.

Table 6. Biomass removals in thinning and final felling.					
Forest management practice		**Commercial thinning**		**Final felling**	
Index	**Name of practice**	**Age**	**% biomass removals**	**Age**	**% biomass removals**
FMP1	Spruce intensive	Any	32	Any	88
FMP2	Spruce	Any	32	Any	88
FMP3	Pine intensive	Any	32	Any	88
FMP4	Low intensity	Any	32	Any	88
FMP5	Protected	NA	NA	NA	NA

The forest management practices are applied to the different strata in accordance with table 3. Thinning and final felling are not restricted to a given age-class, as the data in the reference period shows a large variability in the timing of both thinning and final felling.

For calculations of thinning and harvest intensities the forest is divided into mature and immature forests. Given the large variability in site productivity across the Norwegian forested landscape, the actual age at which a forest is mature vary with site productivity, where low productive forest become mature at a much later age than more productive forests. In order to determine whether a forest is mature, we apply the age thresholds outlined in table 7.

Table 7. Age threshold for classifying a forest as mature in the calculation of harvest intensities.		
Species		Site index
Conifers	Hardwoods	
100	60	6
90	50	8
80	50	11
70	50	14
60	40	17
50	30	20
40	20	23
40	20	>23

The harvest and thinning intensities for each of the seven strata for both mature and immature forests were estimated based on the observed intensities in the NFI in the reference period (Table 8). It should be noted that the intensities vary greatly between the strata, which indicates that the strata definitions were successfully set, in order to dividing the managed forest into strata with homogenous management activities. The pattern is clearly that harvest intensities are high in highly productive conifer forest with low operation costs, while the intensity is low for low productive forest, especially for hardwoods.

Table 8. Thinning and harvest intensities in the reference period.							
Stratification of Managed Forest Land (MFL)				% area managed every 5 years			
				Thinning		Final felling	
Availability for wood supply	Main species	Site index	Cost	Immature	Mature	Immature	Mature
Not protected	Spruce	>= 17	< 300	4.90	2.74	0.90	16.34
		>= 14 and < 17	< 300	2.13	1.53	0.55	11.82
	Pine	>= 14	< 300	8.58	6.17	0.98	9.96
	Hardwoods	>= 14	< 300	1.13	1.10	0.24	1.49
	Any	>= 6 and <12	Any	1.64	0.55	0.71	3.53
		< 6	Any	0.00		0.15	
Protected	Any	Any	Any	NA	NA	NA	NA

3.3 Detailed description of the modelling framework as applied in the estimation of the forest reference level

3.3.1 Starting year for the projection of the FRL

The starting point of the projection is 2010. In practice we have used the 2007-2011 NFI plots on managed forest land (forest remaining forest), corresponding to the national greenhouse gas inventory report in 2009.

3.3.2 General description of the modelling framework

SiTree: Individual tree simulator

Growth, mortality and ingrowth occurring in all the NFI plots were simulated individually with SiTree which is a single tree growth simulator. The simulator is a publicly available R package (https://CRAN.R-project.org/package=sitree) and functions for growth, mortality, ingrowth, regeneration, where management is user-defined. All the functions used for the calculation of the FRL are fitted to the trees and plots in the NFI in the reference period. Specifically, the NFI cycle 2000-2004 (corresponding to the national greenhouse gas inventory report in 2002) until 2007-2011 (corresponding to the national greenhouse gas inventory report in 2009) was used to fit the function that were applied in SiTree for the simulation of the forest reference level.

Functions for growth, mortality, ingrowth and natural regeneration

We used imputation methods to estimate growth, mortality, ingrowth, and natural regeneration. Nearest neighbor (nn) imputation algorithms are methods to estimate one or several variables for each tree or plot using values obtained from related cases in the reference database. The reference database is compiled using remeasurements from the NFI in the reference period. For example, to estimate growth, and mortality of a tree (target tree) during the simulation, we look for a similar tree in similar conditions (e.g. competition and social status) in the reference database, once we found the most similar tree in the reference database (reference tree), we assign its growth and live⁄death status to the target tree. In a similar way ingrowth can be imputed at plot level. To estimate ingrowth for a target plot one finds a similar plot in the reference database with similar characteristics (e.g. site index, basal area, and species composition), and assigns the ingrowth of the reference plot to the target plot, that is, the same number of trees, of the same size and species are assigned to the target plot.

Imputation methods have several advantages over traditional parametric regression techniques. Traditional parametric regression techniques need a predefined functional form, while nearest neighbor imputation methods neither do require to specify the structure of the relationship between the target variable and the predictors, nor they require distributional assumptions. Since several variables can be imputed simultaneously for the same individual (tree or plot), the interrelations between them (e.g. DBH and height growth) are maintained for k = 1 (McRoberts 2009). Another advantage of using imputation methods is that predictions are guaranteed to be within the realm of the biologically possible responses and in line with the reference period, in the sense that they have been observed, and that the range of imputed values is potentially as large as in the reference dataset. As a result, the original variability and range is maintained when k = 1.

3.3.3 Growth and mortality (alive/dead/harvested)

To forecast tree growth and mortality we compiled a database (reference database) using data from the NFI in the reference period. This database consists of a set of variables describing the initial condition of the tree and stand and the outcome, growth and status (alive/dead/harvested), after 5 years. Plots that underwent final felling or thinning during those 5 years were discarded from the reference database. Plots that underwent other type of harvest than final felling and thinning were included. Therefore, the status of each tree in the reference database after the 5 years was alive, dead or harvested. Plot measurements from before 2000 were excluded due to concerns about data quality. For example, site index was not measured before year 2000, but estimated by the field crews, therefore there were inconsistencies in the site index before 2000, compared to the newer measurements after 2000. Plots where we were unable to match all trees (5 full plots and 5 partial plots) were also removed from the reference database.

Growth and mortality were forecasted using the reference database with an imputation-based selection, based on the nearest neighbor (1-nn). To find the nearest neighbor for each tree (tree of interest) at each period we calculated the distance between the tree of interest (target tree) and the trees in the reference database of the same species group (spruce, pine, hardwoods). Distance was calculated based on the same variables as the latest published growth and mortality functions for Norway (Bollandsås et al., 2008), which are: site index (SI), initial DBH, latitude, basal area of larger trees, and stand basal area. Once the nearest neighbor tree was found, its growth (basal area increment and volume increment) and status (live/dead/harvested) was imputed to the tree of interest.

For trees in unproductive sites, where SI is missing, we used the probability of the plot being productive as explanatory variable instead of SI. Four imputation models were fitted using the NFI in the reference period, one for spruce trees in productive sites, one for pine trees in productive sites, one for hardwoods in productive sites, and one for trees in unproductive sites.

DBH increment is calculated as the DBH corresponding to the basal area (BA) which results from the initial BA + imputed BA increment for the tree. Height increment is then calculated by solving the volume equations used in the NFI, which calculates volume using DBH and height. The future volume is calculated as current volume + imputed volume increment.

To estimate the DBH, and height growth of dead and harvested trees, where we don't have estimates for DBH increment or volume increment, we have used DBH increment and volume increment from the next alive imputed tree.

3.3.4 Stand age

Stand age is estimated in the NFI as the BA weighted stand age, and it is assessed in a circular plot of 1000 m^2. Since trees are only measured inside the innermost 250 m^2 circular plot, we initially assigned an age to each tree based on its BA, so that the BA weighted stand age corresponded to the NFI estimated BA weighted stand age. During the simulation, stand age is estimated at each time step as the BA weighted stand age of the living trees in the plot. Therefore, if a large tree dies the BA weighted stand age can potentially vary significantly.

While the stand is in the two (out of 5) youngest development classes (forest under regeneration and young forest) stand age is estimated by adding 5 years to the previous stand age. These two youngest development classes have too few trees (if any) to estimate stand age.

When a plot is harvested it is assumed that the harvest occurs in the middle of the remeasurement period (2.5 years). The stand age after harvest is then 2.5 years if the plot has been replanted or 2.5 years – latency time if the plot will be naturally regenerated. Latency time is the time that it takes for the harvested stand to produce enough seedlings to potentially form a stand. Table 9 gives an overview of the latency time for different site indices.

Table 9. Latency (years) for different site indices.		
Site index	**Conifers**	**Hardwoods**
26	0	0
23	0	0
20	0	0
17	0	0
14	5	0
11	5	5
8	15	5

3.3.5 Ingrowth and regeneration

Ingrowth, the trees that during the 5-years period will grow over the 5 cm DBH limit, are imputed using a reference database based on data from the NFI in the reference period. To impute ingrowth at plot level SI for the main species, latitude, stand basal area, number of trees per ha, proportion of spruce, and proportion of hardwoods were used to find the NN plot in the reference period. For unproductive stands, we substituted SI for the probability of the plot to be productive.

3.3.6 Site index

Site indices for the three main groups of species (spruce, pine, and hardwoods) are required at each productive plot. Site index for the main species, and potential site index for the potential main species are currently estimated by the NFI. Initial site index is taken from the 2007-2011 NFI, when available, either from the current site index or from the potential site index. Boosted regression trees (BRT) models fitted to the NFI plots are used to estimate site index for the species groups when the SI for that species group is not available from the NFI. The probability of a plot being productive, which is used instead of SI in unproductive sites, was also estimated using BRT and NFI data.

3.3.7 Climate change

Climate change affects the forest dynamics in the simulation through changes to the site index. Climate data is used in forecasting both the individual tree development, as well as in modelling of DOM and SOM with Yasso07. Climate data for the simulations follow the IPCC scenario RCP 4.5 downscaled to a 1 by 1 km grid for Norway. The utilized downscaled climate data is freely available at http://www.senorge.no/aboutSeNorge.html?show=on. Site index changes due to climate change is projected using a Norwegian climate-sensitive SI model (Antón-Fernández et al., 2016) fitted to the NFI data.

3.3.8 Forest management practice: Harvest and harvest intensity

Removals of biomass from the forest were classified into three types: final felling (clear-cuts, patch clearcuts, clearcut with edge, seed-tree cutting, shelterwood, and selective cutting), thinning (free thinning, and high thinning), and other harvest (e.g. non structured cutting such as firewood cutting, salvage logging of small disturbances, and commercial thinning).

Other harvest does not follow any planned pattern and was therefore implemented through imputation in the same way as natural mortality.

As described in section 3.2.2, final felling and thinning intensities were estimated based on the observed intensities in the reference period. Table 8 *Thinning and harvest intensities in the reference period* defines the % of area that should be managed at each period. Within each strata and maturity group, plots are rank according to the probability of harvest (Antón-Fernández and Astrup, 2012), and final felling/thinning is scheduled for all plots, starting at the ones with highest probability of harvest, until the target harvest intensity is obtained.

3.3.9 How is harvest applied at tree level

At each plot scheduled to be harvested, the amount of biomass to be removed is calculated as the total standing biomass of the plot multiplied by the % of the biomass removals (Table 6). To achieve the target biomass to be removed at each plot the largest trees (smaller trees for thinning) will be scheduled for removal until the target amount of biomass to be harvested is as close as possible to the target.

Dead and harvested trees are assumed to die in the middle of the period (2.5 years from the last measurement).

3.3.10 Assumptions concerning natural disturbances

We assume that natural disturbances will be similar to the ones observed in the reference period. They are included in the simulation approach when using imputation to model growth and mortality.

4 Forest reference level

4.1 Forest reference level and detailed description of the development of the carbon pools

Norway has an age-class structure where large portions of the forest is in an intensively managed state (highly productive spruce forests) becoming mature in the next decades. As a result, the annual carbon removals are expected to decrease (Figure 5). In addition, the harvest level is expected to increase given the harvest intensity from the reference period (Figure 6).

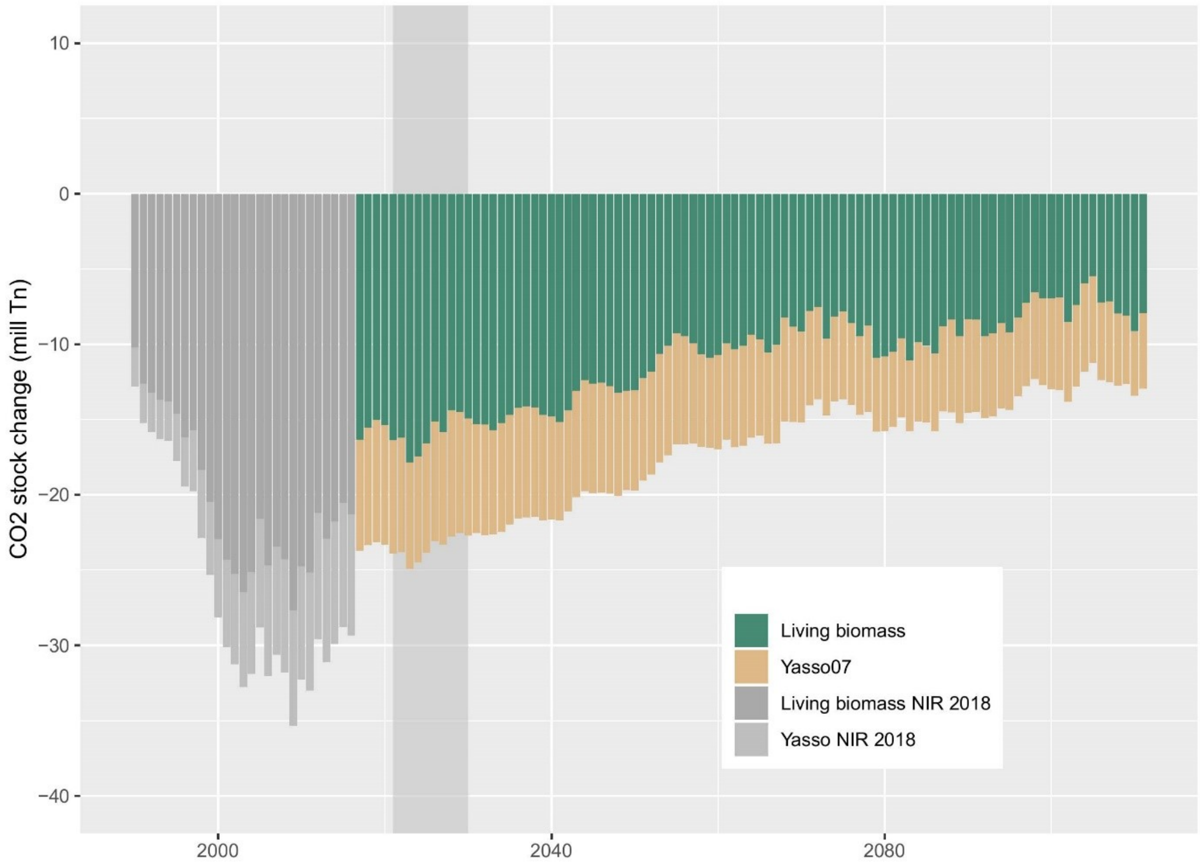

Figure 5. Development in carbon stock changes (in million tonnes CO_2) in living biomass (green) and in mineral soils, dead wood and litter as modelled with Yasso07 (yellow).

However, the managed forests in Norway are still expected to have an increasing standing volume (Figure 6) and to be a significant carbon sink (Figure 5) in the next century even with a higher harvest level than today and an ageing forest composition.

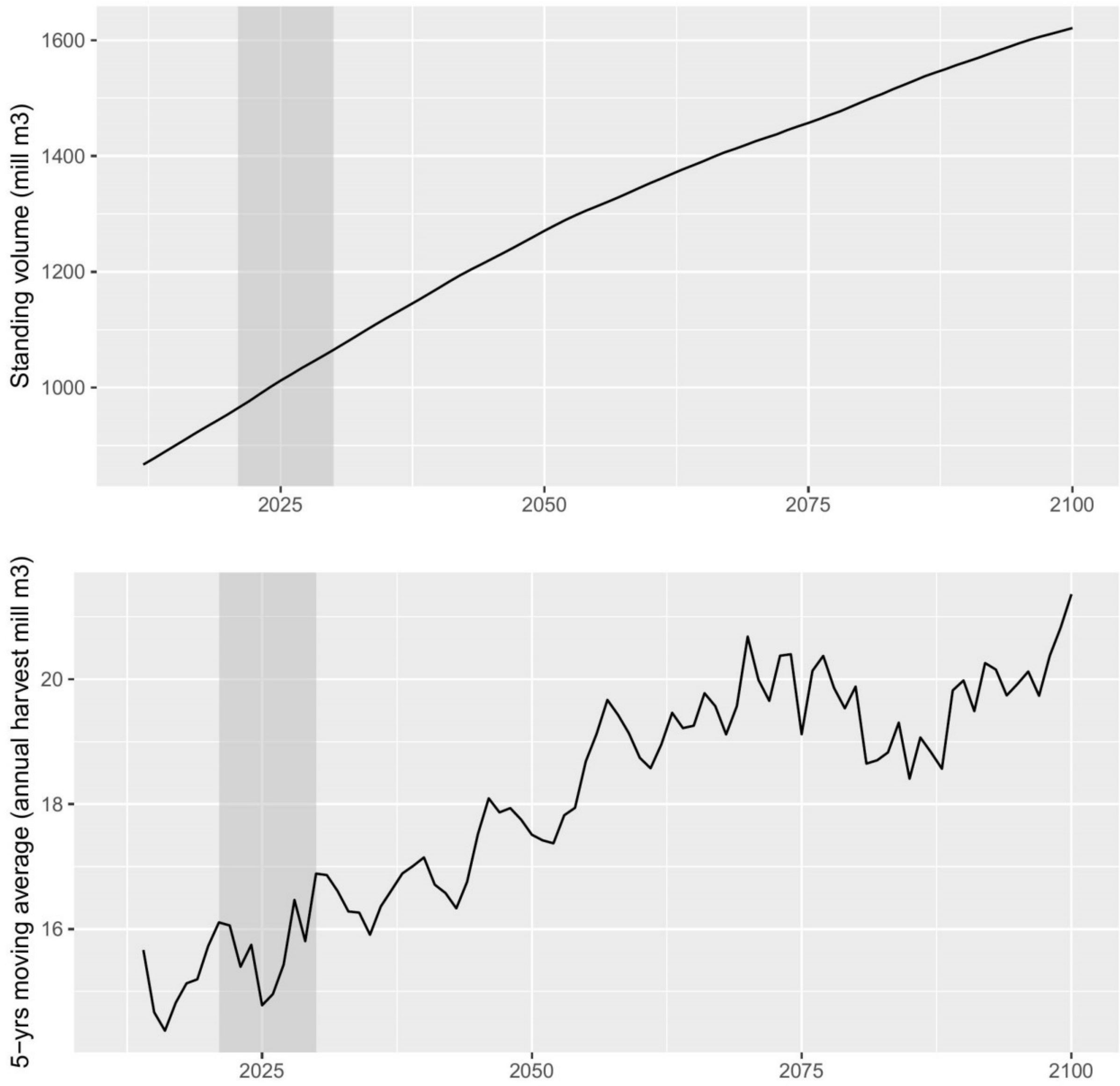

Figure 6. Projected development in standing volume and harvest rates.

Given that the harvest level increases, harvested wood products will also act as a sink in the future (Figure 7). At an annual timestep, the HWP pools show large variability due to the variability in the annual predicted harvest level (Figure 6).

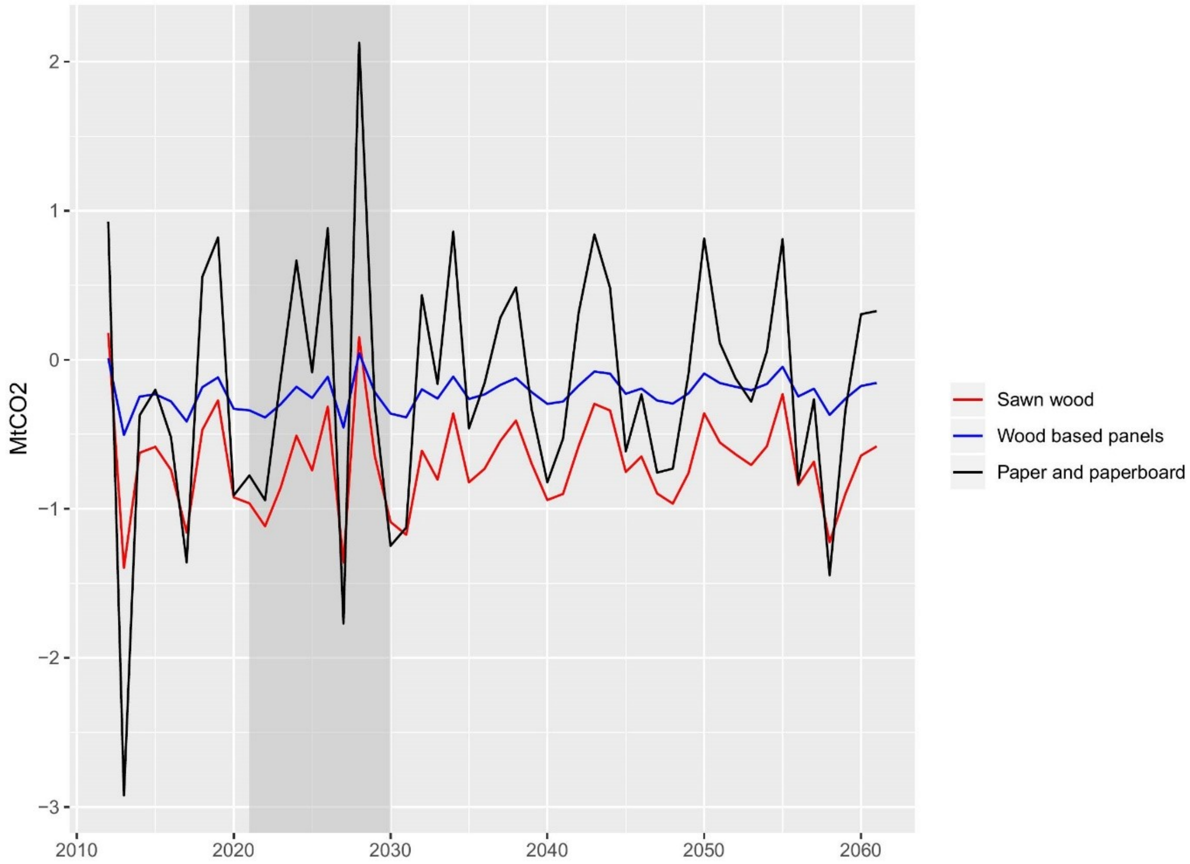

Figure 7. Annual change in HWP categories.

4.2 Consistency between the forest reference level and the latest national greenhouse gas inventory report

We verified the consistency between the FRL and the latest national inventory report (NIR 2018) by comparing the sum of the simulation's output against the sum of the time-series of historical data (Table 10). We verified the consistency of the living biomass stock change (Table 11), the biomass gains (Table 12), the biomass losses (Table 13) and the change in dead organic matter and soil organic matter (Table 14). We also verified their trends (Figures 8, 9, and 10).

The difference between the sum of the simulation's output and the sum of the NIR 2018 (Table 10) is for all carbon pools well within one standard deviation. We use the standard deviation of the different pools to indicate the magnitude of the interannual variability. For living biomass change the standard deviation is 1.62 for the simulation's output, and 2.06 for the NIR 2018, for gains in living biomass the standard deviation is 0.93 for the simulation's output, and 0.72 for the NIR 2018, for losses in living biomass the standard deviation is 1.94 for the simulation's output and 2.04 for the NIR 2018, and for the Yasso07 output the standard deviation is 0.88 for the simulation's output, and 0.81 for the NIR 2018.

Table 10. Comparison of the sum of the living biomass stock change, the biomass gains, the biomass losses, and the stock change in dead organic matter and soil organic matter (Yasso07) in NIR 2018 and the simulation of the forest reference level (Mt CO2) for the period 2001-2016				
	NIR 2018	**FRL**	**Difference**	**Standard deviation**
Living biomass stock change	380.42	381.28	0.86	8.24
Living biomass gains	770.91	773.45	2.58	2.90
Living biomass losses	-390.48	-392.16	-1.71	8.14
Dead organic matter and soil organic matter stock change	118.21	116.63	1.58	3.23

Table 11. Comparison of living biomass stock change (Mgt CO2) in NIR 2018 and the simulation of the forest reference level				
Year	**NIR 2018**	**FRL**	**Difference**	**%difference**
2001	24.3	23.86	-0.44	-1.81
2002	25.24	24.29	-0.96	-3.80
2003	26.45	25.53	-0.93	-3.52
2004	25.14	24.23	-0.90	-3.58
2005	21.59	20.75	-0.84	-3.89
2006	24.7	24.83	0.13	0.53
2007	23.45	23.75	0.30	1.28
2008	24.28	24.26	-0.01	-0.04
2009	27.67	27.5	-0.17	-0.61
2010	24.77	24.49	-0.28	-1.13
2011	25.14	24.78	-0.36	-1.43
2012	21.19	22.04	0.86	4.06
2013	22.91	23.91	1.00	4.36
2014	21.76	22.87	1.10	5.06
2015	20.54	21.71	1.17	5.70
2016	21.29	22.48	1.19	5.59

Table 12. Comparison of living biomass gains (Mt CO2) in NIR 2018 and the simulation of the forest reference level				
Year	**NIR 2018**	**FRL**	**Difference**	**%Difference**
2001	46.46	46.06	-0.4	-0.86
2002	47.56	46.79	-0.77	-1.62
2003	48.12	47.46	-0.66	-1.37
2004	48.41	48.06	-0.34	-0.70
2005	47.85	47.71	-0.14	-0.29
2006	47.57	48.01	0.44	0.92
2007	47.83	48.55	0.73	1.53
2008	48.43	48.68	0.25	0.52
2009	48.95	48.75	-0.19	-0.39
2010	49.39	49.01	-0.37	-0.75
2011	49.33	49.06	-0.27	-0.55
2012	48.68	49.19	0.51	1.05
2013	48.38	49.13	0.75	1.55
2014	48.12	49.09	0.97	2.02
2015	47.90	48.96	1.06	2.21
2016	47.93	48.94	1.01	2.11

Table 13. Comparison of living biomass losses (Mt CO2) in NIR 2018 and the simulation of the forest reference level				
Year	**NIR 2018**	**FRL**	**Difference**	**%Difference**
2001	-22.16	-22.21	-0.05	0.23
2002	-22.32	-22.5	-0.18	0.81
2003	-21.66	-21.93	-0.27	1.25
2004	-23.27	-23.83	-0.56	2.41
2005	-26.27	-26.96	-0.7	2.66
2006	-22.87	-23.18	-0.32	1.40
2007	-24.38	-24.81	-0.43	1.76
2008	-24.15	-24.42	-0.26	1.08
2009	-21.27	-21.25	0.02	-0.09

2010	-24.62	-24.52	0.10	-0.41
2011	-24.19	-24.27	-0.08	0.33
2012	-27.49	-27.14	0.35	-1.27
2013	-25.47	-25.22	0.25	-0.98
2014	-26.36	-26.22	0.13	-0.49
2015	-27.36	-27.25	0.11	-0.40
2016	-26.64	-26.45	0.18	-0.68

Table 14. Comparison of dead organic matter (DOM) and soil organic matter (SOM) with Yasso07 (Mt CO2) in NIR 2018 and the simulation of the forest reference level

Year	NIR 2018	FRL	Difference	%Difference
2001	5.82	5.73	-0.09	-1.55
2002	6.00	5.87	-0.13	-2.17
2003	6.33	6.24	-0.09	-1.42
2004	6.74	6.58	-0.16	-2.37
2005	7.23	7.08	-0.15	-2.07
2006	7.34	7.32	-0.02	-0.27
2007	7.16	7.01	-0.15	-2.09
2008	7.50	7.17	-0.33	-4.40
2009	7.69	7.33	-0.36	-4.68
2010	7.49	7.16	-0.33	-4.41
2011	7.87	7.60	-0.27	-3.43
2012	8.40	8.43	0.03	0.36
2013	8.23	8.35	0.12	1.46
2014	8.13	8.27	0.14	1.72
2015	8.24	8.36	0.12	1.46
2016	8.04	8.13	0.09	1.12

The trends of the different pools are closely following the trends, highs, and lows of the NIR 2018 (Figure 8, 9, and 10). The differences, when present, are relatively small with absolute differences ranging from -1.71 (living biomass losses) to 1.19 (living biomass stock change) Mt CO_2, and relative differences from -4.68% (Yasso07) to 5.70% (living biomass stock change).

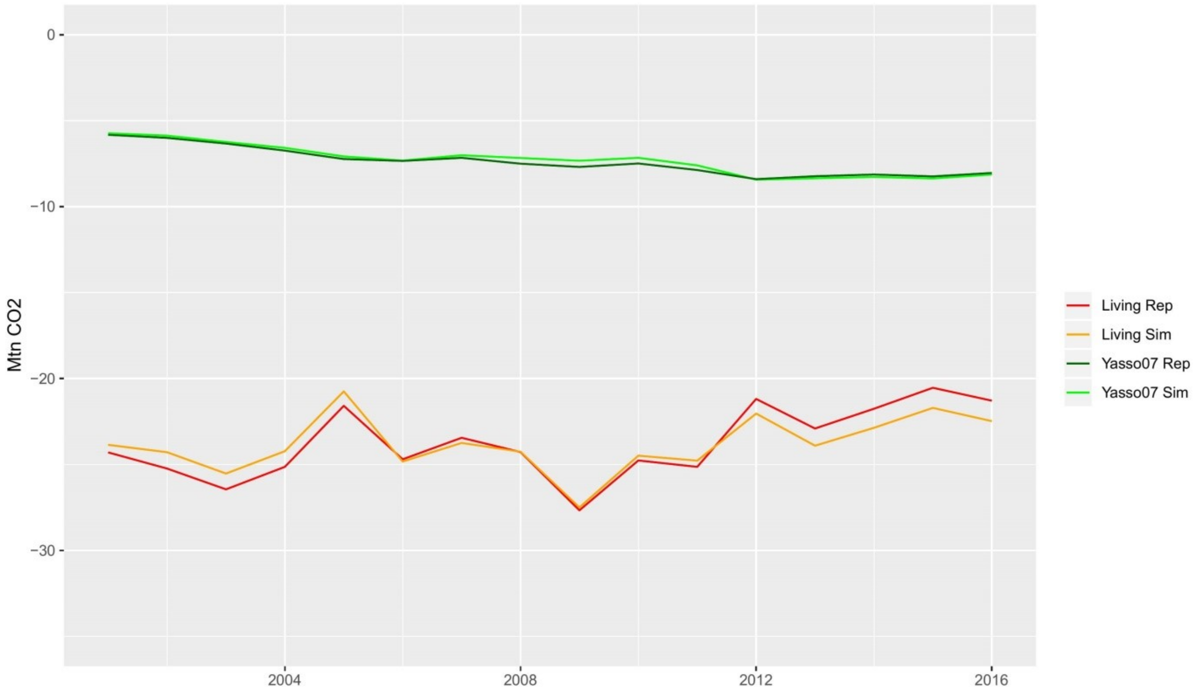

Figure 8. Development of the level and trend for living biomass in the NIR 2018 (Living Rep), and simulation output (Living Sim), and for Yasso07 outputs in the NIR 2018 (Yasso07 Rep) and simulation output (Yasso07 Sim).

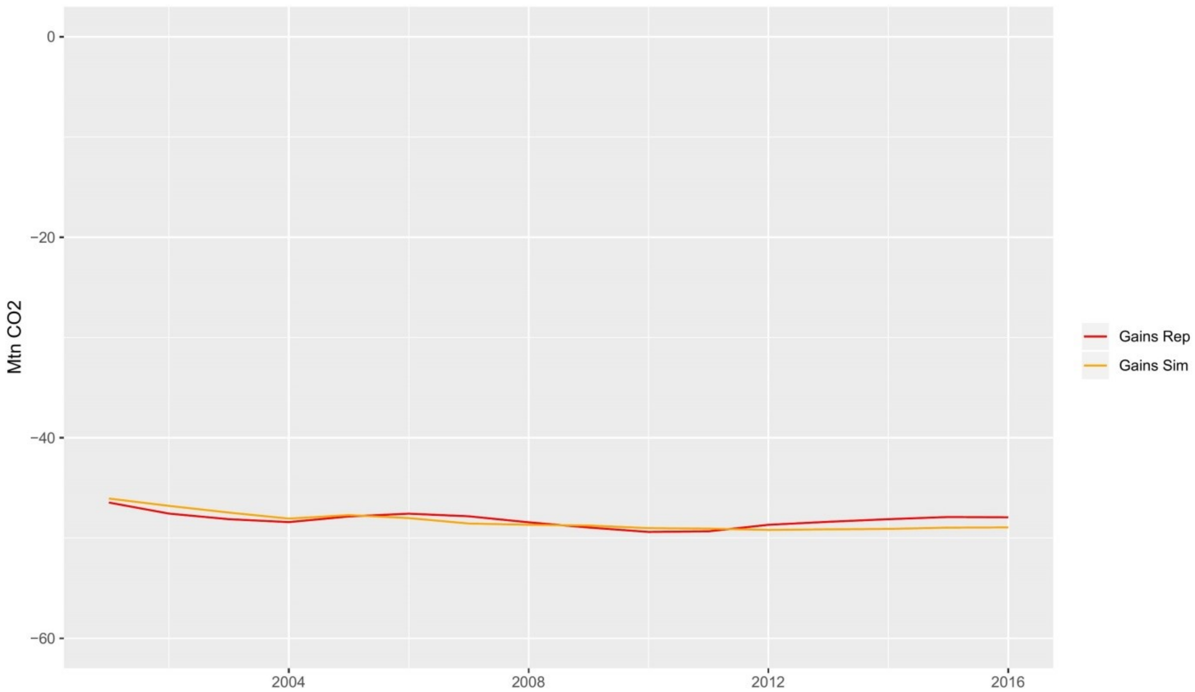

Figure 9. Development of the level and trend for gains in living biomass in the NIR 2018 (Gains Rep), and simulation output (Gains Sim).

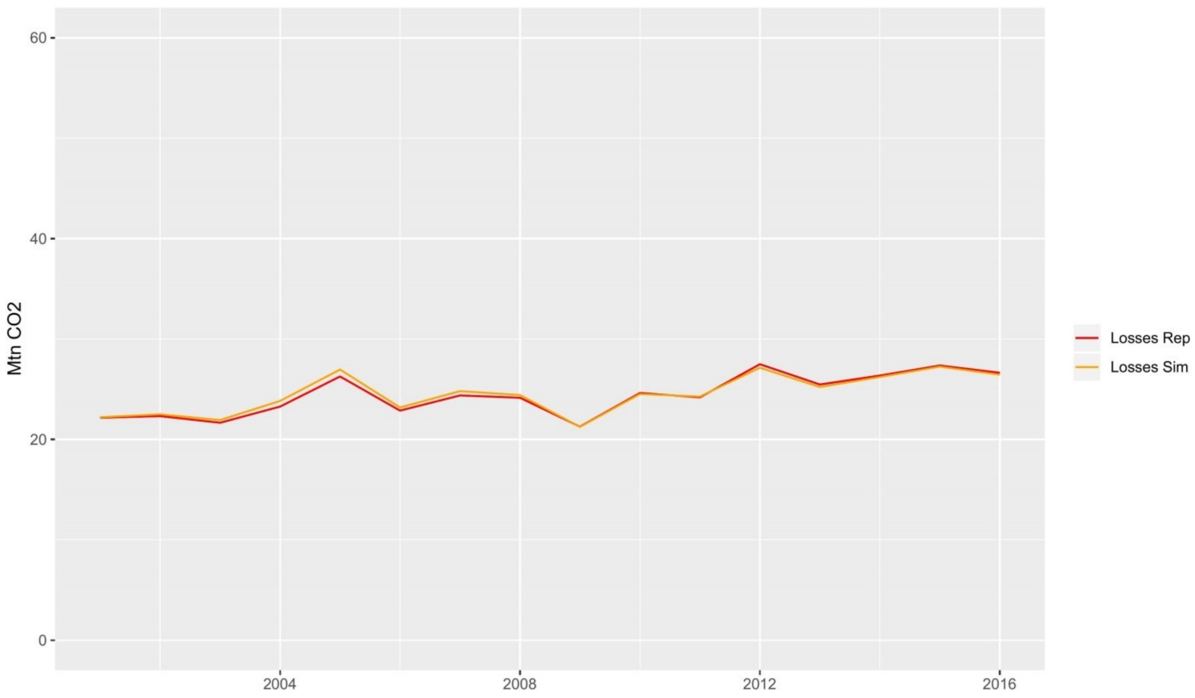

Figure 10. Development of the level and trend for losses in living biomass in the NIR 2018 (Losses Rep), and simulation output (Losses Sim).

4.3 Calculated carbon pools and greenhouse gases for the forest reference level

Based on the simulations of the forest development and application of the carbon estimation approaches applied in the national inventory report, the reference level for the first commitment period can be summarized as illustrated in Table 15.

Table 15. Average annual emissions and removals from the carbon pools included in the Norwegian forest reference level for the first commitment period 2021-2025

Emissions and removals	2021-2025 (Mt CO_2 eq. yr^{-1})
Living biomass (CO_2)	**-16.878**
Mineral soils, including dead wood and litter (CO_2)	**-7.3084**
Below ground	*0.1389*
Dead wood	*1.2059*
Litter	*5.9637*
Drained organic soils (CO_2, N_2O, CH_4)	**1.0356**
CO_2	*0.6948*
N_2O	*0.2903*
CH_4	*0.0506*
Biomass burning (wildfires) (N2O, CH4)	**0.0014**
N_2O	*0.0008*
CH_4	*0.0005*
N-fertilization (N_2O)	**0.0001**
Harvested wood products (CO_2)	**-1.3810**
Sawn wood	

Wood based panels *Paper and paperboard*	*-0,8374* *-0,2922* *-0,2516*
Total without HWP	**-24.0813**
Total with HWP	**-25.4623**

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