



REPORT

M-418 | 2015

# Climate mitigation measures and emission trajectories up to 2030

## Summary



# COLOPHON

---

## Executive institution

Norwegian Environment Agency

## Project manager for the contractor

Norwegian Environment Agency

## Contact person in the Norwegian Environment Agency

Are Lindegaard / Birgitte Laird

## M-no

418

## Year

2015

## Pages

15

## Contract number

## Publisher

Norwegian Environment Agency

## The project is funded by

## Author(s)

Andreas Andersen, Torgrim Asphjell, Kenneth Birkeli, Ketil Flugsrud, Helene Frigstad, Henrik Gade, Eilev Gjerard, Vilde Haarsaker, Hege Haugland, Britta Maria Hoem, Nina Holmengen, Katja Ekroll Jahren, Isabella Kasin, Kristin Madsen Klokkeide, Hans Kolshus, Maria Malene Kvalevåg, Birgitte Laird, Are Lindegaard, Christine Maass, Henrik Norgaard, Tone Sejnæs Pettersen, Catrin Robertsen, Reidun Marie Romundstad, Sissel Sandgrind, Odd Kristian Selboe, Svein Grotli Skogen, Vigdis Vestreng, Fredrik Weidemann, Elin Økstad.

## Title - Norwegian and English

Klimatiltak og utslippsbaner mot 2030. Sammendrag  
Climate mitigation measures and emission trajectories up to 2030. Summary

## Summary - sammendrag

This is the English summary of the third report from the project on a low-carbon transition in Norway, submitted by the Norwegian Environment Agency to the Ministry of Climate and Environment. The report presents new figures for historical emissions and projections based on updated values for global warming potential (GWP) and new emission projections. It reviews measures that could be implemented by 2030 and the emission reduction effect of three different mitigation packages, split between the ETS and non-ETS sectors. The main report presents 84 measures, with emission reduction potentials and rough cost levels. Co-benefits are also described as far as possible, and possible consequences of the measures for the energy sector are assessed.

## 4 emneord

2030-mål, tiltaksanalyse, klimagassutslipp, lavutslippssamfunn

## 4 subject words

2030 target, mitigation analysis, greenhouse gas emissions, low-carbon society

## Front page photo

iStockphoto © Maica

# Summary

## Background

This report describes the Norwegian Environment Agency's assessment of the potential for reducing Norway's greenhouse gas emissions up to 2030. The report presents three different mitigation packages illustrating possible combinations of measures. The results of implementing the mitigation packages are presented as three emission trajectories for Norway's emissions in the period up to 2030. In addition, separate trajectories are presented for emissions from sectors that are covered by the EU emissions trading system (the ETS sectors) and for the non-ETS sectors. The full report also includes a section presenting each of the measures included in the analysis, with a description of the measure, an estimate of its emission reduction potential in 2030, and an assessment of how it could be phased in and its cost and feasibility.

This report completes the third phase of a project the Norwegian Environment Agency was commissioned to carry out by the Ministry of Climate and Environment. The first phase was completed with the submission of the Environment Agency's report *Faglig grunnlag for videreutvikling av den nasjonale og internasjonale klimapolitikken* (report number M-133), an analysis of Norway's 2020 targets and mitigation options. The report on the second phase of the project, *Knowledge base for low-carbon transition in Norway*, was published in October 2014. The Ministry updated the mandate for the project in a letter of 27 May 2015, which asked the Environment Agency to focus mainly on the following in the present report:

- Updated mitigation analyses based on new knowledge obtained since the previous report;
- New figures for historical emissions and projections based on updated values for global warming potential (GWP), new emission projections split between the ETS and non-ETS sectors, and the emission reduction effect of the different mitigation packages split between the ETS and non-ETS sectors;
- A description of the effects of the mitigation measures on other pollutants (SO<sub>2</sub>, NO<sub>x</sub>, particulate matter, etc) and of other co-benefits to the extent possible.

Norway submitted its intended nationally determined contribution (INDC) for 2030 to the UN Climate Change Convention on 27 March 2015, on the basis of the white paper *New emission commitment for Norway for 2030 - towards collective delivery with the EU* (Meld. St. 13 (2014-2015)), which was approved by the Storting in Recommendation 211 S (2014-2015). Norway will conditionally undertake a commitment to reduce its emissions by at least 40 % by 2030 compared with the 1990 level. Norway will enter into a dialogue on collective delivery of its climate commitment together with the EU. If it is not possible to achieve collective delivery with the EU, the target of reducing emissions by at least 40 % compared with 1990 will be Norway's INDC. This target is conditional on the availability of flexible mechanisms under the new climate agreement and on Norway being credited for participation in the EU ETS so that this counts towards fulfilment of the commitment.

At the Council meeting on 23-24 October 2014, EU heads of state and government adopted the new 2030 framework for climate and energy. This includes the target of cutting greenhouse gas emissions by at least 40 % compared to 1990 levels. If Norway and the EU agree on collective delivery, this will entail different approaches for the ETS and non-ETS sectors. The Norwegian ETS sector is integrated into the EU ETS, in which an annual reduction of the cap on emissions will

ensure that overall emissions from all installations in Europe included in the EU ETS are 43 % lower in 2030 than they were in 2005.

Each EU country will be assigned a national emission reduction target for the non-ETS sectors, and these will be set so that the overall target of reducing emissions in non-ETS sectors by 30 % by 2030 compared with 2005 is achieved. Each country's national target will be between 0 % and 40 %.

Targets will be set on the basis of each country's per capita GDP, relatively adjusted to reflect cost-effectiveness in a fair and balanced manner. There will be some flexibility within the EU system for non-EU sectors, making it possible to achieve some of the cuts through the purchase of EU emission allowances or the implementation of measures in other EU countries.

### Updated historical emissions and baseline projections

The Intergovernmental Panel on Climate Change (IPCC) has published revised reporting guidelines on annual greenhouse gas inventories (IPCC, 2013) and on national greenhouse gas inventories (IPCC, 2006). According to these, all Annex I countries<sup>1</sup> are required to revise their greenhouse gas inventories accordingly from the 2015 reports onwards. The guidelines have been updated to take into account new knowledge about the sources of greenhouse gas emissions and the global warming potential of the different greenhouse gases.

The change with the greatest implications for Norway's emission inventory is the updating of values for global warming potentials (GWP). The GWP value for methane (CH<sub>4</sub>) was adjusted upwards by 19 %, while those for nitrous oxide (N<sub>2</sub>O) and SF<sub>6</sub> were reduced by 3.9 % and 4.6 % respectively.

Norway's greenhouse gas emissions in 2013 have been recalculated, and the estimate with these adjustments is 53.7 million tonnes CO<sub>2</sub> equivalents (CO<sub>2</sub>-eq). This is almost one million tonnes higher than the preliminary emission figures for 2013 published in May 2014, when Norway's emissions were calculated to be 52.8 million tonnes CO<sub>2</sub>-eq.

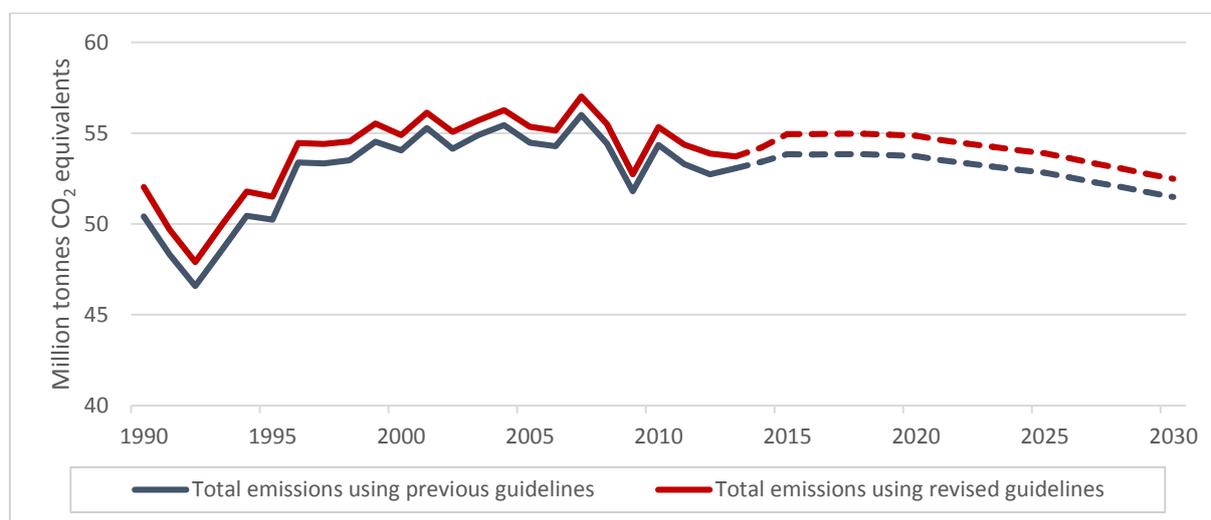


Figure 1 Projections of Norway's greenhouse gas emissions in the 2015 budget and adjusted projections using the revised guidelines. Source: Statistics Norway, Ministry of Finance, Norwegian Environment Agency

<sup>1</sup> Developed countries with specific obligations under the Climate Change Convention are listed in Annex I and Annex II to the Convention.

The projections used in the present analysis have been adjusted accordingly, and using these projections, emissions are expected to total 54.9 and 52.5 million tonnes CO<sub>2</sub>-eq in 2020 and 2030 respectively. Thus, the overall effect of the change in methodology is to increase the projections of emissions in 2020 and 2030 by roughly 1.1 million and 1 million tonnes CO<sub>2</sub>-eq respectively from the figures published in the 2015 budget. These projections are estimates of the future level of emissions if no new measures and instruments are introduced.

The figure below shows Norway's emissions (both historical figures and projections) split between the ETS and non-ETS sectors:

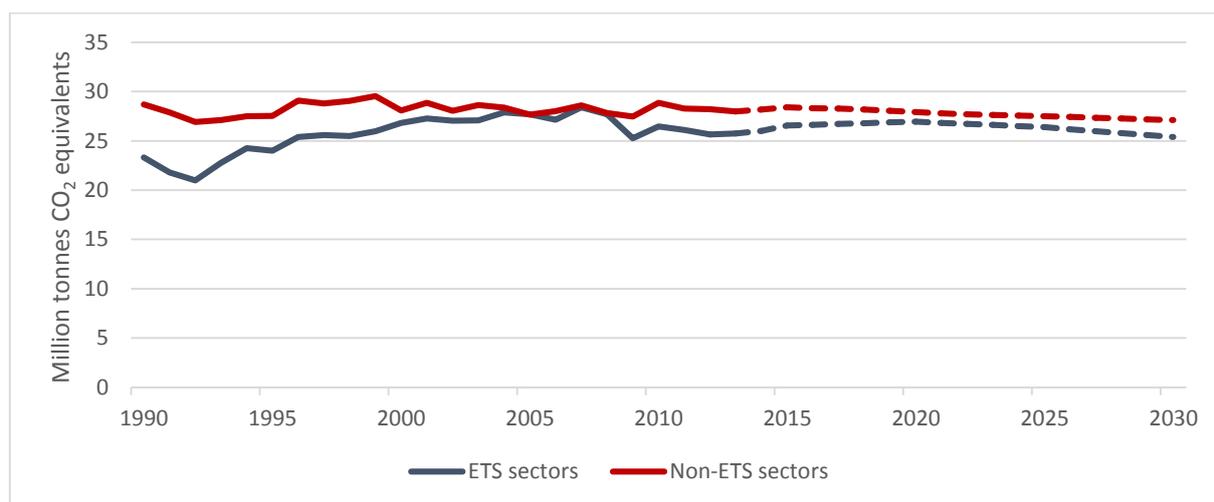


Figure 2 Norway's greenhouse gas emissions split between the ETS sectors (including emissions from domestic aviation that are included in the ETS) and non-ETS sectors, using the current rules for inclusion in the ETS. Source: Norwegian Environment Agency

### Mitigation packages

The measures reviewed here have been organised in mitigation packages, in the same way as in the previous report. The packages were put together using the following general rules:

Mitigation package 1 includes measures with an estimated cost of less than NOK 500 per tonne CO<sub>2</sub>-eq and that are in the high feasibility category. In addition, it is assumed that policy targets and measures that have already been adopted but are not yet included in the baseline projections will be implemented as part of mitigation package 1.

Mitigation package 2 also includes measures with an estimated cost of up to NOK 1500 per tonne CO<sub>2</sub>-eq and that are considered to be in the high or medium feasibility category.

Mitigation package 3 includes all the measures quantified in this report, including those with an estimated cost of more than NOK 1500 per tonne CO<sub>2</sub>-eq and that are considered to be in the low feasibility category.

When the mitigation packages were put together, the estimated emission reductions were adjusted for overlap between the effects of different measures. For example, the emission reductions achieved by a transition to electric and hydrogen vehicles will be reduced if other measures are introduced simultaneously to reduce the traffic volume. It should be noted that the mitigation packages are not intended as recommendations, but as an illustration of how measures can be combined.

### Emission trajectories up to 2030

Figure 3 shows emission trajectories based on implementation of the measures included in mitigation packages 1, 2 and 3. The emission reduction potentials of the three mitigation packages exclude measures involving supplying power from shore to installations on the Norwegian continental shelf, which were included in the previous analysis. This is further discussed in the section on the petroleum sector.

The right-hand axis shows the percentage reduction in emissions from 1990, which is the reference year for Norway's INDC. The solid grey line represents historical emissions, and the dotted grey line shows baseline projections. In this scenario, it is estimated that emissions will total 52.5 million tonnes CO<sub>2</sub>-eq in 2030, which corresponds to a rise of 1 % from the 1990 level.

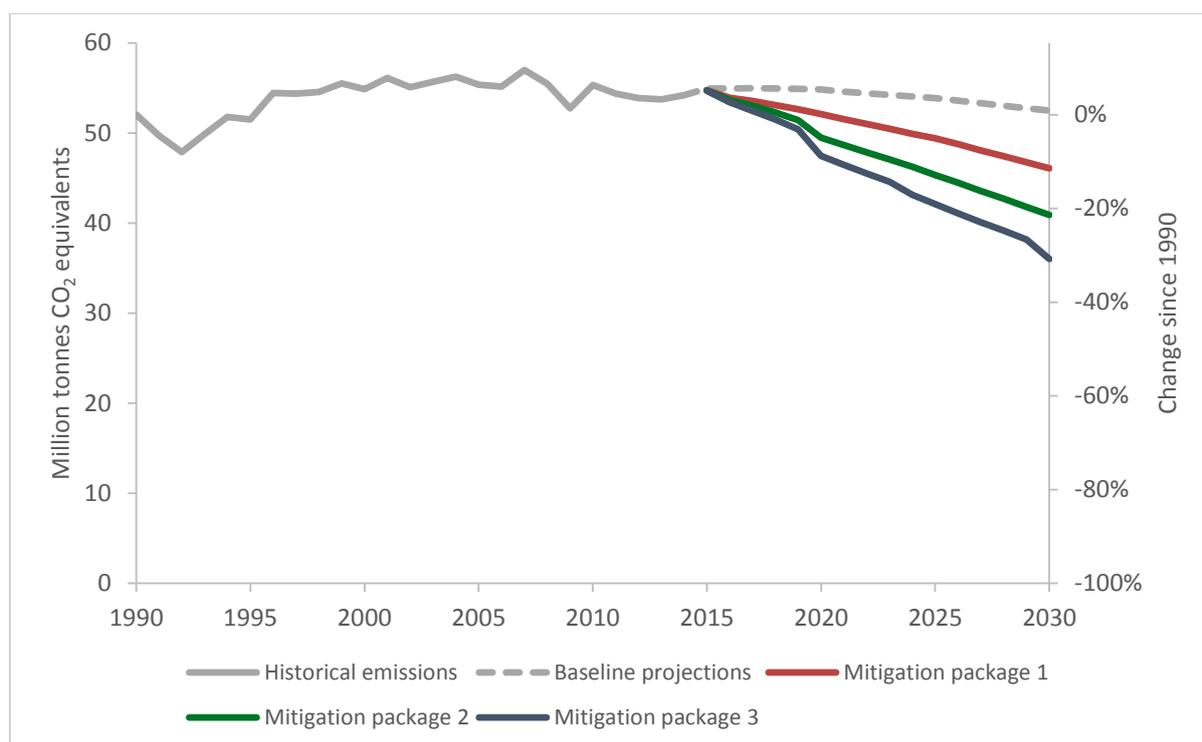


Figure 3 Emission trajectories up to 2030. Source: Norwegian Environment Agency

If all the measures in mitigation package 1 were implemented, the calculations indicate that Norway's total emissions in 2030 would be 46.1 million tonnes CO<sub>2</sub>-eq, which corresponds to a reduction of 11 % relative to the 1990 level.

Similarly, implementing mitigation package 2 would result in total emissions of 40.9 million tonnes CO<sub>2</sub>-eq in 2030, corresponding to a reduction of 21 % relative to the 1990 level.

Mitigation package 3 would result in total emissions of 36.0 million tonnes CO<sub>2</sub>-eq in 2030, corresponding to a reduction of 31 % relative to the 1990 level.

Figure 4 shows the emission reductions split by sector. The transport sector accounts for the largest absolute emission reductions in all three mitigation packages, but a progressively smaller share of the total reduction from package 1 to package 3. Industry is the sector that accounts for the next largest reductions in all three packages, and it accounts for a progressively larger share of total reduction.

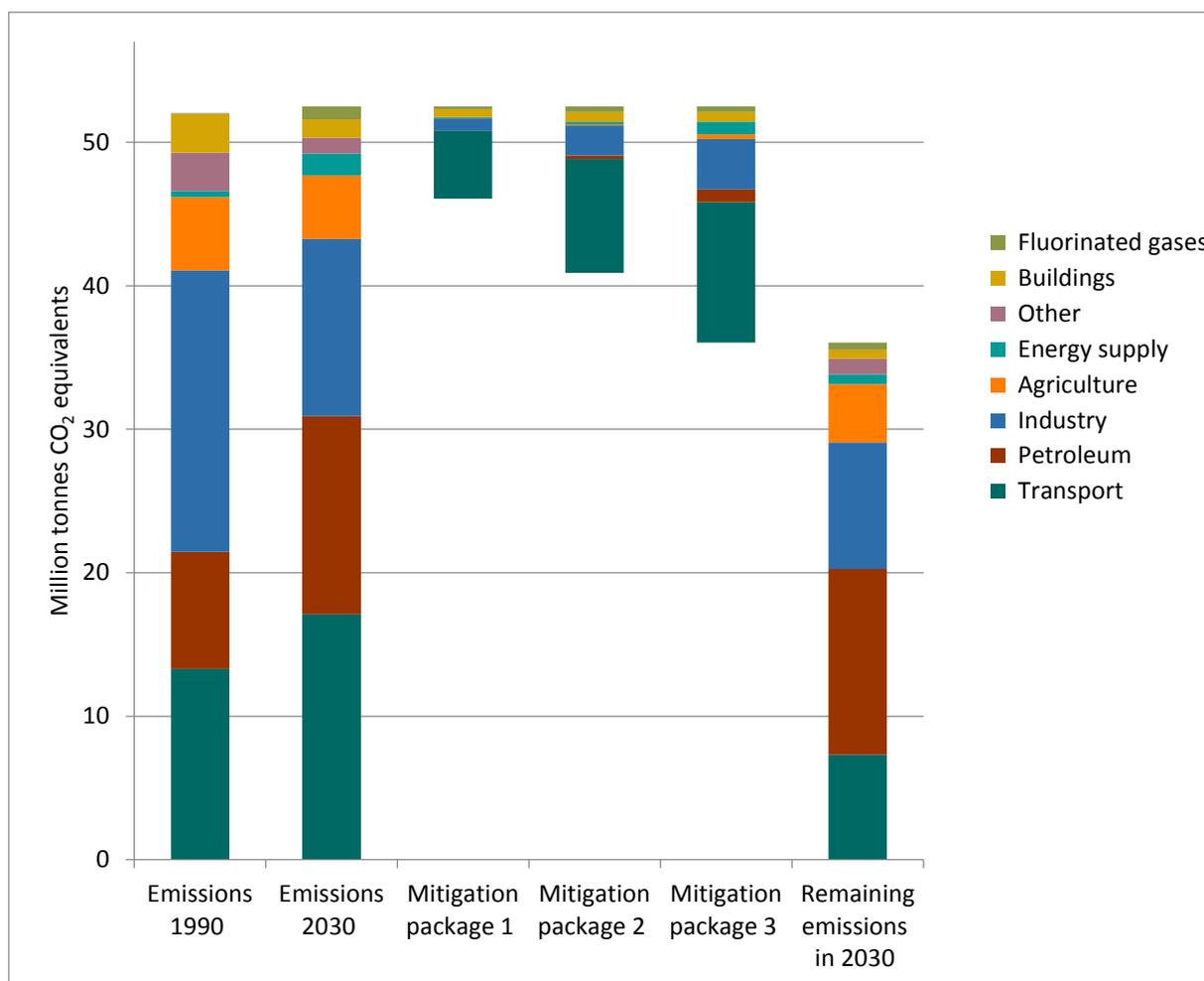


Figure 4 Emission reductions split between sectors. Source: Norwegian Environment Agency

### Emission trajectories up to 2030 for the ETS sector

Figure 5 shows emission trajectories for the ETS sector based on implementation of the measures included in mitigation packages 1, 2 and 3. The right-hand axis shows the percentage reduction in emissions from 1990, which is the reference year for the EU's 2030 target for the ETS sector. The emission reduction potentials of the three mitigation packages exclude measures involving supplying power from shore to installations on the Norwegian continental shelf, which were included in the previous analysis. This is further discussed in the section on the petroleum sector.

Without implementation of any of the mitigation packages, it is projected that emissions from the ETS sector will total 25.4 million tonnes CO<sub>2</sub>-eq in 2030, which corresponds to a reduction of 8 % from the 2005 level.

If all the measures in mitigation package 1 were implemented, the calculations indicate that emissions from the ETS sector would total 24.9 million tonnes CO<sub>2</sub>-eq in 2030, which corresponds to a reduction of 10 % relative to the 2005 level.

Similarly, implementing mitigation package 2 would result in total emissions of 23.4 million tonnes CO<sub>2</sub>-eq in 2030, corresponding to a reduction of 15 % relative to the 2005 level.

Mitigation package 3 would result in total emissions of 20.6 million tonnes CO<sub>2</sub>-eq in 2030, corresponding to a reduction of 26 % relative to the 1990 level.

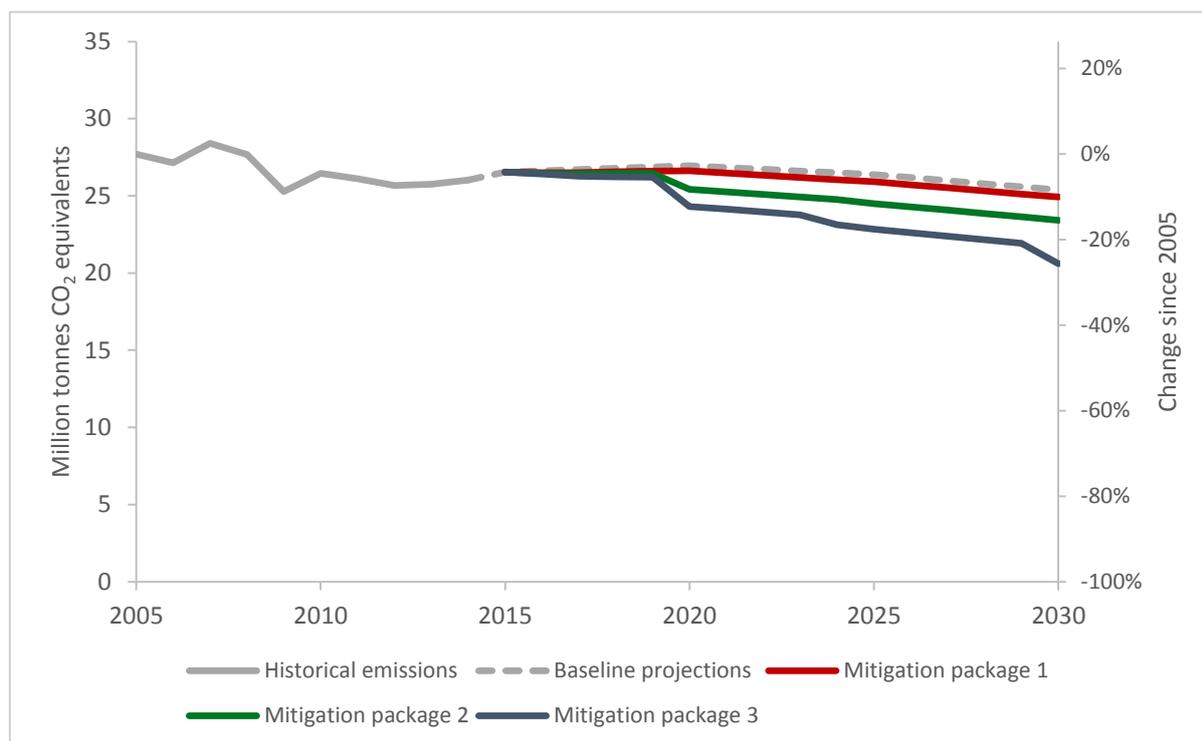


Figure 5 Emission trajectories for mitigation packages 1, 2 and 3 for the ETS sector up to 2030. Source: Norwegian Environment Agency

### Emission trajectories up to 2030 for non-ETS sectors

Figure 6 shows emission trajectories for non-ETS sectors based on implementation of the measures included in mitigation packages 1, 2 and 3. The right-hand axis shows the percentage reduction in emissions from 2005, which is the reference year for the EU's 2030 target for non-ETS sectors.

Without implementation of any of the mitigation packages, it is projected that emissions from the non-ETS sectors will total 27.1 million tonnes CO<sub>2</sub>-eq in 2030. This corresponds to a reduction of 2 % from the 2005 level, which was 27.7 million tonnes CO<sub>2</sub>-eq.

If all the measures in mitigation package 1 were implemented, the calculations indicate that emissions from non-ETS sectors would total 21.2 million tonnes CO<sub>2</sub>-eq in 2030, which corresponds to a reduction of 24 % relative to the 2005 level.

Similarly, implementing mitigation package 2 would result in total emissions of 17.5 million tonnes CO<sub>2</sub>-eq in 2030, corresponding to a reduction of 37 % relative to the 2005 level.

Mitigation package 3 would result in total emissions of 15.4 million tonnes CO<sub>2</sub>-eq in 2030, corresponding to a reduction of 44 % relative to the 1990 level.

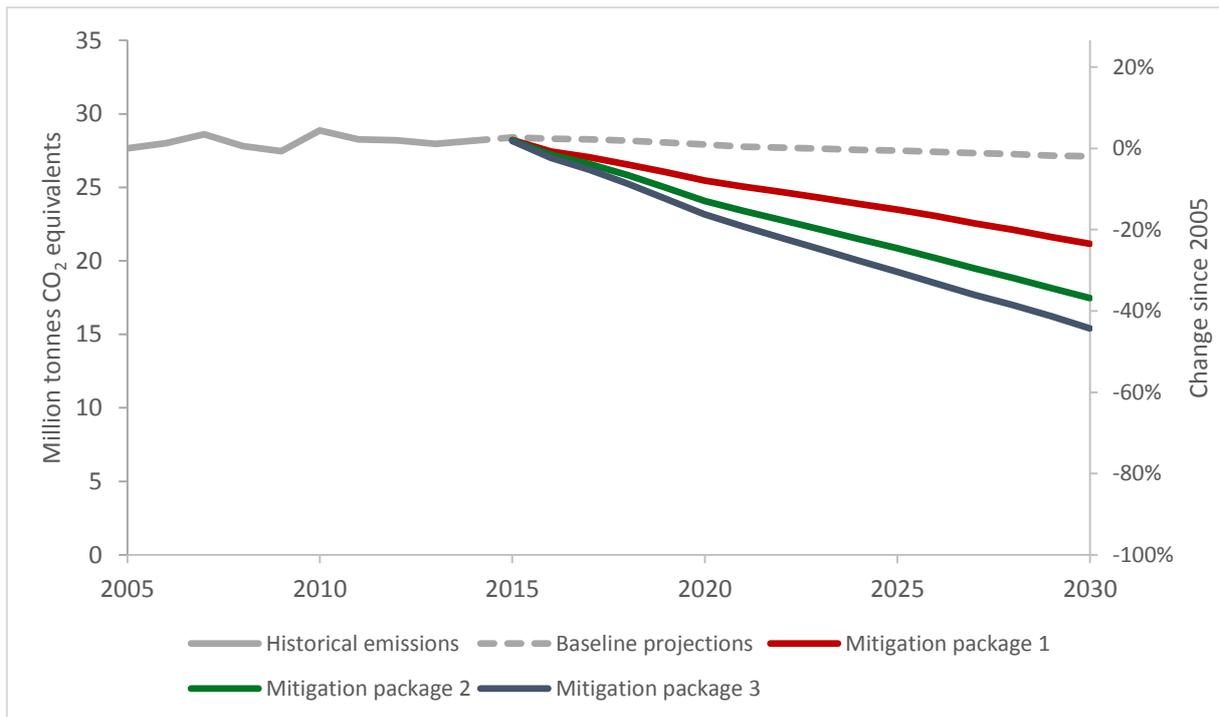


Figure 6 Emission trajectories for mitigation packages 1, 2 and 3 for non-ETS sectors up to 2030. Source: Norwegian Environment Agency

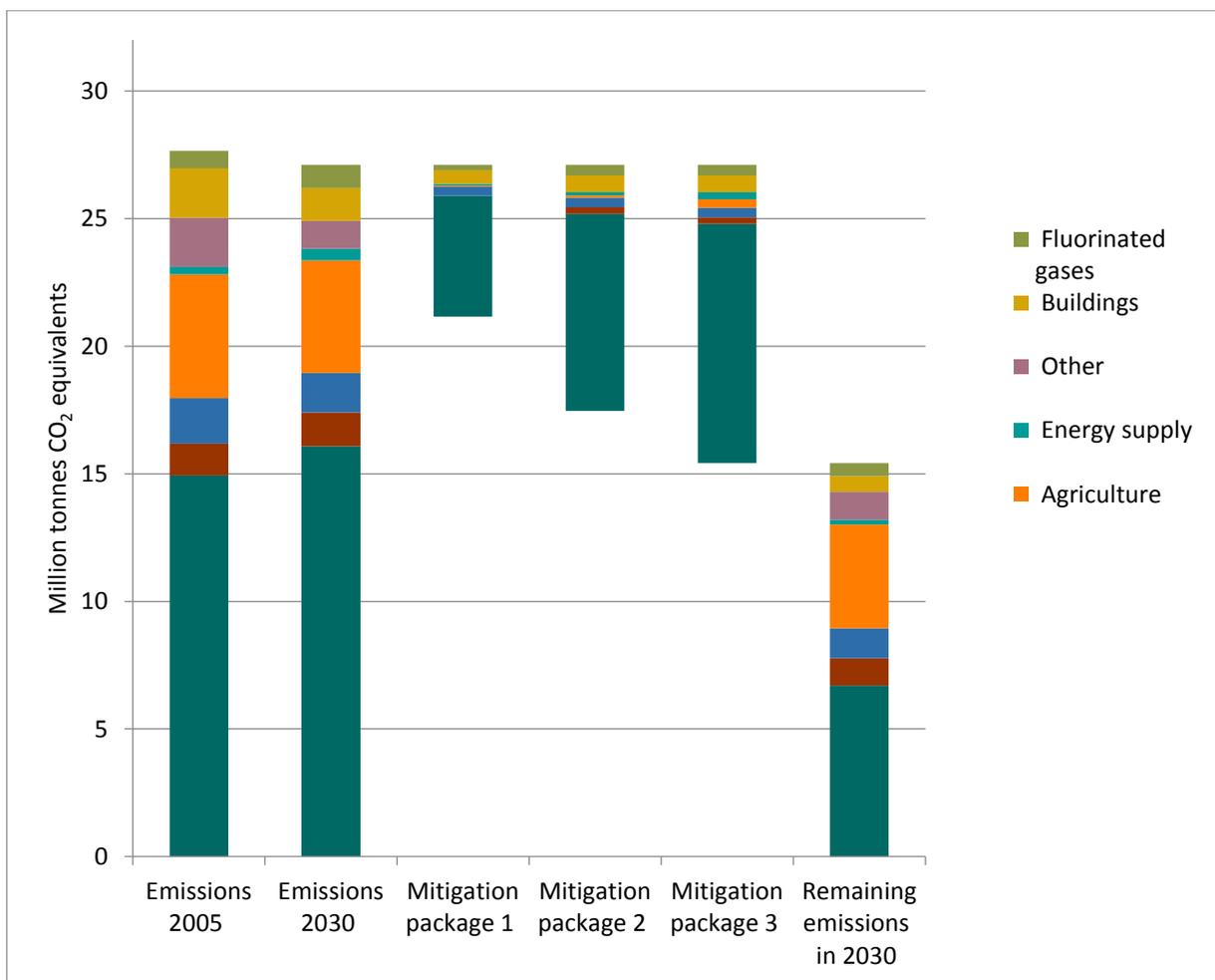


Figure 7 Emission reductions for non-ETS sectors split by sector. Source: Norwegian Environment Agency

Figure 7 shows emission reductions for non-ETS sectors in 2030 split by sector. The transport sector accounts for the largest reductions in all three mitigation packages. Measures in the transport sector can be divided into three main categories: zero- and low-emission technologies; greater use of biofuels; and reductions in transport volumes and modal shifts.

The list below shows the contributions of the three categories to emission reductions. In all three mitigation packages, the emission reduction potential is greatest for measures relating to zero- and low-emission technologies. Such technologies include electric, hydrogen and hybrid vehicles, electrification of ferries and passenger ships and electrification of the railways. Measures to encourage greater use of biofuels for road vehicles, aircraft, other mobile sources, cargo vessels and fishing vessels have the next largest emission reduction potential. The smallest emission reduction potential is offered by measures involving reductions in transport volumes and modal shifts in transport. Chapter 8 of the main report describes all the measures in each of the mitigation packages in more detail.

Emission reductions in the transport sector split by category, mitigation package 1:

- Introduction of zero- and low-emission technologies: 75 %
- Greater use of biofuels: 19 %
- Reduction in transport volumes and modal shifts: 6 %

Emission reductions in the transport sector split by category, mitigation package 2:

- Introduction of zero- and low-emission technologies: 58 %
- Greater use of biofuels: 31 %
- Reduction in transport volumes and modal shifts: 11 %

Emission reductions in the transport sector split by category, mitigation package 3:

- Introduction of zero- and low-emission technologies: 48 %
- Greater use of biofuels: 40 %
- Reduction in transport volumes and modal shifts: 12 %

### Emission trajectories up to 2050

In the mandate for the second part of the project, which resulted in the report *Knowledge base for low-carbon transition in Norway* (Miljødirektoratet, 2014a), the Environment Agency was asked to make a scientific assessment of how a low-carbon society should be defined in Norway's case, to be in line with the two-degree target and the most recent information from the IPCC on average per capita emissions for the world population in 2050. The report showed that given certain assumptions, global emissions must be reduced to a level corresponding to 1.5-3.1 tonnes CO<sub>2</sub>-eq per capita by 2050, and must be further reduced after 2050. On the basis of sector-by-sector mitigation analyses, the report *Knowledge base for low-carbon transition in Norway* concluded that it would be possible for Norway to reduce domestic emissions to a level corresponding to per capita emissions of 1-2 tonnes by 2050.

In Figure 8, the circle indicating 2050 represents an emission level corresponding to per capita emissions of 1.5 tonnes, assuming that the Norwegian population is 6.6 million. The grey dotted lines extending from 2030 to 2050 illustrate the cuts necessary in this period to achieve the target level of emissions in 2050.

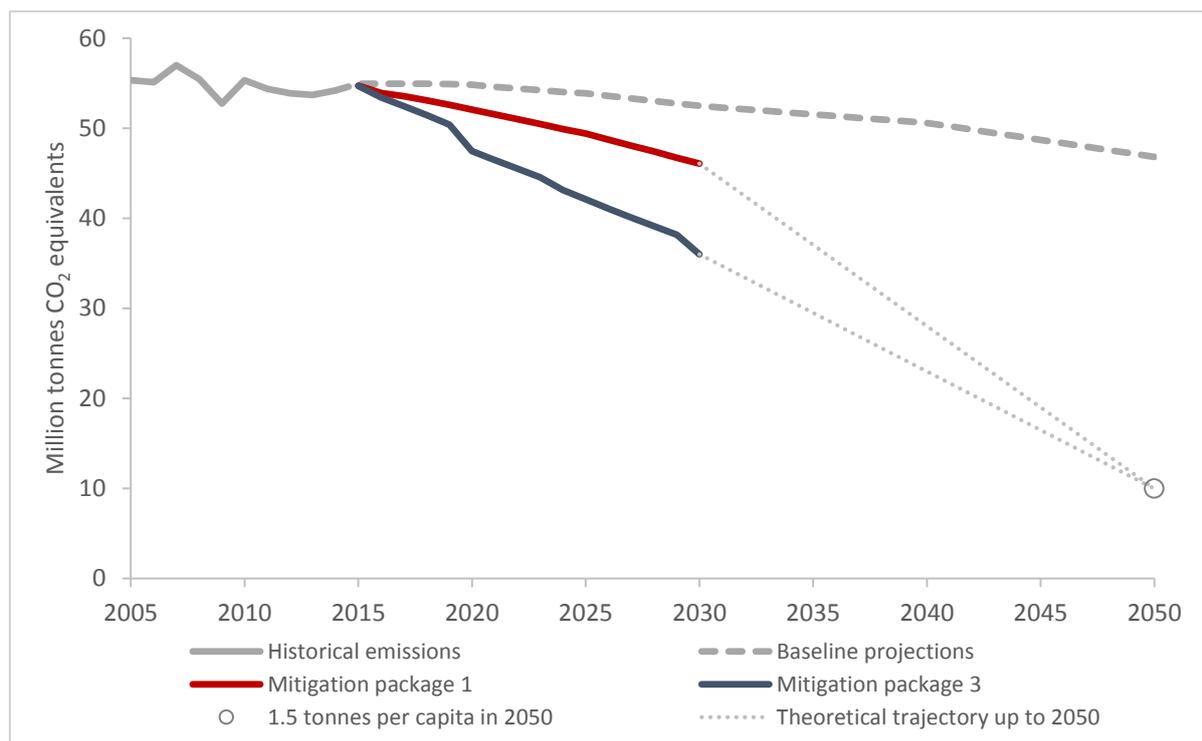


Figure 8 Emission trajectories up to 2050. Source: Norwegian Environment Agency

Assuming that mitigation package 1 is implemented, the average annual reduction in emissions is expected to be 0.6 million tonnes in the period 2015-30. To achieve an emission level corresponding to per capita emissions of 1.5 tonnes in 2050, the average annual reduction in emissions must increase from 0.6 to 1.8 million tonnes in the period 2030-50.

Assuming that mitigation package 3 is implemented, the average annual reduction in emissions is expected to be 1.3 million tonnes in the period 2015-30. To achieve an emission level corresponding to per capita emissions of 1.5 tonnes in 2050, the same average annual reduction in emissions must be maintained until 2050.

### Emission reductions up to 2020

In 2008, most of Norway's political parties signed an agreement on national climate policy, and this was updated in 2012. The interpretation of the 2020 emission target of the cross-party agreement used in *Climate Cure 2020* (Klif et al., 2010) entails a reduction of emissions to 45-47 million tonnes CO<sub>2</sub>-eq excluding emissions and removals from land use, land use change and forestry (LULUCF). Since the targets of the cross-party agreement were adopted in 2007, figures for both historical emissions and emission projections have been changed, particularly as a result of recent changes in calculation methodology, GWP values and emission sources. Overall, these changes have resulted in higher figures for both historical emissions and emission projections. If the level of ambition in the cross-party agreement is to be maintained unchanged using the same interpretation of the target, it will be necessary to adjust the target level for domestic emissions in 2020 upwards to some degree. The methodology for adjusting the target in this way is complex, and we did not have the necessary basis for making the adjustment in the present analysis.

The main focus in this report has been on assessing emission reduction potentials for the period up to 2030. Since this involved constructing emission trajectories up to 2030, it is also possible to assess the potential for reductions in the period up to 2020.

Implementation of mitigation packages 1, 2 and 3 is estimated to result in total emissions of 52.1, 49.5 and 47.5 million tonnes CO<sub>2</sub>-eq respectively in 2020. Mitigation package 3 is based on the assumption that measures will be phased in rapidly, and it also includes measures with an estimated cost of more than 1500 per tonne CO<sub>2</sub>-eq and that are considered to be in the low feasibility category.

Some examples of measures included in mitigation package 3 that can be phased in relatively rapidly are:

- Full-scale CCS at the Norcem Brevik<sup>2</sup> cement plant
- More use of bio char in the ferro-alloy industry
- Switch to a new smelting technology using hydrogen instead of coal at the TiZir Titanium and Iron (TTI) ilmenite upgrading facility
- Biofuels: in road transport, 21 % by volume of petrol consumption to be replaced by bioethanol, and 20.5 % of diesel consumption to be replaced by biodiesel by 2020.
- Electrification of the Hammerfest LNG plant.

The Environment Agency has concluded that it will still be technically possible, but very demanding, to reduce emissions to around 47 million tonnes CO<sub>2</sub>-eq by 2020.

#### Co-benefits of the mitigation packages

There is no overall assessment of the co-benefits of the mitigation packages in the present report, but it does include a closer analysis of the measures in the transport sector that are expected to give the greatest health benefits. These benefits are related to reductions in emissions of NO<sub>x</sub> and particulate matter as a result of measures to limit or reduce the number of vehicle-kilometres driven by passenger cars or to promote a switch from petrol and diesel vehicles to electric, hydrogen and hybrid vehicles. In the calculations, the average monetary value of emission reductions has been set at NOK 3000 per kg PM<sub>10</sub> and NOK 100 per kg NO<sub>x</sub>. These figures are intended to reflect the public health benefits of lower PM<sub>10</sub> and NO<sub>x</sub> emissions.

It is estimated that a combination of zero growth in vehicle-kilometres for passenger cars in Norway's 13 largest towns and an increase in the proportion of new passenger cars sold that are zero-emission vehicles to 60 % by 2030 (from mitigation package 1) would reduce NO<sub>x</sub> emissions by 3 640 tonnes and PM<sub>10</sub> emissions by 93 tonnes in 2030. This would give annual health benefits with an estimated value of about NOK 280 million in 2030.

Similarly, a combination of zero growth in vehicle-kilometres for passenger cars throughout Norway and an increase in the proportion of new passenger cars sold that are zero-emission vehicles to 100 % by 2030 (from mitigation package 2) would reduce NO<sub>x</sub> emissions by an estimated 4 986 tonnes and PM<sub>10</sub> emissions by 212 tonnes in 2030. This would give annual health benefits with an estimated value of about NOK 640 million in 2030.

A combination of a reduction of 10 % in vehicle-kilometres for passenger cars in Norway's 13 largest towns and an increase in the proportion of new passenger cars sold that are zero-emission vehicles to 100 % by 2030 (from mitigation package 3) would reduce NO<sub>x</sub> emissions by an estimated 5 108 tonnes and PM<sub>10</sub> emissions by 244 tonnes in 2030. This would give annual health benefits with an estimated value of about NOK 735 million in 2030.

<sup>2</sup> An alternative to this is roughly 50 % CCS at Norcem based on utilisation of surplus heat combined with storage of already captured CO<sub>2</sub> which is currently released to the air at Yara Porsgrunn

It should be noted that these calculations are based on a simple set of assumptions, so that the results are uncertain. In addition to the health effects, reducing the growth in transport volumes in towns may also reduce queuing, noise and congestion and the need to expand transport capacity. Such effects were not further considered in this analysis, but it is reasonable to assume that considerable savings can be achieved if effective policy instruments are used.

### Consequences of the mitigation packages for the energy sector

The report *Knowledge base for low-carbon transition in Norway* (Miljødirektoratet, 2014a) summarised the possible effects of the three mitigation packages on demand for electricity and bioenergy in 2030. The present report includes an updated assessment of these effects.

For electricity, the highest estimate for the increase in demand in the transport sector has been revised downwards. This is partly because in order to illustrate the maximum potential increase in electricity demand, it was assumed in the previous analysis that 100 % of zero-emission vehicles would be hydrogen vehicles. In this updated assessment, different assumptions have been used for different vehicle segments. The electricity demand associated with supplying power from shore to installations on the Norwegian continental shelf has not been quantified. The analyses show that the increase in electricity demand resulting from the three mitigation packages is relatively small compared with annual electricity production in Norway. In addition, there is a potential for improvements in energy efficiency that has not been included in the analyses.

The present analysis also looks more closely at the demand for various types of bioenergy. It includes an overview of the efficiency of producing bioenergy commodities from different raw materials so that it is possible to estimate gross biomass needs. It should be noted that bioenergy production in Norway will depend on market conditions such as production costs relative to import prices. The biofuels used in Norway at present are largely imported. Potential production volumes in Norway will also be influenced by the availability of raw materials and by the fact that biofuel from forest raw materials is often produced using by-products of other manufacturing processes.

The overall conclusion is that it will be possible to meet the increase in demand for bioenergy resulting from implementation of the mitigation packages through Norwegian biomass production. The only exception is in mitigation package 3, where the use of up to 40 % biofuels in the transport sector could increase demand beyond the production potential in Norway. However, the figures used in the analysis are very uncertain.

It should also be remembered that the mitigation packages are intended as illustrations of how different measures can be combined. The same emission cuts can be achieved in a variety of different ways. Possible alternatives to greater use of biofuels are phasing in electric and hydrogen vehicles more rapidly or reducing growth in transport volumes. If the target is to increase biofuel use towards 40 %, it will be necessary to base some of the increase in the period up to 2030 on imports. In the longer term, the resource base can be expanded by using novel sources such as marine resources.

On 28 April 2015, the European Parliament accepted proposals for amendments to both the fuel quality directive and the renewable energy directive, and the Council is expected to adopt them formally in the near future. The purpose of the new rules is to reduce the indirect land use change (ILUC) associated with biofuel production. The main elements of the proposal are a 7 % cap on conventional (or first-generation) biofuels, which are produced from food crops, used towards the 10 % target set out in the renewable energy directive for the share of energy from renewable

sources<sup>3</sup> in all forms of transport in 2020 (Renewables Directive 2009/28/EC), and a reference value of 0.5 percentage points for advanced (or second-generation) biofuels. Once the amended legislation has been incorporated into the EEA Agreement, the new rules will apply in Norway as well.

The report *Knowledge base for low-carbon transition in Norway* highlighted the development of biomass-based chemicals and fuels as an area where Norway could make a real difference by intensifying its efforts.

### Updated mitigation measures

Continuous improvements are being made in identifying and quantifying mitigation measures. The 84 measures presented in the main report have been checked as far as possible with relevant directorates and other stakeholders. However, the quality of the underlying data varies, and in some cases, uncertainties have made it necessary to use judgement to assess emission reduction potentials, cost levels and feasibility. It should also be noted that the list of measures in the analysis is not exhaustive. Furthermore, only mitigation measures have been analysed. In almost all cases, policy instruments will need to be strengthened to ensure that measures are implemented.

Several of the measures for **land-based industry** have been updated in cooperation with the sector, so that they describe emission reduction potentials, costs and timing better than previously. For example, measures targeting refineries and cement production have been updated on the basis of input from these industries. Some new measures have also been included, for example two new CCS projects, one at Norcem Brevik and one at Yara Porsgrunn. Two options are presented for implementing both these projects.

On the basis of data reported by industrial installations in the ETS sector, the origins of their greenhouse gas emissions have been analysed. Emissions have been split into process emissions, combustion emissions and a third category including combustion emissions originating from the fuel gases formed during industrial processes and from waste destruction, and other combustion emissions from processes where no satisfactory options for conversion to other energy sources can be identified at present. The mitigation analysis identified measures that reduce emissions in all three categories, but the analysis of the origins of the emissions shows that a large proportion of emissions from the process industry will be very difficult to eliminate without using CCS or new process technologies.

Some important changes have been made to measures within the **petroleum sector**. In the report *Knowledge base for low-carbon transition in Norway*, it was assumed that greenhouse gas emissions could be reduced by a further 1 million tonnes CO<sub>2</sub>-eq by 2030 through energy efficiency measures. This was described as a rough estimate, and the report stated that further analysis would be needed to find actual figures for energy efficiency potentials in this sector. The Norwegian Petroleum Directorate is responsible for emission projections for the petroleum sector, and has stated that adjustments for technological progress have been incorporated into the projections. These adjustments include 'energy efficiency measures', 'flare gas recovery', 'operational improvements to reduce flaring for safety reasons', and 'the use of combined-cycle gas turbines (CCGT) offshore'. Given the uncertainty about the proportion of these measures that is already included in the emission projections, they have not been included in the three mitigation packages. The Norwegian Oil and Gas Association is currently running a joint industry project on energy efficiency, and KonKraft, a cooperation forum for the Association, the Federation of Norwegian Industries, the

---

<sup>3</sup> Includes both electricity and biofuels, with separate weighting rules for different types of renewables

Norwegian Confederation of Trade Unions and the Norwegian Shipowners' Association, is preparing an updated climate report that will describe technological opportunities for reducing emissions from petroleum activities on the Norwegian continental shelf (NOROG, 2015).

The analysis of measures involving electrification of offshore installations presented in *Knowledge base for low-carbon transition in Norway* was based on work presented in the 2010 report *Climate Cure 2020*, which in turn was based on a study from 2008 (Oljedirektoratet et al, 2008). Since many of the assumptions on which the earlier analyses were based have been revised, the Environment Agency asked the Petroleum Directorate for updated estimates of the costs and emission reduction potentials of electrification of new installations and partial electrification of existing installations. The Petroleum Directorate's analysis is included as an appendix to the main report (Vedlegg III: *Tiltakskostnadskurve for elektrifiseringsprosjekter*). It presents a general marginal abatement cost curve for these measures, but does not include the time dimension, since no assessment has been made of when each field could be electrified. The Petroleum Directorate points out that further evaluation will be needed to determine the emission reduction potential for 2030 of using power from shore. After consultation with the Directorate, it was therefore decided not to attempt to quantify the potential in the present mitigation analysis.

In *Knowledge base for low-carbon transition in Norway*, mitigation package 3 included emission cuts of 4.28 million tonnes CO<sub>2</sub>-eq associated with supplying power from shore to installations on the Norwegian continental shelf in 2030. This emission reduction potential included the electrification of installations on the Utsira High. This project has now been approved and is included in the baseline scenario.

For **road transport**, the projections based on the 2015 Norwegian budget are a good deal lower than those in the white paper *Long-term Perspectives on the Norwegian Economy 2013*, which were used as a basis in *Knowledge base for low-carbon transition in Norway*. This is mainly because estimates of distances travelled have been reduced and a lower average vehicle emission factor is used in the new baseline projections. Reasons for the lower emission factor include a rise in the number of electric vehicles, greater use of biofuels and the assumption that vehicles will become more energy efficient. A new measure involving more rapid phase-in of electric and hydrogen passenger cars has been reviewed. This assumes that 100 % of new passenger cars sold in 2025 will be zero-emission vehicles. The measure is included in mitigation package 3. Furthermore, the measure '10 % reduction in vehicle-kilometres for passenger cars throughout the country' has been replaced with '10 % reduction in vehicle-kilometres for passenger cars in the larger towns and zero growth in the rest of the country'. This was done on the basis of modelling carried out by the Institute of Transport Economics, commissioned in spring 2015 by the Environment Agency and the National Transport Plan project group on climate. Modelling was used to calculate the effects of different combinations of policy instruments, and the results indicate that very strict policy instruments will be needed to reduce transport volumes for travel outside the larger towns and long journeys. It appears to be considerably easier to reduce emissions related to shorter journeys.

All measures relating to **shipping** have been updated on the basis of a report from DNV GL on measures and instruments to encourage a shift to greener fuels in the shipping industry (DNV GL, 2015), which was finalised in February 2015.

In the **aviation** sector, the effects of using 20 % and 40 % aviation biofuel have been reviewed. The level of ambition has been revised upwards since the previous report, where the measures reviewed were 10 and 20 % biofuel. This has been done because up to 50 % aviation biofuel can be mixed directly with conventional aviation fuel without any need for adaptation of jet motors or the distribution system.

In the **energy supply sector**, Norsk fjernvarme, an interest organisation for the district heating industry, has collected information from the industry on options for phasing out fossil oil and gas. Gassnova has carried out a pre-feasibility study, and concluded in a report published on 4 May 2015 that a full-scale CCS project at the Klemetsrud waste separation and waste-to-energy plant in Oslo would be realistic. The present report therefore includes a general description of this measure.

One new measure has been reviewed in the **agricultural sector**, ‘shift to a diet containing less meat and sugar’ (Bioforsk, 2015). This measure involves lower consumption of meat and higher consumption of cereal products, fruit and vegetables, and an increase in the production of these products in Norway. It is also assumed that fish consumption must rise to maintain people’s intake of protein. Implementing this measure will require greater awareness both of climate change and of the importance of a healthy diet, and it is therefore more than just an agricultural measure.

In the **building sector**, two new measures, ‘phasing out the use of oil-fired boilers in private households and to provide base-load capacity in non-residential buildings’ and ‘phasing out the use of oil-fired boilers to provide peak-load capacity in non-residential buildings’ replace the measures that were included in *Knowledge base for low-carbon transition in Norway*.

#### Land use, land-use change and forestry (LULUCF)

Emissions and removals of greenhouse gases as a result of human activity in the LULUCF sector are reported every year as part of Norway’s obligations under the Climate Change Convention and the Kyoto Protocol. The greenhouse gas inventory for this sector is drawn up separately from that for other sectors, and measures in this sector have not been included in the mitigation packages presented here.

In Norway, forest accounts for the bulk of removals of greenhouse gases in this sector, about 31 million tonnes CO<sub>2</sub>-eq in 2013. Emissions from the sector totalled about 5 million tonnes CO<sub>2</sub>-eq in 2013. These emissions are a result of deforestation and draining of organic soils when land is converted for other purposes, for example construction of buildings. Total net removals from this sector in 2013 were 26.7 million tonnes CO<sub>2</sub>-eq.

Large areas of Norwegian forest will reach harvesting age in the next few years, and greenhouse gas removals in forest are therefore expected to be lower in the years ahead. This will result in a growing need for active management and new mitigation measures. This report deals with measures that have previously been reviewed and also discusses a number of possible new measures that could increase CO<sub>2</sub> removals. They include measures to reduce deforestation and other measures that can increase removals and reduce carbon emissions in this sector. As part of the Government’s focus on the forest sector, the pilot phase of the project ‘afforestation of new areas as a climate mitigation measure’ has already been started. This measure was reviewed in the report *Climate Cure 2020*.

#### Compliance with Norway’s Kyoto commitment (first commitment period, 2008-12)

The first commitment period of the Kyoto Protocol ended in 2012, and assessments of compliance with emission commitments for this period are now being finalised. Norway’s greenhouse gas emission inventory for the years 2008-12 was finally approved in May 2015 after a review process within the UN in 2014 and 2015. Through this process, Norway’s emissions and removals of greenhouse gases in the first Kyoto commitment period were reviewed and the final figures were determined. Norway’s assigned amount for the commitment period 2008-12 was 250.58 million assigned amount units, which corresponds to 250.58 million tonnes CO<sub>2</sub>-eq. Despite the measures and

policy instruments introduced during this period, Norway's overall emissions were 16.3 million tonnes CO<sub>2</sub>-eq higher than its assigned amount. In addition, Norway has undertaken a voluntary commitment to reduce its emissions by 10 percentage points more than its official Kyoto commitment. This corresponds to 25 million emission reduction units.

In the course of 2015, Norway will comply with its Kyoto commitment by surrendering the number of emission reduction units corresponding to its emissions. It will be necessary to purchase emission reduction units abroad to achieve the voluntary extra commitment of 10 percentage points. Any documented increase in CO<sub>2</sub> removals in forest as a result of forest management measures will mean that Norway exceeds its official Kyoto commitment by even more. The main report sets out the calculations for Norway's compliance with its commitments.



## References

- Bioforsk (2015). *Vurdering av klimatiltak i jordbruket. Beregnet reduksjon av klimagassutslipp av ulike tiltak innen 2050* [Assessment of climate mitigation measures in the agricultural sector. Estimated emission reductions by 2050. In Norwegian only]. Vol. 10, Nr. 24, Bioforsk.
- DNV GL (2015). *Vurdering av tiltak og virkemidler for mer miljøvennlige drivstoff i skipsfartsnæringen* [Assessment of measures and policy instruments to encourage a shift to greener fuels in the shipping industry. In Norwegian only]. Report No. 2015-0086: commissioned by the Ministry of Climate and Environment.
- IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Intergovernmental Panel on Climate Change. <http://www.ipcc-nggip.iges.or.jp/public/2006gl/>. Accessed 20 September 2015.
- IPCC. (2013). *Decision 24/CP.19. Revision of the UNFCCC reporting guidelines on annual reporting guidelines for Parties included in Annex I to the Convention*. <http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf#page=2> . Accessed 20 September 2015.
- Klif et al. (2010). *Klimakur 2020. Tiltak og virkemidler for å nå norske klimamål mot 2020* [English summary published as Report no. TA 2678/2010: *Climate Cure 2020. Measures and instruments for achieving Norwegian climate goals by 2020*. [http://www.miljodirektoratet.no/no/Publikasjoner/Publikasjoner/2010/Juli/Climate\\_Cure\\_2020\\_Measures\\_and\\_instruments\\_for\\_achieving\\_Norwegian\\_climate\\_goals\\_by\\_2020\\_Summary/](http://www.miljodirektoratet.no/no/Publikasjoner/Publikasjoner/2010/Juli/Climate_Cure_2020_Measures_and_instruments_for_achieving_Norwegian_climate_goals_by_2020_Summary/) Accessed 20 September 2015]. Oslo: Report TA2590/2010. Climate and Pollution Agency, Norwegian Water Resources and Energy Directorate, Norwegian Petroleum Directorate, Statistics Norway, Norwegian Public Roads Administration.
- Meld. St. 13. (2014-2015). *Ny utslippsforpliktelse for 2030 - en felles løsning med EU*. [Shortly to be published in English under the title *New emission commitment for Norway for 2030 - towards collective delivery with the EU*.] <https://www.regjeringen.no/no/dokumenter/meld.-st.-13-2014-2015/id2394579/?ch=1> Accessed 20 September 2015. Ministry of Climate and Environment
- Miljødirektoratet (2014a). *Kunnskapsgrunnlag for lavutslippsutvikling*. Report M229/2014. [Summary in English published as *Knowledge base for low-carbon transition in Norway*. <http://www.miljodirektoratet.no/no/Publikasjoner/2014/Desember-2014/Knowledge-base-for-low-carbon-transition-in-Norway/>. Accessed 20 September 2015] Norwegian Environment Agency.
- NOROG (2015). *Oljebransjen klar for krafttak* [Oil and gas industry ready for a concerted effort. In Norwegian only]. <https://www.norskoljeoggass.no/Nyheter/2015/02/Oljebransjen-klar-for-krafttak/>. Accessed 20 September 2015. Norwegian Oil and Gas Association
- Oljedirektoratet et al. (2008). *Kraft fra land til norsk sokkel* [Summary in English published as *Power from land to the Norwegian shelf* . <http://www.npd.no/en/Publications/Reports/Power-from-land--summary/> Accessed 20 September 2015]. Norwegian Petroleum Directorate, Norwegian Water Resources and Energy Directorate, Petroleum Safety Authority Norway, Norwegian Pollution Control Authority.
- Renewables Directive 2009/28/EC (2009). <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0028>. Accessed 20 September 2015.

### Norwegian Environment Agency

Telephone: +47 73 58 05 00 | Fax: +47 73 58 05 01

E-mail: [post@miljodir.no](mailto:post@miljodir.no)

Web: [www.environmentagency.no](http://www.environmentagency.no)

Postal address: Postboks 5672 Sluppen, N-7485 Trondheim

Visiting address Trondheim: Brattørkaia 15, 7010 Trondheim

Visiting address Oslo: Grensesvingen 7, 0661 Oslo

The Norwegian Environment Agency is working for a clean and diverse environment. Our primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

We are a government agency under the Ministry of Climate and Environment and have 700 employees at our two offices in Trondheim and Oslo and at the Norwegian Nature Inspectorate's more than sixty local offices.

We implement and give advice on the development of climate and environmental policy. We are professionally independent. This means that we act independently in the individual cases that we decide and when we communicate knowledge and information or give advice.

Our principal functions include collating and communicating environmental information, exercising regulatory authority, supervising and guiding regional and local government level, giving professional and technical advice, and participating in international environmental activities.