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Climate mitigation measures up to 2030

Short term climate effects and health effects

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Title – Norwegian and English

Klimatiltak mot 2030 – klimaeffekt på kort sikt og helseeffekter
Climate mitigation measures to take us to 2030 – short term climate effects and health effects

Summary – sammendrag

Using the Norwegian Environment Agency report Climate mitigation measures and emission trajectories up to 2030 (English summary M-418/2015) and its proposed action plan for Norwegian emissions of short-lived climate forcers (English summary M-135/2014) as a basis, this report answers three questions. 1. What are the short-term climate effects of the measures in the low-carbon transition report, and which of them have the largest short-term climate benefits in addition to the long-term climate benefits described in the report? 2. What are the health effects of the measures analysed in the low-carbon transition report, and which of them yield the largest health benefits? 3. Which of the measures analysed in the action plan are still important for achieving short-term climate effects, and which are less relevant because measures analysed in the low-carbon transition report are a better option?

4 emneord

Kortlevde klimadrivere, helse, tilleggsgevinster, lavutslipp

4 subject words

Short-lived climate forcers, health, co-benefits, low-carbon transition report

Front page photo

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Summary

To limit global warming to less than two degrees, it is necessary to reduce emissions of and other long-lived greenhouse gases. Measures to reduce emissions of short-lived climate forcers can play a part in reducing the rate of warming, but cannot replace those designed to reduce emissions of long-lived greenhouse gases. Steps to cut emissions of both long-lived greenhouse gases and short-lived climate forcers can yield more rapid climate benefits, thus improving the prospects of achieving the two-degree target.

In this project, the Norwegian Environment Agency has analysed both short-term and long-term climate effects of the measures discussed in the report Climate mitigation measures and emission trajectories up to 2030 (or 'low-carbon transition report', summary in English published as report M-418/2015) and assessed which of the measures will also provide health benefits. The following measures were found to give the greatest overall benefit ('win-win-win' solutions):

- switching to electric and hydrogen vehicles (passenger cars and vans);
- electrification of ferries and passenger ships;
- reduction in passenger car traffic in the larger towns and zero growth in the rest of the country.

In addition, the introduction of shoreside electric power to ships at berth will have substantial health benefits. The health benefits of all the measures in the low-carbon transition report are estimated to be worth NOK 900 million per year. Ten measures in the transport sector account for about 90 % of this. It should be noted that there is a high level of uncertainty in these calculations.

The measures that were found to have the greatest additional benefits in the form of short-term climate effects were:

- reduction of HFC emissions through leakage control and collection;
- gas recovery and operational improvements in the petroleum sector;
- electrification of ferries and passenger ships;
- shift from a meat to a vegetable and fish diet.

The Norwegian Environment Agency has also published a proposed action plan for short-lived climate forcers, in which measures specifically to reduce emissions of these substances were analysed (summary in English published as Summary of proposed action plan for Norwegian emissions of short-lived climate forcers, M-135/2014). According to this analysis, measures to reduce emissions of particulate matter from woodburning stoves and retrofitting construction machinery with diesel particulate filters would give substantial health benefits. Their combined health benefits were estimated to be worth about NOK 1 billion per year. These measures are still of interest and could be introduced in combination with measures from the low-carbon transition report.

The estimated short-term climate effect of the measures analysed in the low-carbon transition report is more than twice as large as the combined climate effect of the measures in the proposed action plan. This is mainly because in the short term too, the climate effect of the measures in the low-carbon transition report is dominated by large reductions in CO_2 emissions. However, the health benefits of the measures in the low-carbon transition report are smaller than those of the measures in the proposed action plan, mainly because they result in smaller reductions in emissions of particulate matter.

It is vital to design the measures proposed in the low-carbon transition report in such a way that they do not have unintended negative impacts on health. For instance, depending on how a ban on the use of fuel oil for heating is implemented, it could result in higher emissions of particulate matter in town centres. This example highlights the advantages of using integrated analyses to build up a stronger basis for decision making.

Background

The low-carbon transition report analyses the potential for reducing Norway's emissions of the six Kyoto greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) on the basis of their global warming potential for a 100-year time horizon ($GWP_{100,\ global}$). It provides a basis for the further development of Norway's climate policy given Norway's and the EU's shared target of reducing emissions by at least 40 % by 2030 compared with the 1990 level. This target is based on emissions of the six Kyoto gases, weighted according to their $GWP_{100,\ global}$. The report presents three different mitigation packages and corresponding emission trajectories up to 2030.

The present report describes an integrated analysis, in which we have also considered the effects of the same measures on short-lived climate forcers[1]. We have looked at the short-term climate effect and the health effects of all the measures in the low-carbon transition report. In addition to the six Kyoto gases, we have estimated reductions in emissions of the short-lived climate forcers black carbon (BC), organic carbon (OC), NO_X and SO_2. The climate effect for a 10-year time horizon has been calculated using their global temperature change potential, $GTP_{10,\ Norway}$[2], in line with the methodology described in the proposed action plan for Norwegian emissions of short-lived climate forcers.

In the present report, the long-term climate effect of a measure is calculated on the basis of changes in emissions of the six Kyoto gases, expressed as CO_2 equivalents weighted according

[1] In this report, short-lived climate forcers are defined in line with the definition used in the Fifth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC). Short-lived climate forcers are gases and particulates whose impact on climate occurs primarily within the first 10 years after their emission. They may have either a warming or a cooling effect on the climate. Those with a warming effect include methane (CH_4), black carbon (BC), tropospheric ozone (ground-level ozone) and some hydrofluorocarbons (HFCs), and those with a cooling effect include organic carbon (OC) and sulphur dioxide (SO_2). In addition, CH_4, NO_X, CO and nmVOCs are ozone precursors. The effect of O_3 is not included in the analysis because only a very small proportion of the ozone concentration in Norway originates from Norwegian emissions. For the same reason, the analysis does not include cuts in emissions of the ozone precursors CO and nmVOCs. NO_X is also an ozone precursor, but is included in the analysis because it has health effects in itself. NO_X emissions have a cooling influence over a 10-year time horizon.

[2] $GTP_{10,\ Norway}$ stands for global temperature change potential 10 years after emissions took place in Norway.

to their $GWP_{100,\ global}$, in the same way as in the low-carbon transition report. The short-term climate effect is calculated on the basis of changes in emissions of both the Kyoto gases and the four short-lived climate forcers BC, OC, NO_X and SO_2 expressed as CO_2 equivalents weighted according to their $GTP_{10,\ Norway}$. Calculations of the health effects of the measures are based on established figures for the monetary value of cuts in emissions of PM_{10} and NO_X, expressed in NOK.

The analysis answers the following main questions:

1. What are the short-term climate effects of the measures in the low-carbon transition report, and which of them have largest short-term climate benefits in addition to the long-term climate benefits described in the report?
2. What are the health effects of the measures analysed in the low-carbon transition report, and which of them yield the largest health benefits?
3. Which of the measures analysed in the action plan are still important for achieving short-term climate effects, and which are less relevant because measures analysed in the low-carbon transition report are a better option?

Carbon dioxide (CO_2) dominates the short-term climate effects

The analysis of short-term climate effects was based on the 89 measures included in mitigation package 3 in the low-carbon transition report. This is the most ambitious of the three packages, and includes measures in all the cost and feasibility categories. It was found that implementing mitigation package 3 would reduce emissions in 2030 from an estimated 71.6 million to 53.7 million tonnes $CO_{2e(GTP10,\ Norge)}$, which is 18 million tonnes or 25 % below the level in the reference scenario. The calculations show that the transport sector will account for 56 % of this reduction, followed by industry with 19 %. Figure S-1 shows the short-term climate effect measured as average emission reductions per year in the period 2016-2030 for all measures included in mitigation package 3, split by climate forcer. Positive values show emission reductions with a cooling effect, and negative values those with a warming effect. Carbon dioxide accounts for 84 % of the net short-term climate effect of the measures. By way of comparison, CO_2 accounts for 92 % of the long-term climate effect measured in terms of $CO_{2e(GTP10,\ global)}$. Thus, CO_2 dominates both the long-term and the short-term climate effects of the measures.

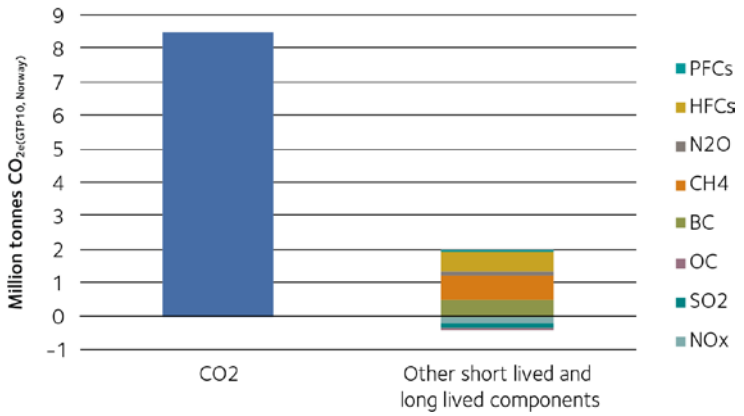

Figure S-1 Short-term climate effects (average emission reductions per year in the period 2016-2030) of the measures in the low-carbon transition report, split by climate forcer. Units: million tonnes $CO_{2e(GTP10,\ Norway)}$. Source: Norwegian Environment Agency

Of the other short- and long-lived climate forcers, methane, HFCs and BC contribute most to the short-term net climate effect of the measures. Cuts in NO_X emissions result in an appreciable warming effect.

The net short-term climate effect of the measures in mitigation package 3 in the low-carbon transition report is about 10 million tonnes $CO_{2e(GTP10,\ Norge)}$ on average for each of the years in the period 2015-2030. This is lower than the estimated climate effect in 2030, mainly because it is expected that many of the measures will be phased in and stepped up during the period covered by the analysis.

Figure S-2 shows the 20 measures from mitigation package 3 that have the largest net short-term climate effect. A cooling effect of a measure is shown to the right of zero, and a warming effect to the left. A measure may have a warming effect because it results in lower emissions of climate forcers such as NO_X, OC and SO_2, which have a cooling effect, or because it results in higher emissions of climate forcers with a warming effect, such as BC. The black border indicates the net, short-term climate effect of each measure.

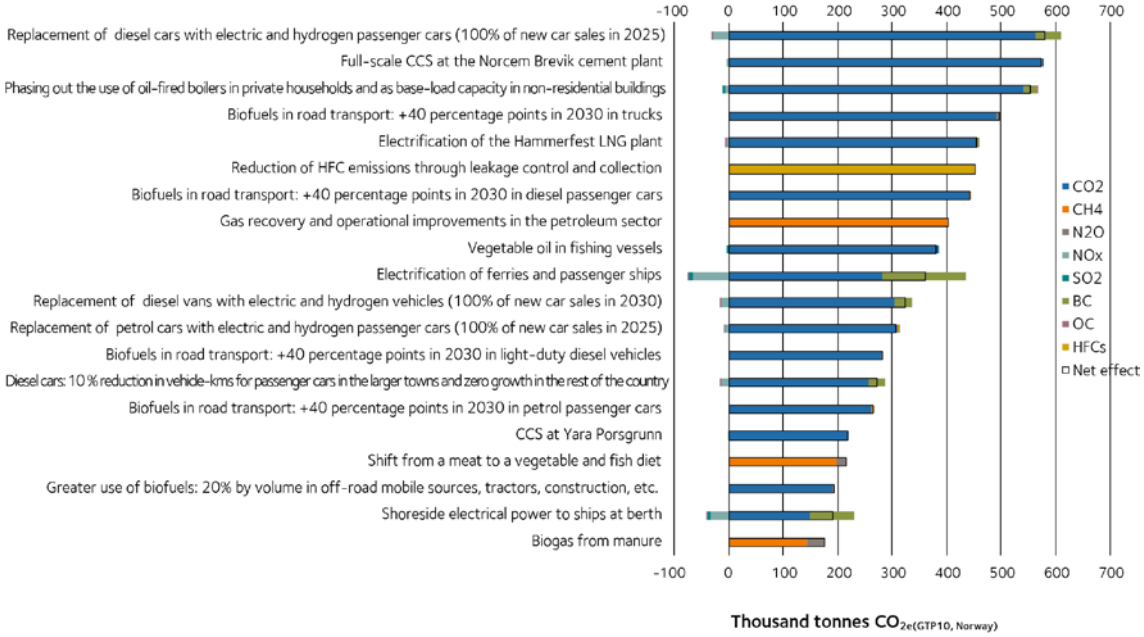

Figure S-2 The measures in the low-carbon transition report that have the largest net short-term climate effect. For each measure, the colours show the climate effect for the climate forcers whose emissions are altered by the measure. Units: 1000 tonnes $CO_{2e(GTP10,\ Norway)}$. Source: Norwegian Environment Agency

For several of the measures in the transport sector, it can be seen that the cooling effect of reducing BC emissions is to some extent counteracted by the warming effect of reducing NO_X emissions. NO_X emissions cause health and environmental problems, and Norway has undertaken commitments under the Gothenburg Protocol to reduce these emissions. This means that it is necessary to compensate for the effect of cuts in NO_X emissions by further steps to reduce emissions of climate forcers with a warming effect in order to achieve short-term climate benefits and at the same time meet Norway's commitments under the Gothenburg Protocol.

Measures in the low-carbon transition report have additional short-term climate effects

Figure S-3 shows the short-term climate effect of the measures as calculated in the present analysis (y-axis) plotted against their long-term climate effect as calculated in the low-carbon transition report (x-axis).

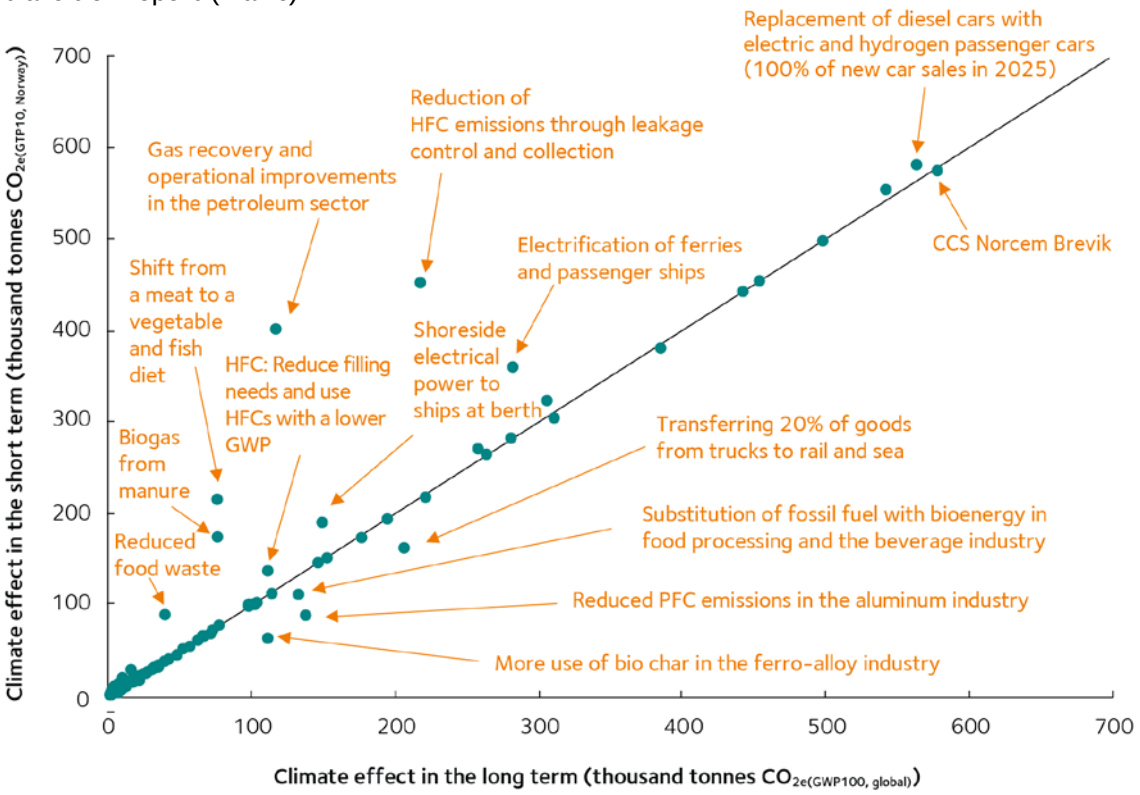

Figure S-3 Long-term (x-axis) and short-term (y-axis) climate effects of measures in the low-carbon transition report. Units: 1000 tonnes $CO_{2e(GWP100, global)}$ (x-axis) and 1000 tonnes $CO_{2e(GTP10, Norway)}$ (y-axis). Source: Norwegian Environment Agency

All the measures analysed in the low-carbon transition report give short-term climate benefits. In the figure, measures that primarily result in cuts in CO_2 emissions lie along the black line. This is because both short- and long-term climate effects are expressed in terms of CO_2 equivalents (CO_2 = 1).

Although this is a well-established method for calculating the climate effects of different climate forcers, it does not mean that the long-term and short-term climate effects of CO_2 emissions are really the same. The values shown on the two axes are therefore not comparable.

The measures that have the greatest climate effect in the sense the expression is used here are found in the top right corner of the figure. They are the replacement of diesel cars with electric and hydrogen passenger cars (100% of new car sales in 2025) and full-scale CCS at the Norcem Brevik cement plant in 2020.

The positions of the measures along the two axes are influenced by the assumptions on which the measures in mitigation package 3 in the low-carbon transition report were based. For

example, the calculations show that the emission reduction potential is greater if electric and hydrogen vehicles replace diesel vehicles than if they replace petrol vehicles. This is partly because the emission projections up to 2030 are based on the assumption that there will be more diesel than petrol vehicles.

The measures above the black line in Figure S-3 are those that have a short-term climate benefit in addition to their long-term climate effect. They include measures that reduce methane emissions (for example gas recovery and operational improvements in the petroleum sector, shift from a meat to a vegetable and fish diet, biogas from manure, reducing food waste), measures that reduce HFC emissions (leakage control and collection of HFCs and using HFCs with a low GWP), and measures that reduce BC emissions substantially more than emissions of climate forcers with a cooling effect (electrification of ferries and passenger ships, shoreside electric power to ships at berth).

Measures below the black line do not have additional short-term climate benefits. They include increasing the use of biochar in the ferro-alloy industry, replacing fossil fuels with bioenergy in the food and beverage industry, and transferring 20 % of goods from trucks to rail and sea. The reason is that these measures result in substantial increases in BC emissions. Reducing PFC emissions in the aluminium industry does not have additional short-term climate benefits either, because PFCs have a very long life-time in the atmosphere and their warming effect is stronger in the long term than in the short term.

Several of the measures from the low-carbon transition report also have health benefits

Figure S-4 shows the estimated health benefits of various measures on the x-axis and their short-term climate effect on the y-axis. The health effects of NO_X and PM_{10} were assigned monetary values, graded according to the number of people estimated to be exposed to the emissions. The measures in the top right-hand part of the figure were calculated to give the greatest health benefits and short-term climate effects.

Several of the measures in the transport sector have both short-term climate effects and health effects. Replacing diesel vehicles with electric and hydrogen vehicles was found to give the largest short-term climate effect and a substantial health benefit. Other road traffic measures such as replacing diesel vans with electric or hydrogen vehicles, replacing petrol cars with electric and hydrogen passenger cars and reduction and zero growth in vehicle-kilometres for passenger cars also have both short-term climate effects and health benefits. In the domestic shipping sector, electrification of ferries and passenger ships and a switch to shoreside electric power to ships at berth were also found to give health benefits and short-term climate effects. One of the assumptions in the analysis was that more people are exposed to emissions from ships in port than to emissions from ferries and passenger ships generally. However, the estimated health benefits from electrification of ferries and passenger ships are larger because this measure gives larger cuts in emissions. Ten measures in the transport sector account for about 90 % of the total health benefits.

Reductions in CO_2, CH_4 and HFC emissions are not considered to have health effects.[3] Measures that reduce these emissions are therefore on the y-axis. Measures that reduce NO_X and/or particulate emissions but only result in small reductions in emissions and/or reductions mainly outside urban areas where the emissions are not considered to result in damage to health lie close to the y-axis.

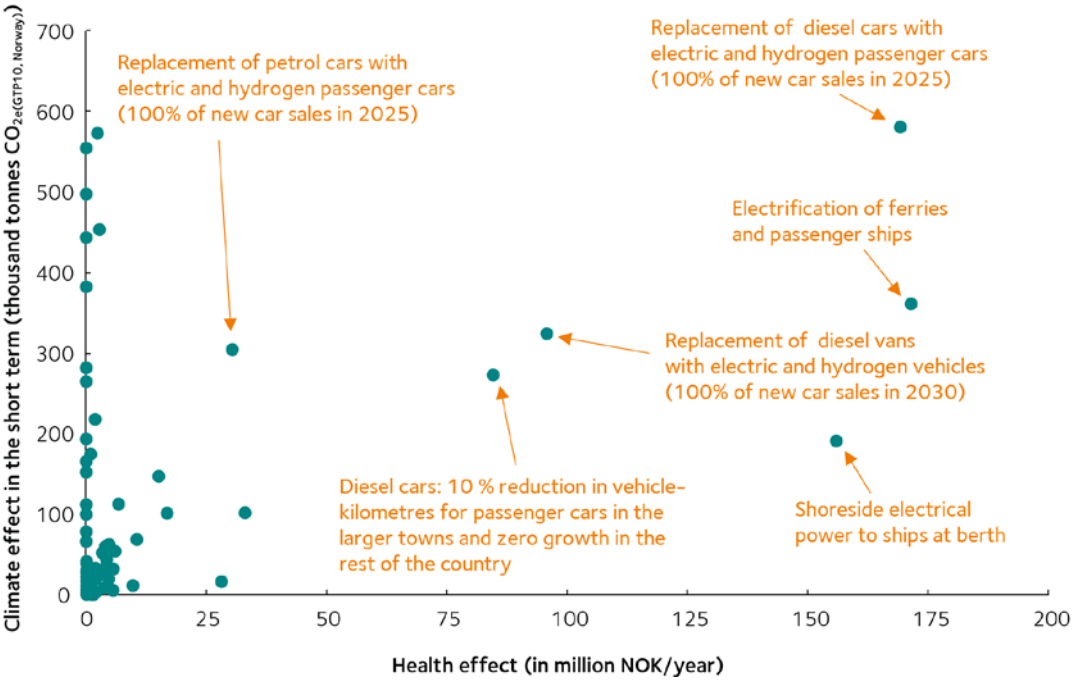

Figure S-4 Health effects (x-axis) and climate effects (y-axis) of measures from the low-carbon transition report. The effects are calculated for average emission cuts in the period 2016-2030. Unit x-axis: NOK million per year (not discounted). Unit y-axis: 1000 tonnes $CO_{2e(GTP10, Norway)}$. Source: Norwegian Environment Agency.

Combustion of wood-based energy carriers generally results in larger emissions of particulate matter (PM_{10}) than combustion of fossil energy carriers containing a corresponding amount of energy, even if the best available technology is used. It is therefore important to make use of technology and firing techniques that minimise particulate emissions, and at the same time be aware that oil and kerosene should not be replaced with wood and pellets in areas where this may cause damage to health. Some of the measures from the low-carbon transition report involve a switch from fossil to other energy carriers including wood-based energy carriers. We assumed that in cases where such measures target households, commercial buildings and the food and beverage industry, there will be a switch to other energy carriers such as electricity in densely populated areas, and the best available technology will be used. With these assumptions, the calculations show that the measures will not result in an increase in health problems.

The average monetary value of the health benefits of all the measures in the low-carbon transition report is estimated to be just over NOK 900 million per year. It should be noted that there is a high level of uncertainty in these calculations.

[3] Methane can have an indirect impact on health since it is an ozone precursor, but this is not included in the analysis.

Overall evaluation of the measures in the low-carbon transition report

We have made an overall evaluation of the measures in the low-carbon transition report, including both short-term and long-term climate effects and health effects. This has identified a number of 'win-win-win' solutions and also some possible conflicts between policy objectives, thus highlighting the need to coordinate policy instruments. The analysis has strengthened the basis for decision making in this field. In the low-carbon transition report, measures were divided into categories on the basis of their estimated cost and feasibility. The categories have not been updated on the basis of new information obtained from the present analysis. Because reductions of emissions that are harmful to health have now been assessed for all the measures, it is possible that some of them are more cost effective than the low-carbon transition report suggested.

Table S-1 lists the measures analysed in the low-carbon transition report that have been found in the present analysis to give the largest short-term climate effects, together with their long-term climate effects and health benefits. The measures are listed in descending order according to their short-term climate effects, and also include the measures from the low-carbon transition report that were found to give the largest health benefits.

Four of the measures from the low-carbon transition report were found to have medium to high short-term climate effects (see column 2) that are also high relative to the long-term climate effects (see column 4):

- reduction of HFC emissions through leakage control and collection;
- gas recovery and operational improvements in the petroleum sector;
- electrification of ferries and passenger ships:
- shift from a meat to a vegetable and fish diet.

The reduction of HFC emissions and electrification have medium long-term climate effects, while the other two measures, which primarily reduce methane emissions, have low-long-term climate effects.

Four other measures from the low-carbon transition report were found to have medium to high short-term (see column 2) and long-term (see column 3) climate effects combined with medium to high health benefits (see column 5); in other words, they are 'win-win-win' solutions:

- replacement of diesel cars with electric and hydrogen passenger cars (100 % of new car sales in 2025);
- electrification of ferries and passenger ships;
- replacement of diesel vans with electric and hydrogen vehicles (100 % of new car sales in 2030);
- diesel cars: 10 % reduction in vehicle-kilometres for passenger cars in the larger towns and zero growth in the rest of the country.

Three of these measures target diesel vehicles. In practice, electric and hydrogen vehicles can replace either petrol or diesel vehicles, depending on market conditions and the legislative and regulatory framework. Switching from petrol vehicles to electric and hydrogen vehicles will also give short- and long-term climate effects and health benefits.

One of the measures involves a reduction in vehicle-kilometres for diesel passenger cars. Reductions in vehicle-kilometres for both diesel and petrol vehicles may have several other benefits that have not been evaluated in this analysis. An effective land-use and transport policy for urban areas can reduce queuing and congestion, noise and accident costs, and also reduce the need for investment to increase road capacity.

Of the 20 measures listed in table S-1, 17 will give emission reductions in sectors not covered by the EU emissions trading system (EU ETS). In this connection, we refer to the white paper *New emission commitment for Norway for 2030 – towards joint fulfilment with the EU* (Meld. St. 13 (2014-2015), https://www.regjeringen.no/en/dokumenter/meld.-st.-13-20142015/id2394579/), in which the Government states that Norway will enter into a dialogue on collective delivery of its climate commitment together with the EU. In the EU system, each member state 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.

Table S-1: The measures analysed in the low-carbon transition report that have the largest short-term climate effects, together with their long-term climate effects and health benefits

Measure	Short-term climate effect (1000 tonnes $CO_{2eGTP10, Norway}$/year)*	Long-term climate effect (1000 tonnes $CO_{2eGWP100, global}$/year)*	Change in relative importance from $GWP_{100, global}$ to $GTP_{10, Norway}$**	Health benefits (NOK million/year) ***
Replacement of diesel cars with electric and hydrogen passenger cars (100 % of new car sales in 2025)	580	562	1.0	169
Full-scale CCS at the Norcem Brevik cement plant	574	577	1.0	2
Phasing out the use of oil-fired boilers in private households and as base-load capacity in non-residential buildings	553	541	1.0	0
Biofuels in road transport: +40 percentage points in 2030 in trucks	497	497	1.0	0
Electrification of the Hammerfest LNG plant	454	453	1.0	3
Reduction of HFC emissions through leakage control and collection	452	217	2.1	0
Biofuels in road transport: +40 percentage points in 2030 in diesel passenger cars	442	442	1.0	0
Gas recovery and operational improvements in the petroleum sector	401	117	3.4	0
Vegetable oil in fishing vessels	381	385	1.0	0
Electrification of ferries and passenger ships	360	281	1.3	171
Replacement of diesel vans with electric and hydrogen vehicles (100% of new car sales in 2030)	323	305	1.1	96
Replacement of petrol cars with electric and hydrogen passenger cars (100 % of new car sales in 2025)	306	309	1.0	31
Biofuels in road transport: +40 percentage points in 2030 in light-duty diesel vehicles	281	281	1.0	0
Diesel cars: 10 % reduction in vehicle-kilometres for passenger cars in the larger towns and zero growth in the rest of the country	271	257	1.1	85
Biofuels in road transport: +40 percentage points in 2030 in petrol passenger cars	265	263	1.0	0
CCS at Yara Porsgrunn	219	220	1.0	2
Shift from a meat to a vegetable and fish diet	216	76	2.9	0
Greater use of biofuels: 20 % by volume in off-road mobile sources, tractors, construction machinery, etc.	194	193	1.0	0
Shoreside electrical power to ships at berth	190	148	1.3	156
Biogas from manure	175	75	2.3	0

*Colour-coding of climate effects: high (dark green) – reductions > 400 000 tonnes $CO_{2e(GTP10, Norway)}$; medium (pale green) – reductions 200 000-400 000 tonnes $CO_{2e(GTP10, Norway)}$; low (yellow) – reductions < 200 000 tonnes $CO_{2e(GTP10, Norway)}$. The intervals used are the same as in the action plan.
**Colour-coding of additional short-term climate benefits: short-term climate effect high relative to long-term effect (dark green) – value > 1.2; short-term climate effect medium relative to long-term effect (pale green) – value 0.8-1.2.
*** Colour-coding of health benefits: high (dark green) – monetary value > NOK 100 million/year; medium (pale green) – NOK 50-100 million/year; low (yellow) – < NOK 50 million/year. The intervals used are the same as in the action plan.

Measures in the low-carbon transition report and the action plan are not mutually exclusive

The measures analysed in the action plan are designed to reduce emissions of short-lived climate forcers, whereas those analysed in the low-carbon transition report are intended to reduce emissions of the Kyoto gases. The action plan included a proviso that there may be other and better ways of reducing Norwegian emissions of short-lived climate forcers, since the analysis did not include typical 'CO_2 measures'.

Although the analyses in the low-carbon transition report and the action plan are not directly comparable, the present analysis indicates that overall, the measures in the low-carbon transition report would reduce emissions of short-lived climate forcers much less than those in the action plan. On the other hand, the estimated short-term climate effect of the measures in the low-carbon transition report is more than twice as large as the climate effect of the measures in the action plan. This is largely because the low-carbon transition report includes measures that will give large cuts in CO_2 emissions. The present analysis thus shows that the short-term climate benefits of measures designed to reduce Norwegian emissions of Kyoto gases may be just as great as those of measures designed to reduce Norwegian emissions of short-lived climate forcers. However, the health benefits of the measures in the low-carbon transition report are smaller than those of the measures in the action plan, since emissions of Kyoto gases do not have direct impacts on health.

Table S-2 shows the 18 measures analysed in the action plan. The right-hand column shows which of them overlap with measures in the low-carbon transition report.

Table S-2: Measures analysed in the action plan for short-lived climate forcers	
Measure	**Overlap with measures in the low-carbon transition report?**
1. Reduced food waste	✓
2. Accelerated introduction of new stoves and pellet burners	X
3. Energy efficiency in parts of industry	✓
4. Transition from red to white meat	✓
5. More efficient use and better inspection and maintenance of woodburning stoves	X
6. HFCs: reduce filling needs and use HFCs with a lower GWP	✓
7. Retrofitting of diesel particulate filters (DPFs) on construction machinery	X
8. Increased recovery of nmVOCs and methane when loading crude oil offshore	✓
9. Retrofitting and phasing in of DPFs on coastal vessels	X
10. Phasing in and retrofitting DPFs on fishing boats	X
11. Monitoring leak control and containment of HFCs	✓
12. Retrofitting and phasing in of DPFs on mobile rigs	X
13. Conversion to Freiland process in the silicon carbide industry	X
14. Retrofitting of DPFs on light vehicles	X
15. Phasing in biogas from manure on buses	✓
16. Retrofitting of DPFs on tractors	X
17. Phasing in biogas from food waste on buses	X
18. Retrofitting of DPFs on heavy vehicles	X

The table shows that seven of the measures in the action plan overlap with measures in the low-carbon transition report (indicated by green ticks in column 2). The low-carbon transition report included updated mitigation analyses and adjustments to new baseline projections, and changes in the ambition level for some of the measures. The remaining measures in the table above (red crosses in column 3) do not overlap with measures in the low-carbon transition report since they are largely designed to reduce BC emissions.

The present analysis shows that there are very few cases where measures in the low-carbon transition report and measures in the action plan are mutually exclusive. This is because the two sets of measures generally do not target exactly the same emissions. For example, retrofitting diesel particulate filters (DPFs) targets the existing vehicle stock, whereas phasing in electric vehicles targets new sales. It is also possible, for instance, to combine greater use of biofuels with retrofitting DPFs on diesel vehicles. Thus, the measures in the action plan will result in additional emission reductions if they are implemented as well as the measures from the low-carbon transition report. The only exception is that it is not possible to combine retrofitting and phasing in DPFs on coastal vessels and electrification of ferries and passenger ships on the same vessels.

The action plan presents five possible emission reduction strategies. The strategy with the largest number of criteria includes measures that have a moderate to high short-term climate

effect, a moderate to high health effect, and satisfactory cost effectiveness and emission reduction effectiveness. Three measures were identified that fitted this strategy:

- accelerated introduction of new stoves and pellet burners;
- retrofitting of DPFs on construction machinery;
- retrofitting of DPFs on light vehicles.

The first of these is still considered to be important as a means of achieving short-term climate effects and health effects. Old woodburning stoves and pellet burners can be replaced independently of the measures included in the low-carbon transition report. Norway's updated cross-party agreement on climate policy (published in a recommendation to the Storting, Innst. 390 S (2011-2012)) includes the introduction of a ban on using fossil fuels for heating in private households and to provide base-load capacity in other buildings in 2020. If wood products are used to replace fossil oil and kerosene, it will also be important to implement the two measures dealing with woodburning stoves (accelerated introduction of new stoves and pellet burners, and more efficient use and better inspection and maintenance of woodburning stoves).

It is also still considered important to retrofit DPFs on construction machinery as a way of achieving short-term climate effects and health effects. The measure from the low-carbon transition report includes a measure involving greater use of biofuels for construction machinery, and this can be combined with retrofitting DPFs.

The time window for retrofitting DPFs on light vehicles will soon be closing. New diesel vehicles have factory-fitted DPFs, and the proportion of vehicles without them is dropping.

In addition, retrofitting and phasing in DPFs on coastal vessels (from the action plan) may become increasingly relevant if 20 % of goods transport is transferred from truck to rail and sea (measure from the low-carbon transition report). It has been calculated that the latter will result in higher BC emissions, and the effect can be counteracted by fitting DPFs.

Uncertainty

The low-carbon transition report includes an evaluation of uncertainties associated with the technological maturity, feasibility and costs of the different measures. The largest uncertainties, particularly in the present analysis, are related to estimates of emission reductions, the monetary valuation of health effects, and the immaturity of the scientific basis for quantifying the climate effects of BC.

The present analysis shows that the road transport measures analysed in the low-carbon transition report only give limited reductions in BC emissions. This is because BC emissions fall sharply in the period up to 2030 according to baseline projections. The emission figures in the baseline scenario are based on data from standardised test cycles for a selection of vehicle types in use in Europe. The data are used to derive emission factors for various combinations of speed, acceleration, traffic density, etc. that are representative of the Norwegian vehicle stock and Norwegian driving patterns. If it turns out in the future that particulate and NO_X emissions from diesel vehicles are higher than estimated using the

standardised driving cycles, the emission reductions achieved by replacing diesel vehicles with electric and hydrogen vehicles will be greater than estimated in the present analysis.

There is considerable uncertainty as regards the emission reductions that can be achieved by phasing out the use of oil-fired boilers in private households and as base-load capacity in non-residential buildings. This is mainly because it is uncertain how high the consumption of oil and kerosene will be in the future without the introduction of new measures. Other projections than the reference projections used here are based on the assumption that oil and kerosene will be phased out more rapidly. The effect of switching from fuel oil and kerosene to biofuels on particulate and NO_X emissions is also uncertain.

We did not have the necessary basis for estimating changes in particulate and NO_X emissions as a result of greater use of biofuels in the transport sector. We therefore assumed that implementing measures involving greater use of biofuels will not reduce emissions of NO_X, PM_{10}, BC, OC and SO_2. A sensitivity analysis of the two measures in the transport sector that were found to give the largest emission reductions shows that a ±20 % change in the emission factors for these emission components does not result in any appreciable change in the short-term climate effect. However, the health effects do change markedly.

There is considerable uncertainty regarding the valuation of health effects. The calculations are based on figures for their monetary value (NOK per tonne reduction in NO_X and PM_{10} emissions) that are themselves uncertain. These figures are based on estimates of the cost of damage caused by local air pollution, and provide only a simplified picture of the health effects of a measure. However, this is a form of uncertainty that is common to many analyses involving valuation of health benefits. In the present analysis, there is also uncertainty as regards the number of people expected to be affected by changes in NO_X and particulate emissions, since the geographical distribution of emission reductions is difficult to estimate for several of the measures. The geographical distribution of emission reductions (whether they will occur mainly in towns, built-up areas or rural areas) has considerable implications for the valuation process. A sensitivity analysis indicates that changes in the monetary values used have a substantial effect on the estimated health effects.

There is still considerable uncertainty regarding the short-term climate effect of BC. The emission metric used for BC in this analysis was updated in line with recent research results. However, a sensitivity analysis indicates that the updated factor has little effect on the results.

An integrated analysis provides a better basis for decision making

This report presents an analysis of the effects of the measures in the low-carbon transition report with respect to both climate and air pollution. We have assessed both short-term and long-term climate effects, taking both warming and cooling effects of the measures into account to find the net climate effect. Carrying out an integrated analysis has made it possible to identify advantages and possible disadvantages of some of the measures in a way that would not otherwise have been possible.

The analysis shows that several of the measures in the transport sector will have health benefits. It also shows that if the assumptions underlying the analysis are changed, certain

measures that have a large climate effect may have negative health effects. These include measures involving a switch from fossil energy carriers to wood-based and other energy carriers. Identifying the negative health effects of measures makes it clearer where there is a need to adjust their design to minimise negative effects or use other measures to compensate for negative health effects.

Last but not least, the analysis makes it possible to take into account the short-term climate effects of measures and the contribution they can make in reducing the rate of warming when assessing which measures to implement and when.

The analysis also enables us to select measures that have positive effects with respect to both climate and health, and to optimise performance in several areas at once. We therefore consider that it gives a better basis for selecting measures and making decisions on implementation.

This analysis considers the short-term climate effects and health effects of measures designed to reduce Norway's greenhouse gas emissions. This methodological approach can also be useful for other countries, although the results of the analysis cannot necessarily be extrapolated to other parts of the world. Other countries may have different emission levels for both Kyoto gases and short-lived climate forcers. The health effects of emission reductions will also depend on population density. Moreover, the emission metrics for short-lived climate forcers, especially BC, may be different from those used for Norwegian emissions depending on a country's geographical location.

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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.