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Knowledge base for low-carbon transition in Norway

Summary

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Knowledge base for low-carbon transition in Norway. Summary

Summary - sammendrag

This is the English edition of the summary of a report submitted by the Norwegian Environment Agency to the Ministry of Climate and Environment. The report describes positive global trends in emissions and contains a sector-by-sector mitigation analysis of Norway's transition to a low-carbon society, using the emission reductions the IPCC identifies as necessary to achieve the two-degree target in its Fifth Assessment Report. Further, the report describes what can be done in Norway to achieve these emission reductions, and reviews measures that can be implemented by 2030. The measures are divided into mitigation packages on the basis of assessments of their costs and feasibility. Possible consequences of the measures for the energy sector are discussed.

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Summary

This report on Norway's transition to a low-carbon economy completes the second 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 on a scientific basis for further development of Norwegian and international climate policy in March 2014 (Norwegian Environment Agency 2014). The mandate for the second phase of the project (19 March) specify that the Ministry wishes to receive scientific input for the process of developing a new international climate commitment for Norway and a basis for strengthening the national cross-party agreement on climate policy. By the end of the first quarter 2015, Norway is to submit to the UN a preliminary target for its cuts in greenhouse gas emissions for the period after 2020, with 2025 or 2030 as possible target years. The Ministry requested the Environment Agency to make a scientific assessment of the emission levels necessary for Norway to be a low-carbon society in 2050 and to present emission trajectories consistent with achieving this. The Environment Agency was also asked to analyse different options for emission levels in 2025 and 2030 and the costs and consequences of achieving these levels.

This report is based on the assumption that there will be continued economic growth in Norway, in line with the projections presented in the white paper *Long-term Perspectives on the Norwegian Economy 2013 (Meld. St. 12. (2012-2013))*. In other words, reduced economic growth has not been included as a possible measure for reducing Norway's greenhouse gas emissions. Norway's current industrial structure was used as a starting point, but the report describes the need for structural measures and technological advances. The consumption patterns of the Norwegian population may influence emission levels in the future. Changes in consumption patterns were considered to some degree as possible mitigation measures in certain sectors, but the project did not include a complete analysis of the effect of changing consumption patterns. Since the project was intended to provide a basis for setting a new Norwegian climate commitment, the main focus was on how to reduce emissions from Norwegian territory. However, national measures and policy instruments have also been considered in a long-term global context.

The time frame for the second phase of the project was barely five months, which meant that it was necessary to limit the scope of the report. There was little opportunity to obtain new information or review new measures, and the report is largely based on already available up-to-date information. Whenever practicable, the Environment Agency has worked with relevant government agencies and others in order to draw up the best possible factual basis in the form of technological assessments and descriptions of mitigation measures. The Environment Agency is entirely responsible for the published report. The report does not contain policy proposals, but provides a scientific basis for decision making.

Climate change

The Intergovernmental Panel on Climate Change (IPCC) has been publishing its Fifth Assessment Report (AR5) in parts in the course of 2013 and 2014. This is the most comprehensive assessment of the state of scientific knowledge about climate change that has been undertaken. Compared with earlier assessment reports, AR5 concludes more clearly and definitely that the climate is changing, and states that it is 'extremely likely' (95—100 %) that human influence has been the dominant cause of the observed warming between 1951 and the present day. Measurements since the late 1800s show that the globally averaged surface temperature rose by 0.85 ^{o}C from 1880 to 2012. Each of the most recent three decades has been successively warmer than the previous one, and they have all been warmer than any earlier decade since 1850.

According to the IPCC, greenhouse gas emissions are continuing to rise. In 2010, global emissions totalled 49 billion tonnes CO_2 equivalents (CO_2-eq), as against 27 billion tonnes CO_2-eq in 1970. Without additional mitigation efforts, we are heading for a situation where the world may be 3.7 to 4.8 degrees warmer than in the pre-industrial era by the end of this century. This would have very severe impacts that might be irreversible. A large temperature rise may result in greater damage from flooding and erosion in coastal areas, and mean that more people are affected by major river floods. In towns, extreme precipitation events and landslides will represent a risk to buildings and other infrastructure and to life and health. The extent of the Arctic sea ice will continue to decline, and the ice will become thinner throughout the year. The loss of mass from glaciers and ice sheets in various parts of the world will continue. Average sea level will continue to rise. Ocean acidification will continue through this century as the atmospheric CO_2 concentration rises, and will in turn have impacts on marine ecosystems. Human society will not be able to adapt to all the changes in the world we are creating if current emission trends continue.

Status of efforts to mitigate climate change

Through international negotiations, world leaders have adopted the target of limiting the rise in global mean temperature to no more than two degrees Celsius (known as the two-degree target). According to the IPCC, the atmospheric concentration of greenhouse gases must be limited to between 430 and 480 ppm CO_2-eq to ensure that the probability of achieving this target is more than 66 %; this is known as the 450 ppm scenario.[1] The IPCC Fifth Assessment Report includes more discussion about emission reductions after 2050 and up to 2100 than the Fourth Assessment Report, which was published in 2007 (IPCC 2007). Many of the climate models that have been used include the option of a combination of temporary overshoot and net negative emissions. This means that the atmospheric concentration of greenhouse gases is permitted to exceed the upper limit of 480 ppm CO_2-eq for a short period in scenarios for achieving the two-degree target, and to compensate for this, there are net negative global emissions towards the end of the century. Possible ways of achieving this are large-scale production of bioenergy combined with carbon capture and storage (CCS) to remove CO_2 from combustion, or large-scale afforestation.

Large-scale energy production based on biomass would necessitate very challenging global transformational change, including afforestation of large areas, and this could come into conflict with goals such as sufficient food production in a world with a growing population. To avoid land-use conflicts and minimise dependence on technology that is not yet mature, the rising emission trend must be reversed before 2030.

Intensive efforts are now being made to reach agreement on a new global climate deal in Paris in 2015. The objective is an agreement that sets binding emission commitments for all the major

[1] By way of comparison, the concentration in 2011 was 430 ppm CO_2-eq (uncertainty range 340–520 ppm). The uncertainty range is so large mainly because of uncertainty about the effects of aerosols.

emitting countries. This would have to include some supranational elements and provisions. However, the outcome of the negotiations is extremely uncertain, and the extent to which the new agreement should include a supranational structure is one of the most controversial points. One possible outcome is a new agreement that is politically binding but not necessarily binding legally or under international law. This type is often called a 'bottom-up agreement'. In this case, each country would determine an emission target arrived at through its own domestic processes. This is in contrast to the top-down approach of the Kyoto Protocol. It is quite possible that an agreement reached in Paris will not reflect an overall level of ambition in line with the two-degree target. A new agreement will apply to the period after 2020. However, the IPCC points out in AR5 that the international commitments for the period up to 2020, which were agreed in Cancun in 2010, are not sufficient to achieve the two-degree target.

Positive global trends

Despite the continued rise in global greenhouse gas emissions and the uncertainty surrounding the climate negotiations, there are some positive trends. These must be reinforced if the world is to avoid the most serious consequences of climate change. Progress in the climate negotiations is dependent on some countries and regions leading the way and developing both climate policy and solutions for dealing with climate change. Other countries can then emulate policies work well and avoid those that prove not to function. Deployment of new technologies in some countries can bring down mitigation costs considerably, thus making it easier for other countries to follow suit.

With its **Energiewende**, or Energy Transition, Germany is playing a pioneering role in transformation of the electricity supply system. In 2010, Angela Merkel's government introduced ambitious targets, with several milestones for the share of renewable electricity production to be achieved: 40—45 % by 2025, 55—60 % by 2035 and at least 80 % by 2050. The most important energy policy instrument in Germany has been feed-in tariffs for renewable energy. The results are impressive, with 40 000 wind turbines and more than 1.4 million solar energy systems by the end of 2013. Large-scale development of solar and wind power has resulted in much lower prices for these technologies than only a few years ago.

There are strong indications that a transformational change in renewable power production is imminent. The IPCC highlights decarbonisation of electricity generation as a vital measure for achieving the two-degree target. In 2013, 22.1 % of global electricity production was renewable, including 16.4 % hydropower, 2.9 % wind power, 1.8 % biomass, 0.7 % solar PV and 0.4 % other sources such as geothermal energy and concentrated solar power (CSP) (IEA 2013). Although solar and wind power still only account for a small share, growth in installed capacity has been far stronger than expected. The price of solar PV cells has fallen by half since 2008. Wind power capacity in the US has grown by a factor of three since 2008, and by 2013 the country's total installed capacity had reached the equivalent of 60 large nuclear power plants. In China, 68 % of the capacity installed in 2013 was renewable. Most of this was hydropower, but there was also substantial wind and solar PV capacity. China is now the world's largest producer of solar PV cells, and Bloomberg New Energy Finance predicts that by 2020, most new installed capacity in China will be solar (Liebreich 2014).

The power supply has traditionally been dominated by large centralised power plants, often coal-fired, which generate power and distribute it to customers, which is a one-way process. This system is increasingly being supplemented by small-scale electricity generation. Private households and companies that install solar panels on the roof can produce some of their own electricity and also sell excess power back to the grid.

The performance of electric vehicles is approaching that of diesel and petrol vehicles, and the price differential is gradually shrinking. According to the US Department of Energy, production costs for batteries that are sold on a large scale have been halved in the past four years. The Department's goal is to achieve further reductions in costs, so that electric cars with a range of 450 km cost the same as standard petrol and diesel vehicles by 2022. California has set a target of 1.5 million zero-emission vehicles on the roads by 2015. China is also focusing on 'new energy vehicles'. The authorities have set a target of 5 million new energy vehicles (electric, hydrogen and hybrid vehicles) on the roads by 2020. In summer 2014, it was decided that buyers of new vehicles of these types would not have to pay purchase tax, which accounts for 10 % of the net value of the vehicle. This exemption will apply until the end of 2017 (The Guardian 10.07.14). In addition, the authorities offer outright subsidies to buyers of electric cars.

One important recent trend has been the growing focus on **climate change risk and carbon risk by financial institutions**, and the increasing popularity of 'green' investment. More and more investors are calling for clearer, longer term climate policies that can reduce the risk of investing in low-emission technology and infrastructure. Another trend that illustrates the shift in financial markets is the growth of a market for 'green bonds'. In 2013, over USD 10 billion was issued in green bonds, and it is estimated that this will rise to about USD 50 billion in 2014. However, this is still a very small proportion of the total market (The Economist 05.07.14).

In China, air quality problems are so serious that they are now at the top of the political agenda. The need to reduce local air pollution is one of the main reasons behind the goals China has set for reducing coal consumption and emissions from the transport sector.

In the US, the Obama administration has chosen to use the Clean Air Act to tighten up emission and fuel-economy standards for vehicles and to limit emissions from the power sector. On 2 June 2014, the **US Environmental Protection Agency (EPA) put forward the Clean Power Plan**, with proposals for new rules on CO_2 emissions from power plants. The goal is to cut emissions from the power sector by 30 % relative to 2005 by 2030. According to EPA, this is equivalent to the emissions from 150 million cars.

Ambitious climate policies in Europe

In 2009, the EU adopted a comprehensive package of climate and energy legislation. The EU's long-term objective is to cut greenhouse gas emissions by 80—95 % by 2050 relative to the 1990 level. Reductions of at least 80 % are to be achieved in the form of cuts within the EU, while the rest can be achieved by using the flexible mechanisms (providing funding for measures to cut emissions in other countries). The EU is now drawing up new targets and policy instruments for the period after 2020. On 3 March 2014, the European Commission put forward a proposal for reducing EU emissions by 40 % by 2030. To achieve this, sectors covered by the EU emissions trading system (EU ETS) would have to reduce their emissions by 43 % and emissions from sectors outside the EU ETS would need to be cut by 30 %. According to the proposal, this is to be achieved entirely through cuts within the EU, without any use of international emission credits. The proposal also includes the retention of a common target for increasing the share of renewable energy and increasing energy efficiency. It is expected that a decision on the overall targets will be taken at the European Council meeting on 23—24 October.

Germany's target is to reduce its greenhouse gas emissions by 40 % from 1990 to 2020. Its official 2050 target is to cut greenhouse gas emissions by 80—95 % compared with the 1990 level, and to increase the renewable share of electricity consumption to 80 %. In addition, energy use is to be cut by half.

The UK's target is to reduce greenhouse gas emissions by 80 % (from the 1990 baseline) by 2050. This was made legally binding in the Climate Change Act, which includes requirements for the government to draw up carbon budgets for succeeding five-year periods. Carbon budgets have so far been set for four periods, the latest covering the period 2023—27. This budget requires a 50 % reduction in UK greenhouse gas emissions by 2027 relative to the 1990 level. The Act allows for the use of international carbon units to achieve the targets, but states that a limit must be set on the amount of carbon units that may be used at least 18 months before the beginning of a budgetary period.

In **Denmark**, the Government presented its Climate Policy Plan in 2013. The overall target is to cut emissions by 40 % by 2020 compared with the 1990 level. Denmark has not formulated a specific target for 2050, but the entire energy supply including transport energy consumption is to be based on renewable energy by 2050. In addition, the policy plan specifies that Denmark's long-term goal is to contribute to the EU target of cutting emissions by 80—95 % by 2050.

Sweden's long-term vision is to have no net emissions of greenhouse gases in 2050, and the country also has a target of reducing emissions by 40 % by 2020 relative to the 1990 level. The extent to which international carbon units can be used is not quantified in Sweden's report on a basis for a roadmap for a Sweden without greenhouse gas emissions in 2050. Sweden's 2020 target applies only to the non-ETS sector of the economy (about 30 % of Sweden's emissions are from the ETS sector), and excludes emissions and removals from land use, land use change and forestry (LULUCF). As part of its climate policy, Sweden has also set an upper limit on the use of international carbon units to achieve this target (a maximum of 6.7 million tonnes, corresponding to one third of the overall reduction target for 2020).

Emission trends in Norway

The preliminary greenhouse gas inventory for 2013 shows that Norwegian greenhouse gas emissions totalled 52.8 million tonnes CO_2-eq. Emissions have risen by 4.6 % since 1990, when the corresponding figure was 50.4 million tonnes CO_2-eq.

Without the policy instruments that have been introduced since 1990, the rise in emissions would have been considerably greater. Norway's sixth national communication under the Climate Change Convention (Ministry of Climate and Environment 2014) discusses the effects of a range of policy instruments and measures, and estimates that if they had not been implemented, emissions would have been 12.6—15.3 million tonnes CO_2-eq higher in 2010.

Figure 0-1 shows historical emissions from 1990 onwards and the emissions projections up to 2050 that have been used in the mitigation analysis for each sector. The projections are based on the national projections for emissions to air published in the white paper *Long-term Perspectives on the Norwegian Economy 2013 (Meld. St. 12. (2012-2013))*. The figure for total emissions corresponds to that presented in the white paper, but the Environment Agency has split the total to give estimated emissions by source.

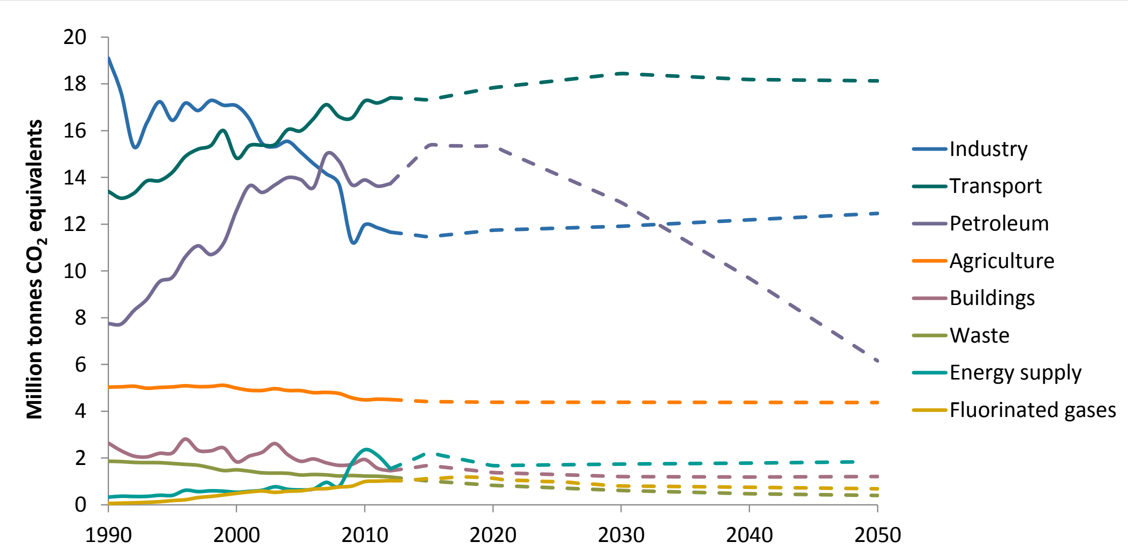

Figure 0-1 Norway's greenhouse gas emissions split by sector for the period 1990–2050. Million tonnes CO_2-eq.

New projections for the period up to 2030 were published in connection with the 2015 budget. This work was carried out at the same time as the Environment Agency was conducting the analyses described here, and it was therefore not possible to take the new projections into account. They show somewhat lower emissions in 2020 and 2030 than the projections published in the white paper.

According to the projections used here, Norway's greenhouse gas emissions will increase by 1.8 million tonnes CO_2-eq from 2012 to 2020 (rising to 54.5 million tonnes CO_2-eq), and then decrease by 2.2 million tonnes CO_2-eq up to 2030. From 2030 to 2050, total emissions are projected to decline further by 6.2 million tonnes CO_2-eq (to 46.1 million tonnes CO_2-eq). The main explanation for these changes is that emissions from the oil and gas sector are expected to rise until 2020 and then decline during the rest of the period up to 2050. Emissions from transport and industry are expected to rise somewhat up to 2050. However, projections for such a long period are very uncertain.

What effect will the cross-party agreement on Norwegian climate policy have in 2030?

In 2008, most of Norway's political parties signed an agreement on national climate policy, and this was updated in 2012 after a new white paper on climate policy was published (Ministry of the Environment 2012). The Environment Agency's report from the first phase of this project (Norwegian Environment Agency 2014) is based on the assumption that Norwegian emissions must be reduced to 42–44 million tonnes CO_2-eq by 2020 in order to achieve the targets of the cross-party agreement, if CO_2 uptake in forests is not included. It also assumes that 3 million tonnes CO_2-eq will be eligible for inclusion in Norway's greenhouse gas inventory, so that Norwegian emissions must be reduced to 45–47 million tonnes CO_2-eq in 2020 if CO_2 uptake in forests is not included.

The mitigation measures reviewed in the Environment Agency's report from the first phase were estimated to give emission reductions of 4.9–8.4 million tonnes CO_2-eq compared with the reference scenario for 2020. The report concluded that it will be necessary to achieve overall cuts in the upper part of this range to ensure that it is very likely that the targets of the cross-party agreement will be achieved. This would require the introduction of more and stronger policy instruments than those currently in use.

This report on the second phase of the project contains an overall assessment of the emission reductions that can be expected by 2030 if the mitigation measures identified as needed to achieve the targets of the cross-party agreement for 2020 are maintained until then. The conclusion is that the effect of these measures would be fairly constant throughout the period up to 2030, and that emissions would be an estimated 5—8 million tonnes CO_2-eq lower in 2030 than without the effects of the cross-party political agreement. In addition, expected trends that are already included as part of the basis for the projections should result in a further reduction of about 2 million tonnes CO_2-eq by 2030. It is therefore expected that Norway's total emissions in 2030 will be about 45 million tonnes CO_2-eq if the mitigation measures for achieving the targets of the cross-party agreement are implemented.

If the targets of the cross-party political agreement are not achieved until a couple of years after the 2020 deadline, this will not necessarily alter emission levels in 2030 substantially, provided that most of the mitigation measures are implemented as quickly as possible. In the transport sector, an early start will increase the potential for later cuts in emissions, since it takes time to develop and deploy new technology and carry out major infrastructure projects. Moreover, it is less difficult and costly to ensure that new oil and gas installations are supplied with electricity generated onshore as soon as they are operative than to carry out electrification projects later. Any delays in achieving the targets of the cross-party agreement will result in an increase in cumulative greenhouse gas emissions to the atmosphere.

Norway's transition to a low-carbon society

The overall approach in this phase of the project was to describe Norway as a low-carbon society, on the assumption that emissions in the rest of the world are also being reduced in line with the two-degree target. This was done partly from a top-down perspective, with the emission reductions the IPCC considers necessary to avoid the most serious impacts of anthropogenic climate change as a starting point, and partly through a sector-by-sector mitigation analysis of Norway's transition to a low-carbon society, describing options for reducing emissions in the period up to 2050.

According to the emissions trajectories presented by the IPCC, global average per capita emissions must be reduced to between 1.5 and 3.1 tonnes CO_2-eq. Factors such as economic growth, population growth, industrial structure and international trade influence the level of emissions in different countries and regions. The report discusses the possible effects of such factors in Norway in greater depth.

If Norway is to reduce its emissions to the global average range consistent with the two-degree target, i.e. 1.5—3.1 tonnes per head, total emissions must be cut from the current level of 52.7 million tonnes CO_2-eq to 10.2—20.4 million tonnes CO_2-eq, assuming that the population rises to 6.6 million. This is equivalent to cutting emissions by 60—80 % relative to the 1990 level.

According to current knowledge, uncertainty about whether emissions can be reduced to very low levels by 2050 is highest for the agricultural, industrial and petroleum sectors.

- Given the current self-sufficiency ratio and the projected population growth, emissions from **agriculture** may be of the order of 3—4 million tonnes CO_2-eq in 2050 after further mitigation measures have been implemented.
- The level of **industrial** emissions is uncertain because of the need for technological innovation. If technologies for carbon capture and storage or other technologies that give equivalent reductions in process emissions become available, it may be possible to cut emissions from this sector to 2—3 million tonnes CO_2-eq by 2050. This would require a wide range of long-term, targeted R&D initiatives.
- The level of emissions from the **petroleum** sector is also uncertain, but in this case the uncertainty is related more to costs (electrification of existing installations that are expected to have a long lifetime) rather than to the development of new technology.

There have been rapid technological advances in recent years in the transport sector, and it should therefore be possible to achieve very low emissions from the transport sector in 35 years' time. It is also likely that very low emissions can be achieved in other sectors in 2050.

The overall conclusion of this review is that it is likely to be possible to reduce Norway's emissions to around 7—12 million tonnes CO_2-eq in 2050. Assuming a population of 6.6 million in 2050, this corresponds to per capita emissions of 1—2 tonnes CO_2-eq.

However, it will be a very challenging task for Norway to reduce emissions to this extent unless other countries are also pursuing an ambitious climate policy. Norway will for example be dependent on vehicle technology and carbon capture and storage technologies that are being developed internationally. In the same way, other countries can benefit from what Norway achieves. Norway can influence these developments, but not steer them alone. At the same time, any delay to the transition to a low-carbon society will involve a risk of lock-in to emission levels that can be difficult to reduce afterwards. One option for avoiding lock-in is to supply new oil and gas installations on the continental shelf with electricity generated onshore. Another is to construct infrastructure such as roads and buildings in a way that reduces transport needs in the long term. It should also be noted that replacing a country's fleet of vehicles takes time. For example, the average lifetime of passenger cars in Norway is 18.4 years. This means that to achieve a Norwegian car fleet with virtually zero emissions in 2050, the last petrol and diesel cars must be sold in 2031.

Implementing the measures quantified in this report for the LULUCF sector could increase net uptake of greenhouse gases by roughly 3 million tonnes CO_2-eq per year in 2050 compared with the figure in the projections used as a basis here. The projections for this sector show an estimated carbon uptake of about 16 million tonnes CO_2-eq in 2050 as a result of earlier active forest management.

Possible emission levels in 2030

A large number of mitigation measures in various sectors were reviewed to assess possible emission levels in 2030. Within each sector, measures were evaluated according to their estimated cost effectiveness and feasibility. These evaluations were based largely on already available up-to-date information, since there was little opportunity to review new types of measures during the preparation of the report. Because of the high level of uncertainty in the cost calculations, it was decided to divide the measures into cost categories rather than quoting specific costs for each measure. The three categories chosen were less than NOK 500, NOK 500—1500 and more than NOK 1500 per tonne CO_2-eq. The feasibility of the measures was evaluated on the qualitative scale high—medium—low, on the basis of:

- the maturity of the technology involved;
- whether a suitable policy instrument (or more than one) is already available or can be implemented to ensure that the measures are carried out. To identify the most suitable instrument in each case, they were assessed according to:
    - their effectiveness – how certain is that a policy instrument will lead to implementation of the measure and bring about the estimated reduction in emissions?
    - their distributional effects – will some groups be particularly severely affected, or will the costs be split between a large number of people (for example through the government budget)?
    - the administrative costs of the instrument – for example, regulating many small sources of emissions individually involves high administrative costs, in addition to the costs of the measure itself.

There may also be other reasons why a particular measure is difficult to implement. In a report published in 2010 (Klimakur 2020. 2010)on measures and instruments for achieving Norway's climate targets by 2020, a distinction was made between social and private costs in reviewing many of the measures, because measures that have low social costs may have high costs for individuals or businesses, and strong policy instruments will therefore be needed to ensure that they are implemented. It was not possible to review such costs within the time frame for this project, so that it is difficult to assess whether high private costs are a barrier to implementing measures. Other possible reasons for difficulties in implementing measures are that they come into conflict with other political goals or that they require large-scale projects involving cooperation between a range of actors. Examples of the latter are electrification projects for whole areas of the continental shelf in the petroleum industry and shifting goods transport from road to rail and sea.

On the basis of the evaluation of costs and feasibility, three mitigation packages have been put together. They are presented in Figure 0-2. Most of the measures in mitigation package 1 have an estimated cost of less than NOK 500 per tonne CO_2-eq and are in the high feasibility category. Mitigation package 2 also includes measures that have an estimated cost of NOK 500—1500 per tonne CO_2-eq and are in the medium feasibility category. Mitigation package 3 includes almost all the measures that have been reviewed. The figure shows emission reductions for the three packages in tonnes CO_2-eq, adjusted for overlap between the effects of different measures. Estimates of future emission levels are based on the emission projections currently in use.

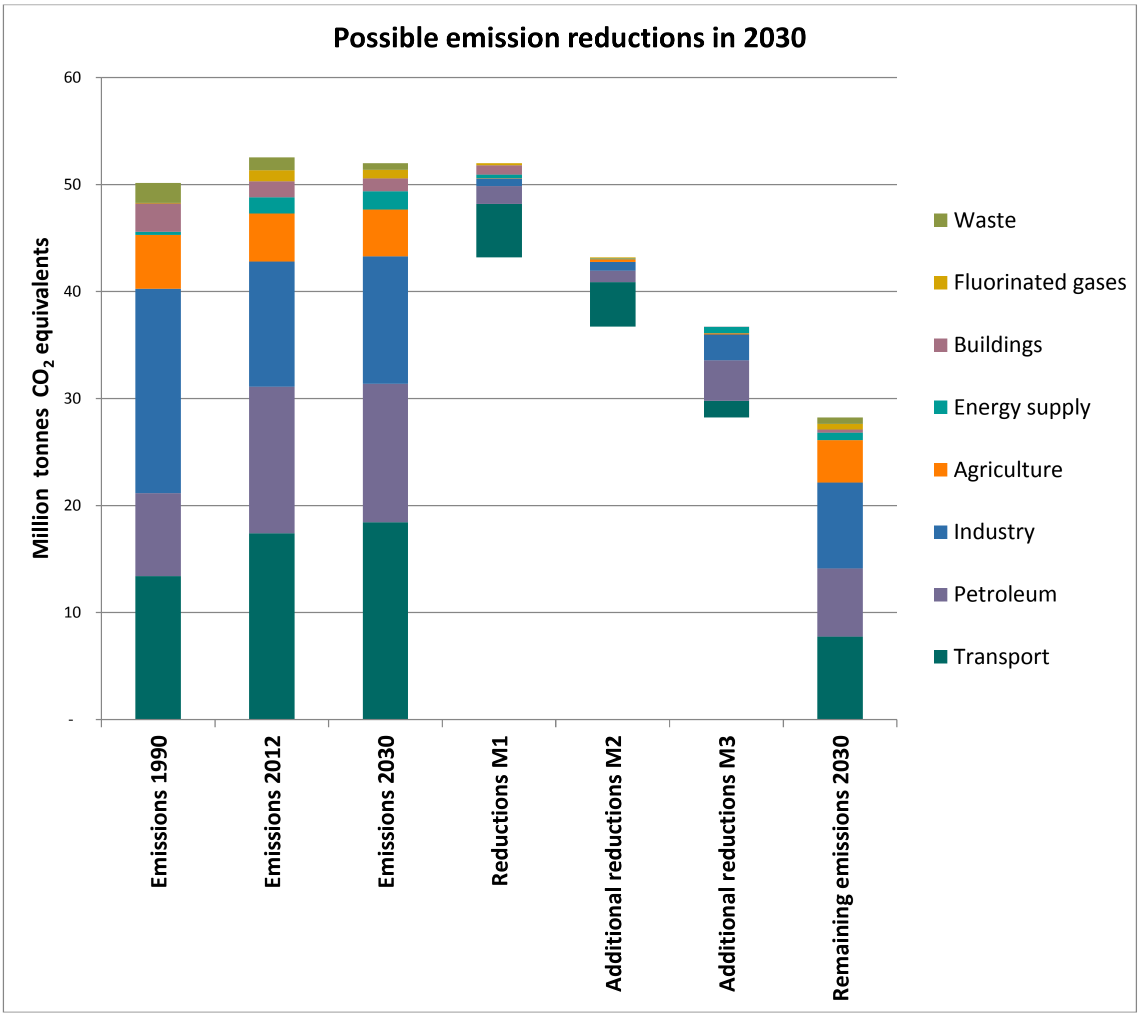

Figure 0-2 Estimated emission reductions achieved using different mitigation packages (M1, M2, M3).

Mitigation package 1. Given current predictions for emission trends, this package is estimated to reduce emissions to about 43.5 million tonnes CO_2-eq in 2030, which corresponds to about 14 % below the 1990 level. The largest cuts are in the transport sector. Measures in this sector include zero growth in transport by passenger car in the largest towns, transfer of 5 % of goods from road to rail, more rapid phase-in of electric and hydrogen vehicles, and 10 % biofuels in road transport and shipping. Examples of measures in the oil and gas sector are improvements in energy efficiency, a reduction in flaring and electrification of new installations near land. Measures included in the industrial sector are conversion from fossil to renewable fuels and improvements of the aluminium manufacturing process.

Mitigation package 2. This package is estimated to reduce emissions to about 37 million tonnes CO_2-eq in 2030, which is a reduction of about 26 % from the 1990 level. Measures that would need to be implemented in the transport sector to achieve this include zero growth in vehicle-kilometres for passenger cars throughout the country, transfer of 10 % of goods from road to rail, rapid phase-in of zero-emission technology for road vehicles, 20 % biofuels in road transport and shipping and 10 % biofuels for other mobile emission sources and domestic aviation. One of the additional measures in the oil and gas sector is electrification of new installations further from land than those in mitigation package 1. Measures in the industrial sector include elimination of a very large proportion of the fossil fuels used for stationary combustion in branches where conversion to other fuels can be carried out using already existing technology and without any increase in emissions elsewhere. There are also two measures in the metal industry involving a transition from fossil to renewable reducing agents.

Mitigation package 3. This package is estimated to reduce emissions to about 28.5 million tonnes CO_2-eq, which is a reduction of about 43 % from the 1990 level. Measures that would need to be implemented in the transport sector to achieve this include 10 % reduction in vehicle-kilometres for passenger cars, transfer of 20 % of goods from road to rail, 40 % biofuels in road transport and shipping and 20 % biofuels for other mobile emission sources and domestic aviation. In the oil and gas sector, measures include partial electrification of two areas (the Norwegian Sea and the northern part of the North Sea). Measures included in the industrial sector are three projects involving carbon capture and storage, a switch to biogas in the metal industry and further conversion and energy efficiency measures at refineries.

If technological breakthroughs are made, for example in the use of inert anodes in the aluminium industry or relating to other technologies that can reduce process emissions from industry, the reductions in industrial emissions in 2030 could be larger in all three mitigation packages. However, it is not possible to plan a technological breakthrough.

Possible emission trajectories up to 2050

Emission trajectories excluding LULUCF

Figure 0-3 illustrates possible emission trajectories from 1990 to 2020 and on to 2030 and 2050, based on the assumption that the emission target for 2020 set out in the cross-party agreement is achieved. The black line shows historical emissions. The grey line shows the projected emissions used as a basis for the analysis. The blue line indicates a linear reduction in emissions from the 2020 target in the cross-party agreement to the estimated emission level in 2030 if mitigation package 1 is implemented. Correspondingly, the red line indicates a linear reduction from the 2020 target in the cross-party agreement to the estimated emission level achieved in 2030 if mitigation package 3 is implemented. From 2030 to 2050, the lines are extended to indicate possible emission levels in 2050, after Norway's transition to a low-carbon society, assuming that other countries also pursue an ambitious climate policy. In practice, there would not be a smooth reduction in emissions, but a stepwise reduction with the implementation of large-scale projects such as the introduction of CCS at industrial plants. It is not possible to determine exactly when such projects would be carried out.

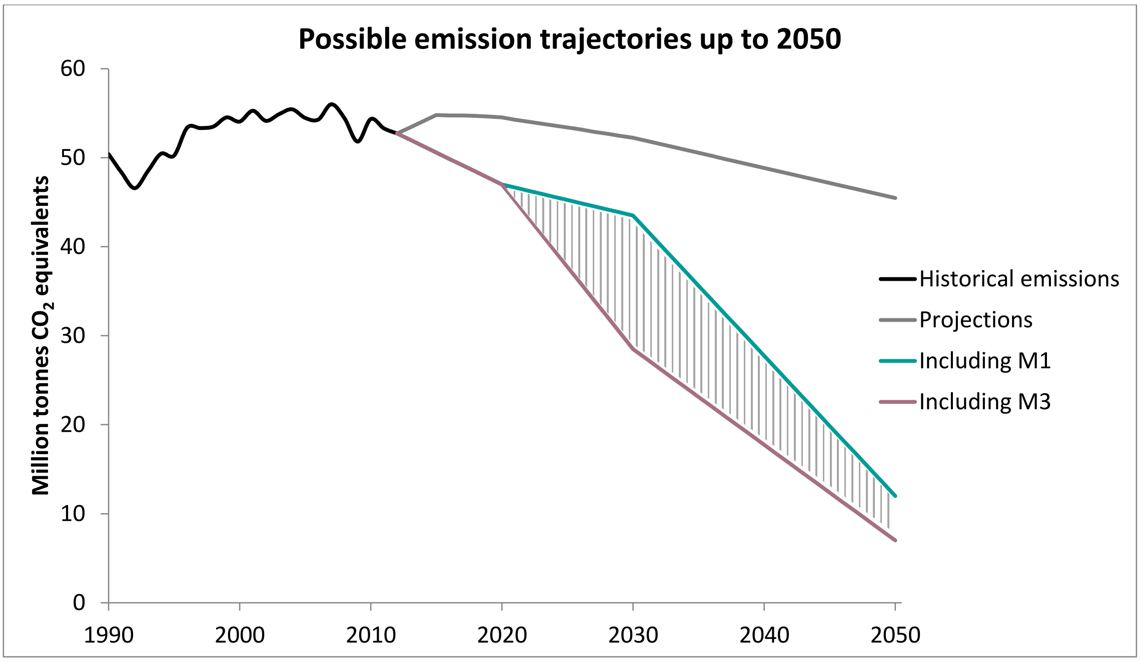

Figure 0-3 Possible emission trajectories up to 2050. (M1=mitigation package 1, M3=mitigation package 3)

It is estimated that the measures included in mitigation package 1 will reduce emissions to about 43.5 million tonnes CO_2-eq by 2030. As explained above, it is expected that Norway's total emissions in 2030 will be about 45 million tonnes CO_2-eq if the measures identified as needed to achieve the 2020 emission target of the cross-party agreement are implemented. However, mitigation package 1 does not provide any guarantee that the target will be achieved in 2020; this depends on how quickly measures are phased in. The deployment of carbon capture and storage technology in industry and a switch to biochar in the ferro-alloy industry were some of the measures for achieving the 2020 emission target included in the Environment Agency's report on the scientific basis for further development of Norwegian and international climate policy (Norwegian Environment Agency 2014). These measures are not included in mitigation package 1: on the other hand, the package includes larger emission cuts in the transport sector because the time frame gives an extra 10 years to phase in measures.

Mitigation package 1 may involve a certain risk of lock-in as regards future emission levels, perhaps especially in the transport sector, where it takes time to phase in zero-emission vehicle and reduce transport volumes.

It is estimated that the measures included in mitigation package 3 will reduce emissions by about 43 % relative to the 1990 level in 2030, in other words slightly more than the overall reduction of 40 % compared with the 1990 level proposed by the European Commission for the EU as a whole. This demonstrates that if Norway chooses the same level of ambition as the EU, it will be necessary to implement measures that are both costly and difficult to carry out. Achieving emission cuts on the scale of the EU proposal will be a more demanding task for Norway than for the EU. One important reason for this is that while EU greenhouse gas emissions dropped by 19.2 % in the period 1990—2012, Norway's emissions rose by 4.6 % in the same period. This is partly because Norway's population has risen by 21 % from 1990 to 2014, whereas the population of the EU has risen by only 7 %. Many of the low-cost measures in EU countries will involve switching from fossil to renewable electricity generation. Norway does not have this option, since electricity generation here is almost entirely hydropower-based and virtually emission-free. In addition, an emission target for the EU as a whole allows for greater flexibility in implementing measures than a national target for Norway alone. It should also be noted that the various measures were assessed separately for this report, and that the Norwegian economy may run into capacity problems if there are a number of major technological projects to be carried out at the same time.

The emission level in Norway in 2050 after the transition to a low-carbon society has been roughly estimated at 7—12 million tonnes CO_2-eq. Achieving this would require technological advances both in Norway and in the rest of the world. If emissions reach the level that can be achieved with mitigation package 1 in 2030, it will be necessary to make reductions of almost 4 % per year in the period 2030—50 to bring emissions down to the midpoint of the estimated interval for 2050.

Emission trajectories including LULUCF

In order to avoid dangerous climate change, it is crucially important to limit greenhouse gas emissions. However, all sectors should be included in an integrated approach to the transition to a low-carbon society. It is therefore useful to illustrate what trends can be expected if the LULUCF sector is included. Unlike other sectors, LULUCF accounts for a net uptake of CO_2 in Norway. If this carbon uptake is included in the reference scenario, Norway's aggregate net emissions are lower, around 40 million tonnes CO_2-eq in 1990. Net emissions in 2050 would be around 30 million tonnes CO_2-eq.The projections in Figure 0-4 show total net emissions from Norway for all sectors, including LULUCF.

It is important to note that the figures presented here include the entire net carbon uptake from LULUCF. Under the Kyoto Protocol, only a small proportion of emissions and removals in this sector are eligible for inclusion in countries' emission inventories. It is uncertain how the sector will be included in a post-2020 climate agreement.

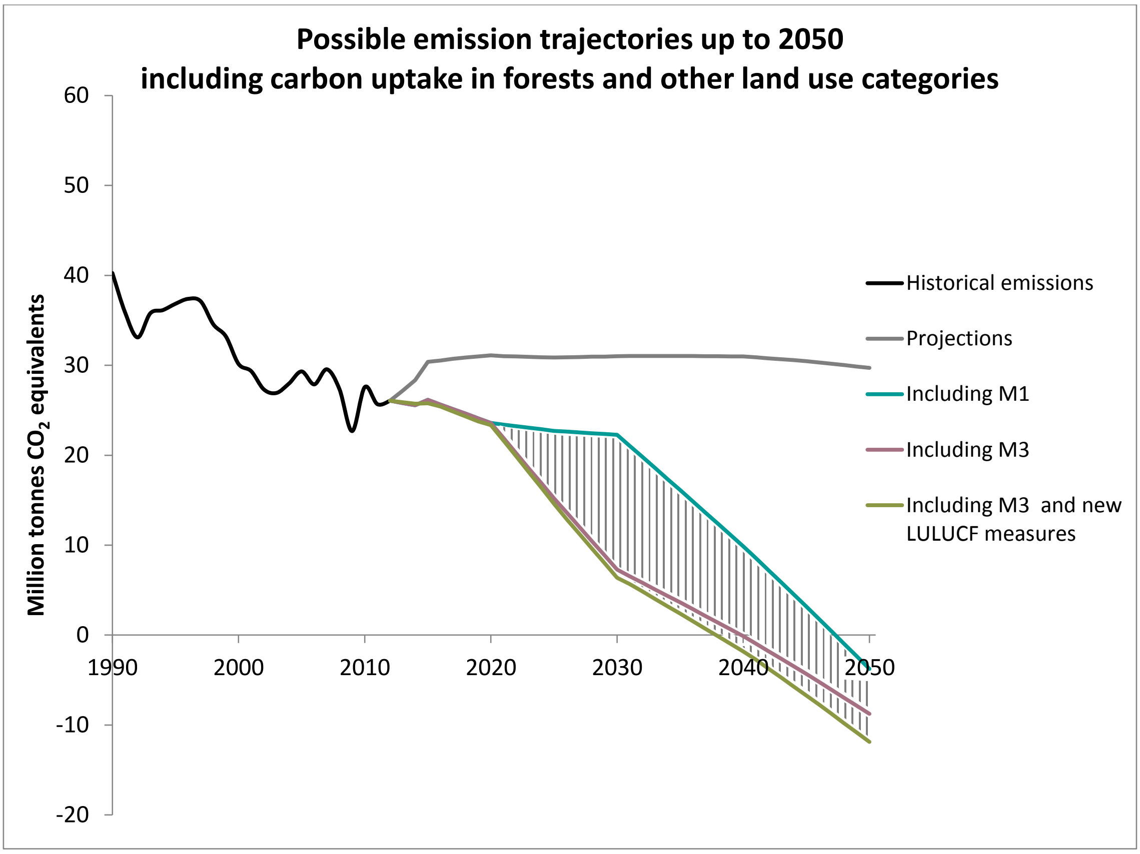

Figure 0-4 Possible emission trajectories up to 2050 including all LULUCF emissions and removals, ignoring the current restrictions on their inclusion under the Kyoto Protocol. (M1=mitigation package 1, M3=mitigation package 3)

The figure shows that if net carbon uptake in the LULUCF sector is included, Norway could achieve net negative emissions around 2045, provided that all measures needed to bring about reductions equivalent to mitigation package 1 are also implemented. If the measures included in mitigation package 3 are implemented and LULUCF is included, Norway would have net negative emissions before 2040. If Norway does not implement any mitigation measures in other sectors, but does implement measures in the LULUCF sector, Norway's emissions would remain at about 30 million tonnes CO_2-eq in 2050.

To ensure that Norway makes the transition to a low-carbon society, the net carbon uptake in LULUCF should be additional to and not a replacement for cuts in emissions in other sectors.

Consequences for the energy sector

The Norwegian power supply system is based on a high proportion of renewable energy. At the same time, energy use in Norway is generally high, and includes a substantial amount of fossil energy. Norway has a large natural potential for increasing renewable energy production. This offers opportunities both within the country and as regards the exchange of power with other countries.

Part of this project was a review of the consequences for the energy sector of the transition to a low-carbon society described in the rest of the report. The conclusions can be summarised as follows:

Electricity: The effect of the mitigation packages reviewed in this report on electricity demand up to 2030 varies from none to moderate. Demand will depend on the level of ambition in sectors that are heavily dependent on fossil energy use, particularly transport and the petroleum sector, and on the extent to which energy efficiency measures are introduced. A great deal can be done to increase energy efficiency in the industrial sector and in buildings, and thus compensate for a rising demand for electricity. Energy efficiency is also important because all energy production has environmental impacts. The potential for increasing production of electricity from renewable sources is considerably larger than increase in demand resulting from the mitigation packages up to 2030.

Towards 2050, a rising proportion of zero-emission vehicles may result in higher demand for electricity, particularly if there is a major breakthrough for hydrogen-powered vehicles. Further conversion from fossil forms of energy to electricity suggests that there will be a rise in electricity demand in the industrial sector. In the petroleum sector, energy demand is expected to be somewhat lower in 2050 than in 2030.

Bioenergy: Implementation of the mitigation packages reviewed here would result in a moderate to considerable increase in demand for bioenergy up to 2030. The increase appears to be within the theoretical potential for bioenergy production in Norway. However, using biomass for energy purposes would make it necessary to weigh up this use against alternative areas of use, for example as building materials or reducing agents. The degree to which making greater use of bioenergy has impacts on biodiversity, landscapes and outdoor recreation will depend mainly on which biomass resources are used and on how large a scale.

Demand for bioenergy may rise further up to 2050. If advanced biofuels become dominant in the transport sector, biomass resources will be needed on a large scale. There may also be increasing demand for biomass as a source of energy or raw materials in industry, for example in the production of biomass-based chemicals and plastics. It is expected that biorefineries will be able to use biomass extremely efficiently to manufacture biomass-based products. Other biomass resources such as algae may become available by 2050.

Costs

It is a very complex process to estimate the costs of individual mitigation measures, and particularly to estimate what the total costs of different levels of emission reductions will be for Norway over such a long time period. It is not possible to predict with any degree of certainty which technological breakthroughs will be achieved and when. The speed at which technologies for zero-emission vehicles such as electric and hydrogen fuel cell vehicles are developed, and how long it takes before they can compete with petrol and diesel vehicles, will for example have major implications for costs. For other types of measures, there is less uncertainty about what is needed to achieve the two-degree target. This applies for example to the development of infrastructure to promote cycling and the use of public transport. The overall changes needed are on such a scale that the tools available for economic analysis have their limitations. The measures have therefore been divided into three cost categories as a way of highlighting the high level of uncertainty in the estimates.

Table 0-1 Estimated emission reductions that can be achieved using the measures in mitigation package 3, by cost category. Emission reductions are given in tonnes CO_2-eq relative to the reference scenario for 2030.

Sector	Measures costing <NOK 500/tonne	Measures costing NOK 500-1500/tonne	Measures costing >NOK 1500/tonne
Transport	2 870 000	2 470 000	5 350 000
Petroleum	1 675 000	1 075 000	3 803 000
Industry	1 100 000	1 135 000	1 620 000
Agriculture	228 000	183 000	-
Energy supply	270 000	110 000	620 000
Fluorinated gases	190 000	95 000	-
Buildings	880 000	20 000	20 000
Waste*	-	-	-
Total	**7 213 000**	**5 088 000**	**11 413 000**

** Emission reductions achieved through measures and instruments in the waste sector are recorded in the sector where reductions will take place.*

The table summarises the results of the sector-by-sector mitigation analyses. It shows estimated emission reductions in tonnes relative to the reference scenario for 2030 for mitigation package 3 (which includes all the measures) in 2030, split by sector and in total, and divided into three cost categories. These results indicate that it should be possible to cut Norway's emissions by about 7 million tonnes by 2030 using measures that cost less than NOK 500 per tonne CO_2-eq, and by a further 5 million tonnes at a cost of up to NOK 1500 per tonne. Thus, it should be possible to reduce emissions by more than 12 million tonnes at a cost of less than NOK 1500 per tonne. It is estimated that the remaining cuts, around 11 million tonnes, will cost more than NOK 1500 per tonne.

In the case of the transport sector, the methodology used means that the results for mitigation package only as shown in the table do not give a complete picture. In this sector, the proportion of the measures expected to be in the lowest-cost category is higher in mitigation packages 1 and 2. Mitigation package 1, in which the measures are expected to cost less than NOK 500 per tonne CO_2-eq, is estimated to give cuts of about 5 million tonnes CO_2-eq in the transport sector. This is illustrated in Figure 0-2.

How can Norway make a difference?

Positive trends that are important in a global context are discussed earlier in the summary. In all the cases described, national authorities are leading the way and supporting technological advances and phase-in of new technologies. The mitigation analyses for each sector describe areas where Norway can play a part in the global effort that will be required, and at the same time take steps to reduce Norwegian emissions and develop a forward-looking business sector. Some key areas are highlighted below. Although many strategies must be developed over time, it is important to start the processes now.

Large-scale electrification of the transport sector

Decarbonisation of the transport sector has major implications for emission levels in 2030 and 2050. Norway has played a pioneering role in this field by using policy instruments to promote the market deployment of electric cars and the development of charging stations. It is important to continue the promotion of low-emission vehicles by maintaining the same policy instruments and expanding their application to include other vehicle types than passenger cars (lorries, buses, construction machinery and tractors, and also ships and ferries). Because turnover of the vehicle stock is slow, it is important to start the changeover to zero-emission vehicles as soon as possible. For example, 100 % of new passenger cars sold must be zero-emission vehicles by 2030 to give a zero-emission passenger car stock in 2050.

Building towns and built-up areas for the future

Infrastructure investments involve a wide range of decisions of varying importance, and it is vital to ensure coordination so that all decisions promote low-carbon development. This applies for example to decisions on the construction of new commercial buildings, shopping centres and residential areas. Buildings must be energy efficient, and they must be sited in a way that minimises transport needs. Large-scale development of public transport infrastructure and walking and cycling routes in and around the most densely populated areas is needed to encourage more use of buses, trains and other rail transport, and to promote cycling and walking.

Improving land-use and transport planning

The transition to a low-carbon society will require adaptation by and contributions from actors in many different sectors. Norway's municipalities are particularly important in this context. They are planning authorities and the owners of buildings and other infrastructure, they purchase goods and services and they are responsible for local coordination. They therefore have a key role to play in providing a framework that results in cuts in greenhouse gas emissions. Their role as planning authorities puts them in a particularly strong position to influence developments in key areas. Patterns of development of service functions, homes, workplaces and infrastructure have a strong influence on the options available for meeting transport needs, and thus on local emission levels. It is not possible to envisage reductions in transport needs and in dependency on private cars unless considerably more weight is given to considerations of climate change in land-use and transport planning.

Carbon capture and storage (CCS)

This report shows that CCS will probably play a crucial role in reducing Norway's industrial emissions, for example from the manufacture of cement and mineral fertiliser and the chemical industry. Technology for both emissions capture and carbon transport and storage needs to be further developed. Norway can play a part in developing technology that can be shared with other countries. For example, world cement production accounts for about 5 % of global emissions. To ensure that CCS is widely deployed, it is necessary to carry out large-scale demonstration projects.

Developing new processes that minimise greenhouse gas emissions from Norwegian process industries

Developing technologies that can reduce emissions from cement and fertiliser manufacturing is important because these sectors are major sources of emissions globally. In the case of industries such as ferro-alloy and aluminium production, technology to reduce process emissions is needed so that production can be increased worldwide without a rise in global emissions. Further emission reductions in these sectors will require technological breakthroughs, and continued research and development and the establishment of pilot plants are important as a basis for success.

Intensifying efforts to develop biomass-based chemicals and fuels

Norway already has industrial expertise in this field, and access to resources including wet organic waste and Norwegian forests. In the longer term, the resource base can be expanded by using new resources such as algae and seaweed.

Making use of the resources in waste

A low-carbon society will need to make use of a larger proportion of the resources in waste than is the case today. Most of the previously identified potential for reducing emissions from landfills is thought to have been realised already, and the main areas where the waste sector can contribute to emission reductions are recycling and biological treatment of waste. Measures that promote waste prevention can also reduce emissions over the whole life cycle of products, from the extraction of raw materials and manufacturing to waste treatment.

Which measures should be implemented first?

In addition to the long-term strategies that need to be devised, a range of measures can be implemented in the short term that will give rapid cuts in emissions and help to avoid lock-in to fossil infrastructure, which would make the transition to a low-carbon society more difficult.

One important task is to assess whether current policy instruments are effective enough to ensure that the 'easy' cuts in emissions are made. For example, it was decided in the cross-party agreement that the use of fossil energy to heat buildings is to be phased out, but the necessary policy instruments must be introduced. Another area where action can be taken early is phasing out the use of fossil energy carriers for stationary combustion in industry where possible, by switching to electric boilers, heat pumps, biomass boilers or using biogas or bio-oil. A third example is implementing energy efficiency measures in business and industry and households.

Building more demonstration plants or systems, for instance for CCS technology or low-emission transport systems, will increase awareness and understanding that it is possible to deal with the challenge posed by climate change.

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Our principal functions include monitoring the state of the environment, conveying environment-related information, exercising authority, overseeing and guiding regional and municipal authorities, cooperating with relevant industry authorities, acting as an expert advisor, and assisting in international environmental efforts.