Enova SF
Report

Towards a low-emission Norwegian industry

CONTENTS

PREFACE

Norway's industrial sector, including both the offshore petroleum industry and onshore industries, contributes 25% of GDP and 8% of jobs. It also produces more than half of Norway's greenhouse gas (GHG) emissions. The challenge in the years ahead is to maintain or advance the sector's economic and social contributions while dramatically reducing its greenhouse gas emissions. The research presented here shows that this is possible if government, industry and research institutions can work together.

This report was commissioned by Enova and supported by McKinsey & Company as an external advisor. The report gives a synthesized perspective on the path towards a low carbon industrial sector in Norway. In addition to close examination of the existing literature, the authors conducted 14 interviews with industrial companies, industry associations, research institutes and government entities. The report also builds on McKinsey's research on emission abatement and more than 25 interviews with McKinsey subject-matter experts from around the globe. A brief overview of the methodology, including a synthesis of the interviews, is given in the Appendix.

Norway must have a competitive and climate neutral industry in the future, with world class energy and climate technology. Innovation and technology development in the industrial sector are crucial to delivering on Norway's international climate obligations by 2030.

Enova is mandated to be a driver of energy transition and technology development with the ambition to reduce GHG emissions and secure energy supply through targeted programs. For Enova, it is important to support technology development with a long term perspective towards a low emission society.

Enova is prioritizing technology development that has significant potential to proliferate across Norway and internationally. Enova supports accelerated introduction of new energy and climate technology in the Norwegian industrial sector, and it aims to reducing technical risk through support in the early development stages, before full scale implementation.

This report will contribute to the knowledge base for Enova's strategy and priorities, and it examines the climate challenge for the Norwegian industry across four areas:

- Prospects for Norwegian industry in a low-emission society (chapters 2 and 4)
- Drivers, barriers, and risks related to emission abatement (chapters 3 and 5)
- Potential for new Norwegian industries in a low-emission society (chapter 4)
- Competence, capital, and financing required to deliver on the climate aspiration (chapters 5 and 6)

We thank all parties who contributed to this work, especially those in the organizations where we conducted interviews: Alcoa Norway, Borregaard, Eramet, Marine Harvest, Norwegian Environment Agency, Norcem, Norsk Hydro, Orkla, Pemco, RISE PFI, Statoil, SINTEF, Tine and Yara.

We encourage those in government and in business to find effective ways to reach deep decarbonization in the Norwegian industrial sector.

Enova SF
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EXECUTIVE SUMMARY

Norway and the world will need to make significant shifts away from business as usual to meet 2050 emission targets.

- In the Paris Agreement of 2016, 195 UN member states agreed to limit the global temperature rise to well below 2 degrees Celsius by 2100 and to pursue efforts to limit it even further to 1.5 degrees. According to scientific consensus documented by the Intergovernmental Panel on Climate Change, this implied a remaining budget of about 1,000 billion tons of carbon dioxide equivalent (tCO2e) globally starting in 2011. Today, around 800 billion tCO2e remain.
- As a signatory to the Paris Agreement, Norway has committed to reducing greenhouse gas (GHG) emissions by 40% from 1990 levels by 2030, and the new Norwegian Climate Act sets a target of 80-95% reduction by 2050 in line with EU aspirations – meaning that industry emissions would need to approach zero.
- In spite of exciting developments in some areas, Norwegian industry is not on track to deliver the required emission abatement. Industry GHG emissions in Norway have been flat since 1990, despite individual success stories such as reductions in PFC gases from the aluminum industry and nitrous oxide from the fertilizer industry. These reductions have been offset by increased emissions from offshore oil & gas facilities, and onshore industries have made limited progress in developing solutions to the remaining carbon dioxide emissions.

The large industry clusters in Norway are a cause of the climate challenge –and an important part of the solution.

- Today, about 27 MtCO2e per year, or more than 50% of total Norwegian GHG emissions, derive from industrial activity – 23% from onshore industries and 30% from the offshore petroleum sector.
- Norwegian industry production is also of great value to society, of course. It contributes 25% of the nation's GDP and 8% of its jobs. Modern society depends on industrial products such as oil, metals, chemicals and cement – and producing these and other products in Norway is typically cleaner than producing them elsewhere.
- While making accurate predictions several decades ahead is never easy, we expect that the products created by Norway's large industries will continue to be in demand in a low-emission future. The nation must therefore find solutions that enable continued or increased production with close to zero GHG emissions.

Norwegian industry will need to develop and lead the adoption of "deep decarbonization" technologies to close the emission abatement gap.

- Most Norwegian onshore industries are already electrified, and Norway has a clean power sector, putting it ahead of most other countries. It now faces the more difficult challenge of decarbonizing offshore petroleum facilities and onshore industry process emissions.
- A combination of conventional and deep decarbonization technologies could bring the country close to zero industrial emissions: energy efficiency improvements; further electrification, primarily of new offshore oil & gas facilities; bio-based fuel and feedstock; hydrogen; carbon capture and storage or use; and other initiatives, including reducing demand through reuse, remanufacturing and recycling – a more "circular" economy.

Norwegian industries could find new opportunities in deep decarbonization technologies in the mid to long term.

- Climate-friendly technology can unlock new business opportunities. This is underway now in the power sector, where a few countries are driving technology development in renewables, including Germany and Denmark in wind power and Germany and China in solar power.

- Norway starts from a position of strength in deep decarbonization technologies. It is ahead of most countries in electrification and energy efficiency, which allows investment in next-generation technologies. It has strong competence and collaboration across industry clusters and research institutions. And Norwegian industries can harness powerful synergies, such as petroleum and gas reservoirs that could be used for carbon storage, and byproducts from the forestry, pulp and paper industries that could be used as bio-based fuel and feedstock in other industries.
- Leadership in deep decarbonization technologies could become a source of competitive advantage for existing products as export markets introduce new carbon footprint requirements, and licensing or sale of technology may provide new income streams. A low-emission future may also generate opportunities for new industries in Norway, such as large-scale data centers or hydrogen exports to Europe.

The main barriers to accelerated progress lie in the lack of short-term incentives to invest in technology innovation and adoption.

- The principal theoretical barrier stems from the "negative externalities" of emissions: most of the costs of climate change are borne by people other than those who cause them, typically in other countries. Hence, industrial companies and even nations may have few short-term economic incentives to reduce emissions.
- History shows that externality problems can be overcome, but typically only once immediate negative effects of business as usual are widely accepted. For example, the world rapidly phased out ozone-depleting substances during the 1980s and 1990s. Similarly, a rapid shift in the perceived urgency of curbing climate change may be underway today.
- To accelerate progress, industrial companies are facing three practical barriers:
  - First, they will need to develop and lead the adoption of immature technologies to close around 40% of the abatement gap. Individual companies have few economic incentives to make such long-term R&D investments.
  - Second, another 50% or so of the abatement gap can be closed with technologies that are mature today but that are not profitable for individual businesses. These include electrifying new offshore oil & gas facilities, creating and using biofuels, and making many energy efficiency improvements.
  - Third, companies are slow to adopt even the profitable technologies that can close 10% of the abatement gap, often because they have strong incentives to deliver quick rather than longer-term returns.

Industries can change with the help of powerful, coherent new policies and long-term commitments that empower industry and research institutions.

- No single policy can solve the industry emission abatement challenge – one of the most complex challenges in the world today. Tax hikes and emission caps, for example, could force otherwise viable companies out of business, adding a layer of complexity relative to emission abatement in sectors such as transport and power that are less exposed to international competition.
- Policymakers need to develop a coherent, comprehensive set of policy mechanisms, with long-term commitments tailored for each stage of the technology development cycle. We believe three types of programs will be required:
  - *Research programs* to invent cleaner and more cost-efficient production processes, such as new ways to produce hydrogen or bio-based feedstocks for metals and chemicals. Individual companies can find it difficult to protect intellectual property from early-stage research, so public funding and subsidy schemes are required. Broad programs will be necessary until specific technologies emerge as candidates for pilots and scaling.
  - *Development programs* to pilot and scale immature technologies such as carbon capture and storage (CCS) or mixing increasing amounts of bio-based material into feedstocks for metals or chemicals. Government subsidies will be required, but they may focus on fewer high-potential technologies in close collaboration with industrial companies.
  - *Adoption programs* to cover existing technologies that need a combination of direct regulation, taxes and subsidies to drive industry adoption. Successful programs often use technology-neutral competitive tenders to benefit from international competition.

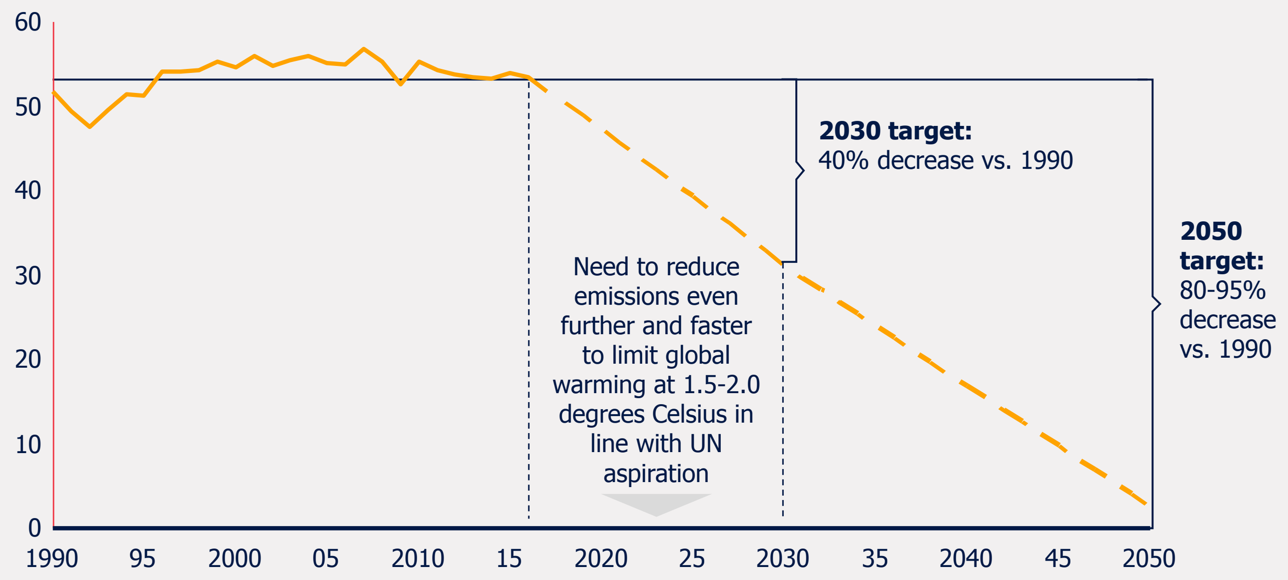
1. THE CLIMATE CHALLENGE FOR NORWEGIAN INDUSTRY

Most climate scientists and the leaders of nearly all the world's nations agree that man-made greenhouse gas emissions are causing global climate change. But despite efforts around the globe to limit these emissions, their growth has accelerated over the last decade. The available data suggest that stabilizing temperature increases in this century will require fundamental departures from business as usual.

In the Paris Agreement of 2016, 195 UN member states reached an accord to keep the global temperature rise to well below 2 degrees Celsius by 2100 and to pursue efforts to limit the increase to 1.5 degrees. According to scientific consensus documented by the Intergovernmental Panel on Climate Change, this implied a remaining carbon budget of about 1,000 billion tons of carbon dioxide equivalent (tCO2e) globally starting in 2011.[1] Since then, the world has already used about 200 billion tCO2e of that budget. As a signatory to the Paris Agreement, Norway has committed to reducing emissions by 40% from 1990 levels by 2030 – just 12 years away. Also, the new Norwegian Climate Act sets a target of 80-95% reduction by 2050 in line with EU aspirations – meaning that industry emissions would need to approach zero.

Exhibit 1

A radical shift is required to meet 2030 and 2050 abatement aspirations
Norwegian GHG emissions (Mt CO2e)



SOURCE: Statistics Norway; Table 08940: Klimagasser, etter kilde, energiprodukt og komponent

In spite of exciting developments in some areas, Norwegian industry is not on track to deliver the required emission abatement. Its emissions have been flat overall since 1990, despite individual success stories such as reductions in fluorinated gases from the aluminum industry and nitrous oxide from the fertilizer industry.

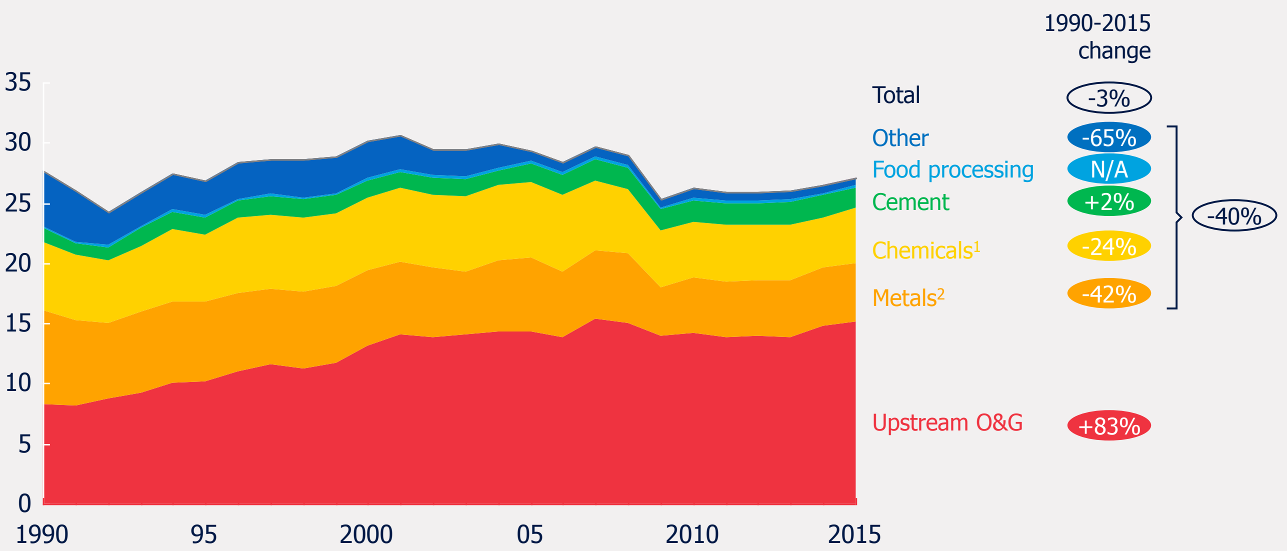
However, this overall trend conceals wide differences among sectors and types of GHGs. Emissions from the offshore petroleum sector have increased by more than 80% since 1990, driven by capacity expansions and higher energy intensity at aging fields. In the same period, onshore industrial companies reduced their emissions by almost 40%, but most of this reduction has been from non-CO_2 GHGs, such as methane, fluorinated gases and nitrous oxide. Overall direct CO_2 emissions from the onshore industry have been stagnant since 1990, with around 95% of remaining emissions consisting of CO_2.[2] Abatement of these remaining CO_2 emissions require new solutions, and the current pace of technology development is insufficient to meet the 2050 abatement aspirations.

> ***"There are a lot of incremental improvements, but few dare to think big and back it up with long-term investments."***
>
> – Industry interview

To do its part to limit global warming to well below 2 degrees, in line with UN aspirations, Norwegian industry emissions will have to approach zero before 2050. This will require a fundamental departure from business as usual with clear step-ups in emission abatement from both onshore and offshore industries in Norway.

Exhibit 2

Overall industry emissions have been stable since 1990, hiding opposing trends for land-based (-40%) and offshore industry (+80%)
Norwegian industry GHG emissions (Mt CO_2e)



1 Refineries, fertilizers, petrochemicals and pulp and paper
2 Aluminum and ferroalloys

SOURCE: Statistics Norway; Table 08940: Klimagasser, etter kilde, energiprodukt og komponent

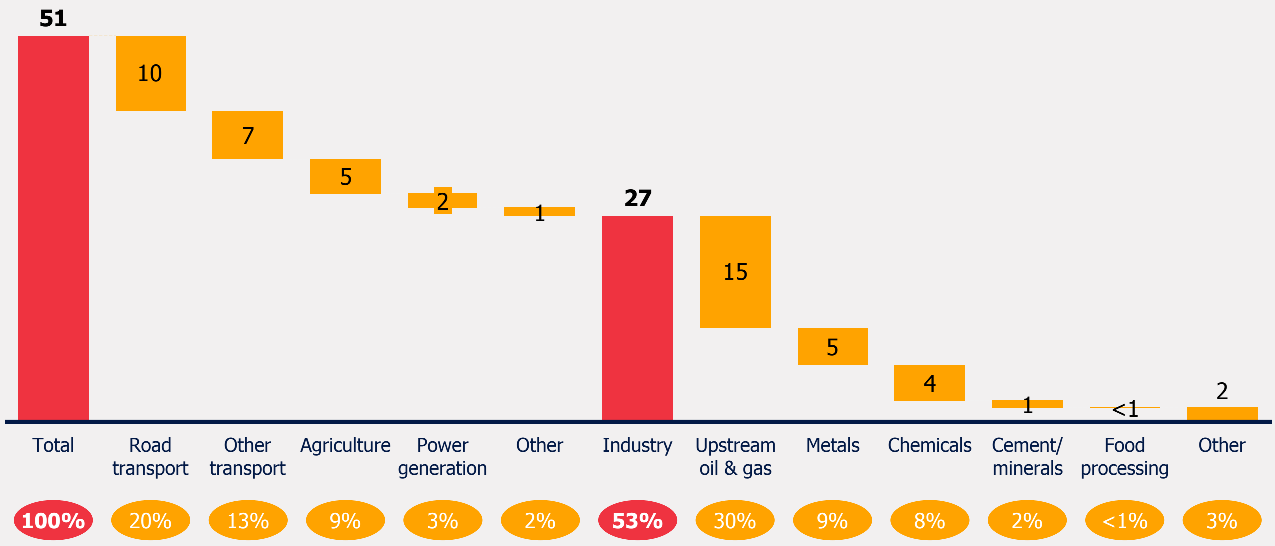
2. PROSPECTS FOR NORWEGIAN INDUSTRY IN A LOW-EMISSION SOCIETY

Today, more than half of the greenhouse gases emitted in Norway derive from industrial activity: 23% from onshore industries and 30% from the offshore petroleum sector (Exhibit 3). At the same time, Norwegian industry contributes 25% of the nation's GDP and 8% of its jobs,[3] and it provides materials that go into products people take for granted – including metals, chemicals and cement. Meanwhile, most Norwegian companies are cleaner than those making the same products elsewhere. Norwegian aluminum production, for example, has an emission intensity around 35% lower than the global average, primarily driven by access to renewable hydro power.[4] Norway therefore needs to deliver on its climate ambitions while securing continued or increasing industrial production.

Exhibit 3

Industry constitutes >50% of Norwegian GHG emissions with the offshore O&G sector accounting for ~30% alone

Norwegian 2016 GHG emissions (Mt CO2e)



SOURCE: Statistics Norway; Table 08940: Klimagasser, etter kilde, energiprodukt og komponent

Making accurate predictions several decades ahead is difficult, especially with the pace of change accelerating. That said, based on global McKinsey perspectives combined with a compilation of views from subject-matter experts, we expect that the products from most of Norway's large industries will continue to be in demand in a low-emission future.

With these perspectives in mind, onshore industries are likely to become increasingly important relative to the offshore oil and gas sector; aluminum is likely to grow as a substitute for steel; and biochemicals will replace many petrochemicals. Cement is more difficult to substitute, but subject-matter experts still expect shifts in demand towards wood and other green building materials. In addition to new products, a low-emission society will rely on a more circular economy, where reuse, remanufacturing and recycling are more common, presenting challenges and opportunities for several Norwegian industries. Still, at an aggregate level, most of Norway's major industry sectors will likely continue to play significant roles in the abatement efforts towards 2050:

- **Upstream oil & gas (57% of Norwegian industry emissions; 15.1 MtCO2e):** This is likely to be a significant industry in Norway for decades to come, with Johan Sverdrup and other large fields under development. Still, overall production has likely reached its peak and is widely expected to decline over the coming decades. Current emissions derive largely from gas turbines that create heat and electricity for the platforms (93% of upstream oil & gas emissions) and process emissions including flaring, venting and leakage (7%).[5] While natural gas could play an important role by replacing coal in the short to medium term, a need to reduce emissions by 80-95% within 2050 is incompatible with our reliance on fossil fuels unless the industry implements carbon capture and storage or use (CCS/U).
- **Metals production (17% of Norwegian industry emissions; 4.5 MtCO2e):** In Norway, this industry consists largely of primary aluminum, which represents about 8% of Norwegian industry emissions, and ferroalloys at about 9%.[6] We expect both industries to grow, particularly aluminum, which is increasingly substituting for heavier materials. Global steel production will continue to drive demand for the Norwegian ferroalloy industry, and ferroalloys are an important input factor for the aluminum, solar and electronics industries, which we expect to grow. Emissions from the metals industry stem from the consumption of anodes (aluminum) and use of fossil-based reductants (ferroalloys). No commercial technologies can radically reduce these emissions today, so new technology would be required for both aluminum and ferroalloy production in a low-carbon economy.
- **Chemicals (16% of Norwegian industry emissions; 4.3 MtCO2e).** Most of the emissions from these industries in Norway stem from refineries and petrochemicals (about 12% of Norwegian industry emissions), fertilizers (4%) and pulp & paper (less than 1%).[7] Refineries offer significant emission abatement potential, but given the industry's low margins and declining demand due to increasing penetration of electric vehicles, the economics of investing in new equipment are unclear. We expect fertilizer production to remain stable in Norway. Natural gas would have to be replaced as feedstock, for example with hydrogen, for the industry to remain sustainable in the low-carbon economy. Alternatively, CCS could be applied to tackle emissions if no other solution is economically viable. Norwegian wood-based industries contribute marginally to emissions. While the demand for graphic paper is declining, the packaging industry is growing. We expect Norway's world-leading biochemical industry to become more relevant as a substitute for the petrochemical industry in a low-emission society.
- **Cement (4% of Norwegian industry emissions; 1.1 MtCO2e).** We expect this critical component of concrete to be required in construction for decades to come. Emissions from cement manufacturing stem from burning fossil fuels to heat kilns (40%) and process emissions from the production of clinker (60%).[8] While energy emissions can be cut by electrification or a shift to bio-based fuels or hydrogen, process emissions can be reduced only by reducing clinker production or applying CCS. While a low-emission society must gradually shift towards concrete recycling and substitutes such as wood for buildings and potentially plastics for infrastructure, a large-scale move away from concrete is unlikely in the near to medium term.
- **Food processing (less than 1% of Norwegian industry emissions; less than 0.1 MtCO2e):** In this growing industry, most emissions stem from on-site combustion for heating, cooling and distribution. Besides distribution, the industry is largely electrified and produces relatively low emissions, but further electrification and energy efficiency are possible. For example, heat pump technology could help meet the industry's need for both cooling and heating at low to medium temperatures.

3. EMISSION ABATEMENT MEASURES

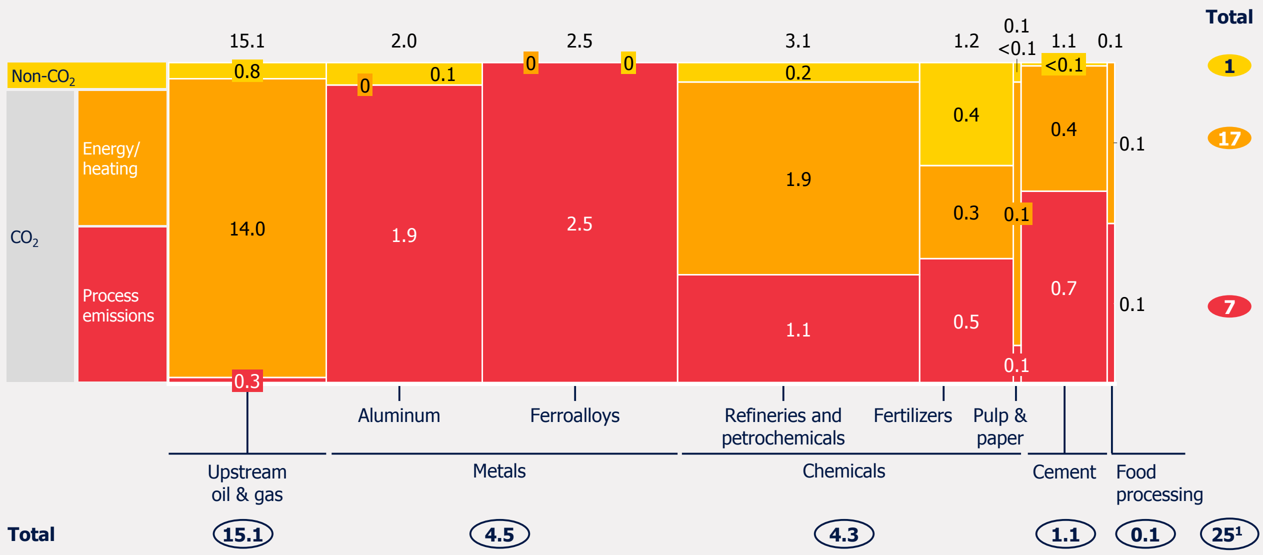
Norway starts from a different point and faces greater challenges than many other countries in achieving the next significant leap in emission reductions (Exhibit 4):

- More than half of Norwegian industry emissions come from offshore oil and gas facilities, raising technical challenges different from those onshore.
- About 30% of GHGs are pure CO2 process emissions,[9] which are generally more difficult to reduce than non-CO2 GHGs and energy-related CO2 emissions.
- In many industries, Norway's baseline emissions are already lower compared to other countries. Land-based industry is highly electrified, for example, receiving energy from one of the world's cleanest grids. Emissions from energy and heating are therefore relatively low. Norway's onshore industries have already largely exhausted the potential for electrification, a key abatement lever for many other countries.

Exhibit 4

Industry GHG emission abatement is more complex in Norway than in other countries due to high share of offshore (>50%) and CO2 process emissions (~30%)

Norwegian industry 2016 GHG emissions (Mt CO2 e)



1 Excludes ~1,5 Mt CO2e from other industries

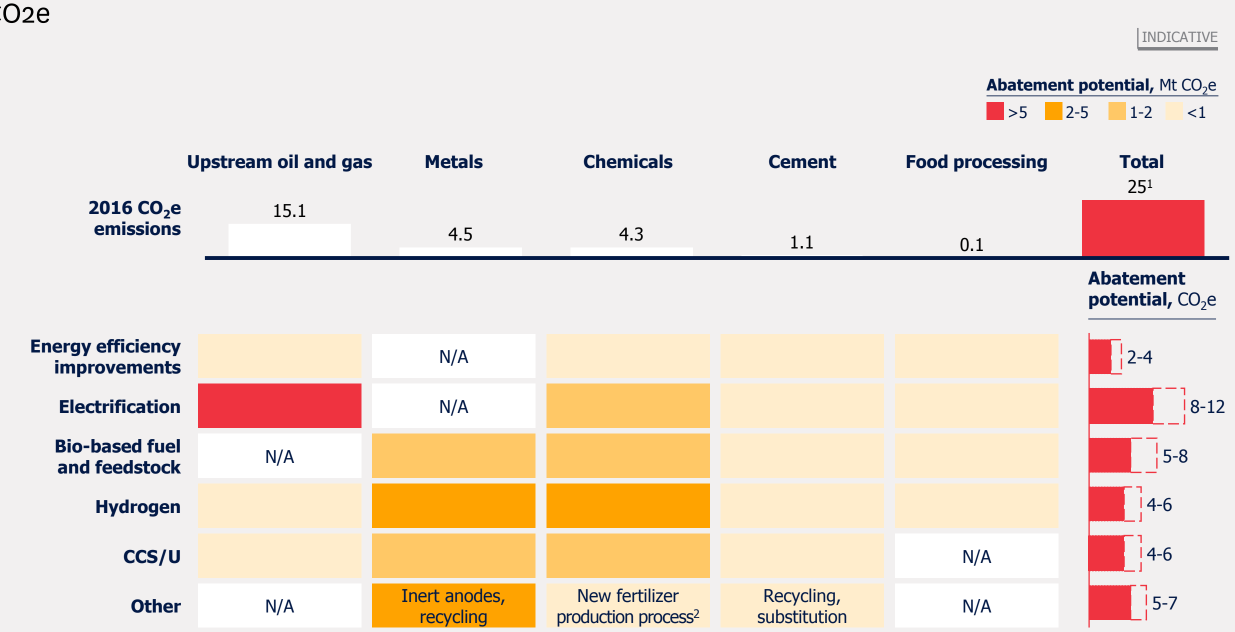
SOURCE: Statistics Norway; Table 08940: Klimagasser, etter kilde, energiprodukt og komponent

In short, Norway is ahead of most countries in adopting conventional decarbonization technologies such as electrification and renewable energy. To make substantial new progress, the country will need to develop and lead the adoption of "deep decarbonization" technologies, including bio-based feedstocks, hydrogen and CCS/U (Exhibit 5).

Exhibit 5

A portfolio of different abatement measures will be required to handle GHG emissions

Mt CO2e



1 Excludes ~1,5 Mt CO2e from other industries

2 Solid state ammonia synthesis, nuclear electrolysis, direct nitrate route

SOURCE: McKinsey analysis

Energy efficiency improvements (2-4 million tCO2e potential): Norwegian industry has already made major improvements in energy efficiency; the remaining technical potential varies across installations and industries. The main levers include reusing waste heat, upgrading and/or replacing existing equipment and production facilities, and improving operational efficiency and process control. While most of the technology has been proven, new developments will help to unlock the potential, such as recently developed heat pumps that turn 80-degree waste heat into 130-150 degrees.

Electrification (8-12 million tCO2e potential): Gas turbines running on offshore oil & gas installations contribute almost half of total industry emissions in Norway, all of which could theoretically be electrified.[10] But retrofitting equipment can be particularly difficult and expensive on offshore oil & gas facilities due to the limited space available. Electrification is therefore relevant primarily for new installations, which will account for roughly half of Norway's oil & gas production by 2050.[11] Pockets of electrification potential for onshore industry include refineries and cement, where electrical, hybrid or dual-fuel systems can generate medium-temperature heat. New electric technologies are being rolled out to produce high temperatures; some modern electric furnaces can reach 1,500 degrees Celsius. Many of these will require significant process changes, refitting equipment in existing installations and adjusting power infrastructure.

Bio-based fuel and feedstock (5-8 million tCO2e potential): Replacing fossil-based fuels with bio-fuels can eliminate energy-related emissions in several onshore industries, including cement, refineries, pulp and paper and food processing. Refineries could eliminate emissions upstream and downstream by switching to bio-based fuel and feedstock – transforming the industry to biochemical products. Biomass can also reduce emissions in metal production, where bio-based feedstocks could theoretically replace fossil carbon-based anodes in the aluminum industry and fossil-based reductants in the ferroalloy industry. While cutting slow-growing trees to produce bio-based fuel and feedstock would have limited effects on emissions to 2050, waste from the forestry industry and households both provide sizable sources of bio-based materials.

Hydrogen fuel and feedstock (4-6 million tCO_2e potential): Hydrogen can be used as feedstock in the fertilizer and to some extent in ferroalloy industries, and replace natural gas in offshore oil & gas and refineries. While hydrogen can be produced through electrolysis from water and renewable energy, this is not economically viable even in a scenario with very low energy prices – the capital costs of electrolysis will need to come down, too. The alternative is using steam methane reforming to produce hydrogen from natural gas, combined with CCS/U. It is also possible to produce hydrogen from natural gas with solid carbon black as byproduct, which is easier to capture, store and use. This is highly energy-intensive with conventional methods, but more efficient methods are now at the piloting stages.

Carbon capture and storage or usage CCS/CCU (4-6 million tCO_2e potential): Carbon capture can reduce any emissions that cannot be eliminated by other means, such as those produced in cement manufacturing and refinery processes. For CCS, the first focus should be on high-purity CO_2 flows such as natural gas processing or ammonia production. At today's cost for many decarbonization measures, carbon capture and storage seem more economical than alternatives for some industries. Norway is already making steps in this direction with carbon capture at Klemetsrudanlegget, Norcem and Yara, and Statoil's Northern Lights project for carbon storage on the Norwegian continental shelf.

Other initiatives (5-7 million tCO_2e potential): Other industries are developing industry-specific technologies to reduce emissions. For example, some aluminum manufacturers are developing inert anodes that can eliminate process emissions,[12] and the global fertilizer industry is exploring several new production processes, including solid-state ammonia synthesis, nuclear electrolysis and the direct nitrate route.[13] Technologies to produce low-carbon cement are also on the drawing board.

Beyond reducing emissions from production, Norway will need to change demand patterns by moving towards lower-carbon alternatives and increasing reuse, remanufacturing and recycling. Such examples include but are not limited to use of wood-based high-rise buildings, full electrification of the transport sector, or precision farming that uses less fertilizer. The scope of this report does not allow for a detailed assessment of such measures, but the relative contributions of each decarbonization option will depend heavily on its business case and what policymakers do to stimulate it.

In sum, progress has been slow but not for lack of opportunity: several abatement levers available today could significantly reduce the emissions of Norwegian industry.

4. OPPORTUNITIES FOR NORWEGIAN INDUSTRY IN A LOW-EMISSION FUTURE

The costs of moving Norwegian industry to a low-emission future will be high, but a global transition to a low-carbon economy can also unlock new business opportunities. This is underway now in the power sector, where a few countries are driving technology development in renewables, including Germany and Denmark in wind power and Germany and China in solar power.

Norway is in a good position to become a global leader in industry decarbonization:

- **Poised to lead in deep decarbonization technologies.** Norway is in a natural position to take the lead, since it has already come far in "first-generation" decarbonization measures such as electrification and energy efficiency improvements. To achieve the next wave of emission abatement and deliver on its international obligations, the nation will need to venture into deep decarbonization technologies.
- **Strong technical competence and cooperation.** Norway has exceptionally high-quality human capital, fueled by first-rate education and research institutions in technical and natural sciences, such as NTNU and SINTEF. The country also has a strong technical track record in areas that will be strategically important in the low-carbon economy. For example, despite low-scale bioenergy production today, Norway has relevant competencies in the pulp and paper industry. The Norwegian oil & gas industry might also tap its unrivaled knowledge of offshore and deep-water technologies in developing CCS technologies.
- **Cross-industry synergies.** Norway might use petroleum reservoirs for carbon storage or use by-products from one industry as input factors for other industrial processes. As noted, byproducts from the forestry, pulp and paper industries could serve as bio-based fuel and feedstock in other industries.

> ***"Norway has big opportunities in the circular economy, through reuse of byproducts from industrial processes. We have a large process industry with associated infrastructure that creates both supply and demand for industrial byproducts – and strong competence in academia and industry to support it."***
>
> – Industry interview

Overall, Norwegian industry could find three types of opportunities in a low-emission future:

Low-carbon products: If major export markets introduce new limits on carbon footprints, several Norwegian industries may be well positioned to provide clean yet energy-intensive products including metals and chemicals. As low-carbon products could provide competitive advantages for export industries, many new opportunities may arise along the value chain, such as providing bio-based fuel and feedstock to other industries.

Producers of "green" aluminum have already started charging a premium thanks to the rising demand from customers such as Toyota and Apple that are under pressure to reduce their carbon footprints.[14] Operators of smelters running on hydro-power such as those in Norway, Russia and Canada are promoting their environmental credentials – and may increasingly develop a competitive advantage over those that rely on coal or gas. The recent move by Norsk Hydro to sign the largest corporate wind power purchase agreement to date, at 650 megawatts,[15] will further solidify its position in supplying low-carbon aluminum to an expanding market for such products.

> ***"We expect increasing demand for low-emission products in the future."***
>
> – Industry interview

Sale and licensing of deep decarbonization technologies: A natural benefit of Norwegian industry's decarbonization progress would be a wealth of knowledge and technology that could be marketed to countries that may be years if not decades behind. Examples of such success in the past include Yara's nitrous oxide abatement catalyst, which significantly reduced greenhouse gas emissions. Licensed to the chemical industry, it is now in use around the world. Similarly, Norwegian companies could potentially sell or license deep decarbonization technologies like CCS, production processes based on bio-based feedstocks, or new ways to produce hydrogen.

New industries: Existing industries may evolve to produce new product categories, and completely new industries may emerge in a low-emission future. For example, the oil & gas industry may begin to mix hydrogen into existing natural gas export pipelines to Europe. Over time, the gas pipeline infrastructure could be used to export pure hydrogen or even to funnel CO_2 from Europe to Norway for storage in Norwegian petroleum reservoirs. The country could host large-scale data centers for cloud computing, which require clean and inexpensive electricity, low political risk and a cold climate to cool the servers. Battery manufacturing has already begun, with PBES and Siemens setting up maritime battery factories in Trondheim. Access to clean and inexpensive power and a dynamic domestic market for electric maritime and road transport may justify battery manufacturing in Norway.

5. BARRIERS AND DRIVERS FOR DEVELOPING AND ADOPTING DECARBONIZATION TECHNOLOGY

The principal theoretical barrier to accelerating industry decarbonization stems from the "negative externalities" of emissions: the costs of climate change are borne mainly by people other than those who cause them, typically in other countries. Hence, companies and even nations may have few short-term economic incentives to reduce emissions.

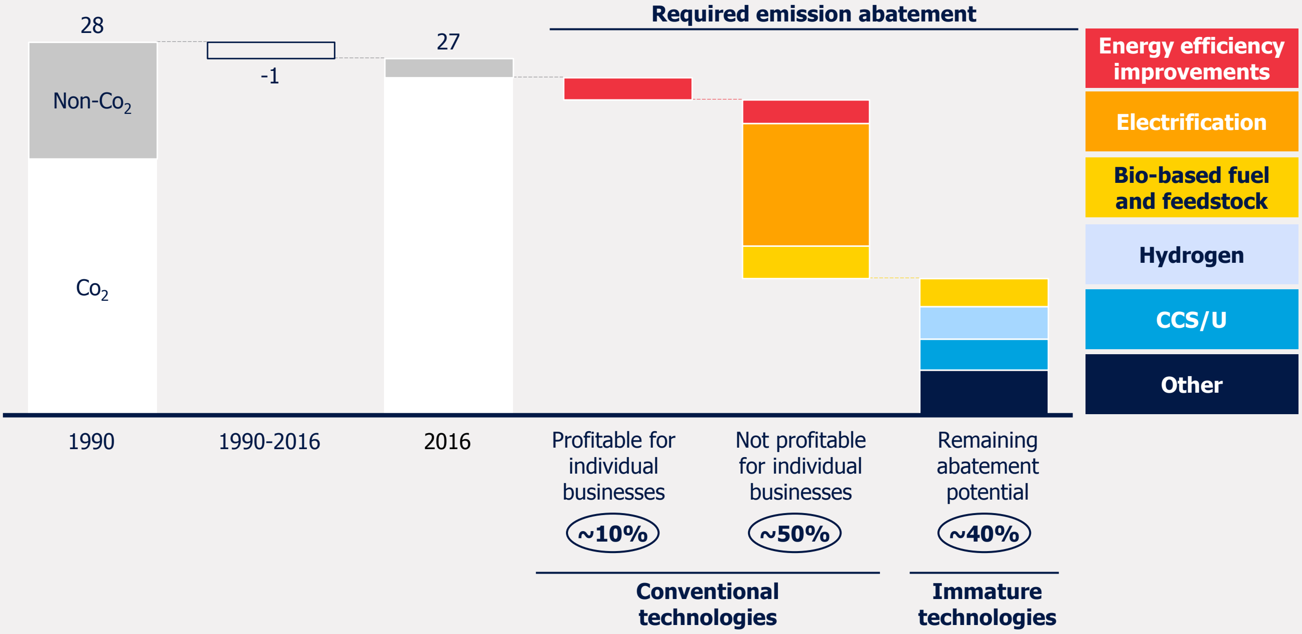
History shows that similar externality problems can be overcome, but typically only once immediate negative effects of business as usual are widely accepted. For example, the world rapidly came together in the 1980s and 1990s to phase out ozone-depleting substances. A rapid shift in the perceived urgency of curbing climate change may be underway today.

From the industrial perspective, however, three practical barriers typically stand in the way of accelerated progress:

Immature technology: The development and early adoption of immature technologies will be required to close around 40% of the abatement gap. Examples include cost-efficient production of hydrogen, bio-based anodes for the aluminum industry and bio-based reductants for the ferroalloy industry. This type of innovation can take decades – from early lab tests through pilots and scaling to full-scale application – and few individual companies have incentives to make such long-term R&D investments. For example, the process industries typically operate in environments with limited technology differentiation, where IP laws provide only limited protection and the diffusion of technological developments happens fast. Some industry leaders fear a "first-mover disadvantage," preferring instead to take a "wait-and-see" approach to technology development.

Exhibit 6

~40% of required emission abatement to meet 2050 aspirations can only be achieved if we unlock new technologies
Mt CO2e



SOURCE: McKinsey analysis

> ***"Technology diffusion is quick – innovation in one place quickly appears in another, and there is limited technology differentiation across the industry."***
>
> – Industry interview

Lack of profitability: Another 50% or so of the abatement gap can be closed with technologies that are mature but not profitable for individual businesses. They include electrification of new offshore oil & gas facilities, biofuels, and many energy efficiency improvements. These abatement technologies may well be profitable for society at large, but few individual businesses have financial incentivizes to invest in them; benefits to the environment are external.

> ***"The technology is there. If we were forced to, we could achieve zero emissions. But this would be costly, and our competitors would need to face the same requirements."***
>
> – Industry interview

Suboptimal decision-making: Companies are slow to adopt even profitable technologies that can close 10% of the abatement gap, even though they should in principle be adopted automatically. This is often true of energy efficiency measures and in some cases replacing fossil fuels by bio-fuels in industrial processes. Many of these decisions not to invest are explained by short-term bias, organizational barriers such as inadequate power and influence in the relevant department, or behavioral barriers such as bounded rationality.

> ***"We don't make investments with more than two or three years' payback time, even when longer-term investments could yield higher returns."***
>
> – Industry interview

Industrial companies do have some incentives to develop and adopt decarbonization technologies, but they are currently insufficient to generate the required investments:

Economic profit under current market conditions: In recent decades, Norwegian industry has made impressive strides in energy efficiency, driven largely by economic value from reducing energy costs. As noted, however, most of the economically viable potential is already exhausted.

Prospects of business opportunities: As shown in chapter 4, a low-emission future could provide new business opportunities for industrial companies. In interviews, we found some clear examples of companies acting on such opportunities already, including Pemco's development of wood pellets to replace coal, but most initiatives are still sub-scale relative to the need for technology development and adoption.

Stakeholder demands: Customers and other stakeholders may require and/or be willing to pay a premium for a lower carbon footprint. This is already driving consumer-facing industries to go carbon-neutral, but similar dynamics are not yet affecting the large process industries in Norway.

Government intervention: The industry naturally responds to interventions such as emission caps, taxes or subsidies, but government action has not yet yielded the progress that is required.

In sum, the industry is facing real barriers to developing and adopting decarbonization technologies, and few individual companies are being driven to invest. The nation is therefore unlikely to see a swift and significant step-change in industry decarbonization without clear government action.

What does economic theory tell us about the barriers?

Based on our interviews with industry decision-makers, most of the barriers to decarbonization are practical. Economic theories bear this out:

- **Negative externalities of emissions:** The cost of climate change is borne by people other than those who cause emissions, often in other countries.
- **Positive externalities of innovation:** Similarly, the benefits of innovation cannot be fully captured by those bearing the cost, creating a “first-mover disadvantage” and associated “wait-and-see” attitudes in some areas.
- **Short-term bias:** Short leadership cycles and shareholder demands for quarterly results skew incentives towards investments that pay off quickly and predictably.
- **Information gaps:** Companies may underinvest because they are unaware of relevant abatement technologies, do not understand their full value, are uncertain about government support and regulations, or face immature markets for renewable factors of production such as hydrogen and biofuels.
- **Not economically viable for society at large:** Some abatement initiatives are not economically viable even taking into account the benefits to society. Examples may include decarbonizing mature oil fields or refineries whose remaining lifespans are short. In such cases, Norway could discontinue operations or compensate with zero or negative emissions elsewhere.

6. GOVERNMENT POLICY MECHANISMS TO OVERCOME THE BARRIERS

No single policy or program can help industry abate emissions enough to reach 2050 targets – one of the most complex challenges in the world today. By themselves, mechanisms like carbon taxes and emission caps could force viable companies out of business without significantly reducing overall emissions. This partly explains why the world has made more progress decarbonizing power, heating and transport, which are less exposed to international competition, than industries such metals or chemicals.

Government policies and programs can be grouped in three categories along the technology development cycle, with a tailored mix of policy mechanisms (Exhibit 7):

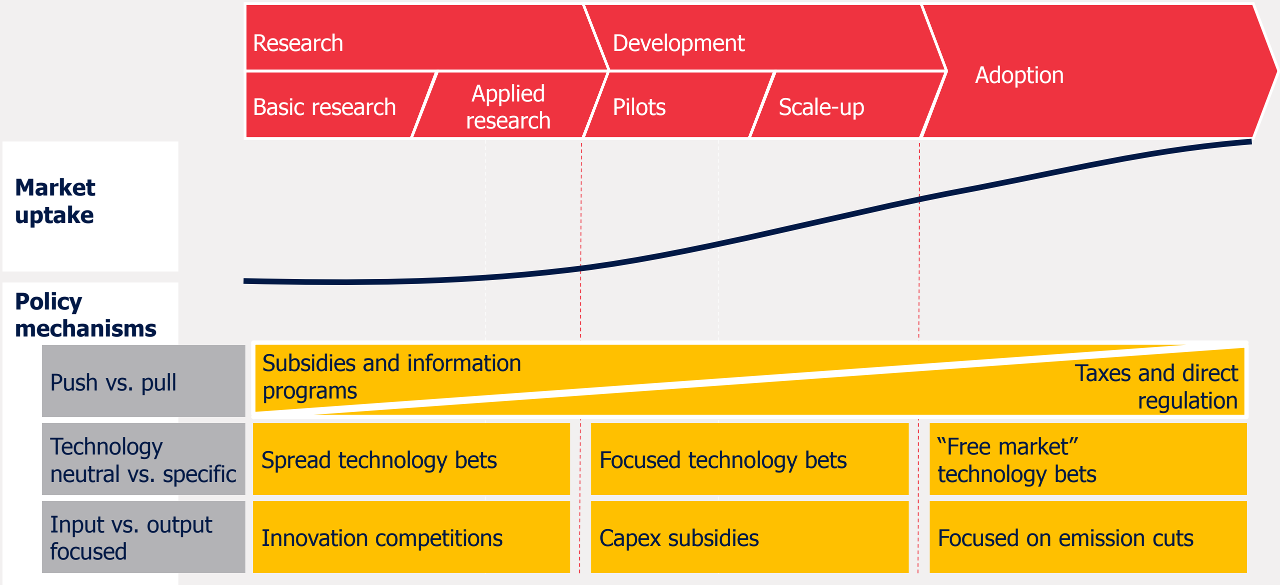
Research programs support innovation at the basic and applied stages. Examples could include new cost-efficient ways of producing hydrogen without associated CO2 emissions or deploying 100% bio-based feedstocks in metal production. At this stage of technology development, spillover effects are typically large and learning curves steep, which means large benefits to society that cannot easily be captured by individual businesses. Public funding and subsidy schemes are therefore required to drive sufficient R&D activity. Given the uncertainty around individual technologies, many small bets are necessary. Innovation competitions can help develop global online communities in search for technological breakthroughs, such as the Big Ideas Competition hosted by the UN and the government of South Korea, MIT's Climate CoLab, and the US government's broader innovation competition, Challenge.gov.[16]

Development programs target pilots and scaling of immature technologies, such as CCS or mixing increasing amounts of bio-based material into the feedstocks for metals or chemicals. At this stage of technology development, capital is required for piloting, testing, and full-scale facilities, while there are still spillover effects and first-mover disadvantages connected to learning curves. Capex support or risk-sharing programs are typically required to encourage industry to make the required investments – in combination with "pull" mechanisms such as targeted emission caps and carbon taxes. Higher capital requirements typically make it necessary to narrow the scope and focus on fewer high-potential technologies. Close collaboration across government, industry and research institutions is also required, for example through the HighEFF project, which has been well received by the industry as an arena for collaboration and idea-sharing.

Adoption programs target more mature technologies. As noted in chapter 5, around half of the abatement gap can be closed with technologies that are mature today but not profitable for individual businesses, including electrification of new offshore oil & gas facilities, using biofuels, and making many energy efficiency improvements. At this stage, with plenty of information about the cost and risks of individual technologies, the market is often best equipped to select specific solutions. Therefore, regulation, taxes or subsidies focused on specific outputs, such as emission abatement from a defined baseline, is likely to work well. International tenders can spur global competition and achieve cost-efficient solutions. While subsidies may still be required for adoption of some technologies, a gradual shift towards taxes and direct regulation is necessary as technologies mature.

Exhibit 7

Different policy mechanisms are relevant along the technology development cycle



SOURCE: McKinsey analysis

A comprehensive set of policy mechanisms will be required across all phases of the technology development cycle. At an aggregate level, as exemplified by the case examples on pages 29 to 31, such mechanisms should be developed in accordance with five guiding principles:

- **Long-term commitment:** Investing in innovation and adopting new technology in industry are inherently long-term decisions. Governments and private parties alike must therefore make long-term commitments to reach mutually beneficial arrangements. In the late 1970s, for example, Germany launched a decades-long subsidy scheme to develop its wind power industry. Those investments are paying off today – on a windy weekend in October 2017, German utilities generated so much power from wind that they paid customers to use it.[17]
- **Global sourcing of ideas:** National programs become stronger when they tap into global pools of ideas. For example, the Copenhagen Cleantech Cluster includes 25 foreign companies and collaborates with 15 other cleantech clusters globally.[18]
- **Pull *and* push mechanisms:** Carbon taxes, emission caps and other pull mechanisms force companies to change. Push mechanisms, on the other hand, such as subsidies and information programs, give companies incentives to invest in emission abatement technology. Global pull mechanisms might be the most powerful option, but it currently seems unattainable to reach the required international cooperation. On the other hand, the success of push mechanisms is most evident in the development stage (Exhibit 8). We believe the most successful national policies will balance pull and push mechanisms to achieve required emission abatements while protecting the competitiveness of local industries.
- **Technology-neutral *and* specific:** In general, we believe the most effective policies should be technology-neutral in the early research phases and avoid "picking winners." As technologies emerge, however, support can shift to developing the most promising. And as technologies mature, policies can provide incentives for certain outcomes and let companies decide for themselves which technology to adopt.
- **Output- *and* input-focused:** Building on the concept of technology-neutral and specific policies, authorities can provide incentives for output, such as innovation or emission reductions, or input, such as funding for specific projects to achieve the same aims. In early research phases, innovation competitions could incentivize output by rewarding those who find solutions to defined technical problems. Similarly, in the adoption phase, policies could reward companies for reaching a specific emission abatement target and let them choose the technical solutions. For piloting and scaling up specific technologies, however, governments may need to provide capex subsidies, as they did for decades in space exploration and other fields.

Exhibit 8

Push mechanisms can be designed in many ways, and must be tailored along the technology development cycle

Category	Mechanism	Description	Research (Basic research / Applied research)	Development (Pilots / Scale-up)	Adoption
Subsidies	Price guarantees	Guaranteed price for R&D output, e.g. technology license fee		✓	(✓)
Subsidies	Production tax credits	Premium paid to suppliers on top of wholesale price i.e. for renewable input factors like bio-fuels		✓	(✓)
Subsidies	Investment tax credits	Credit paid as percent of R&D spend on abatement technologies	✓	✓	
Subsidies	CO_2 certificate	Credit paid per unit CO_2e reduced from baseline year		✓	✓
Subsidies	Lump sum subsidy	Lump sum subsidy for R&D activity on abatement technologies	✓	✓	
Subsidies	Innovation competitions	Competitions on well-defined technology problems (often with pre-qualification round)	✓		
Subsidies	Preferential loans	Preferential loan conditions (e.g. favorable interest rate)		✓	✓
Subsidies	Risk-sharing programs	Risk-sharing contracts, i.e. government taking on downside risk of failed/underbudgeted R&D projects		✓	✓
Information programs	Demand-side information campaigns	Information campaigns to inform and influence customer behavior			✓
Information programs	Supply-side information campaigns	Information campaigns to inform industrial companies about opportunities and risks related to technology development and adoption	(✓)	✓	✓
Information programs	Industry platforms	Cross-industry platforms for collaboration and information-sharing	(✓)	✓	✓

SOURCE: McKinsey analysis

Success stories: lessons from the wind and solar power revolution

The sharp growth in renewable energy provides valuable insights from a field that is overcoming barriers similar to those faced by Norwegian industry. The results are promising, with renewable electricity generation likely to surpass that of fossil fuels before 2035. Examples from solar in China and wind in Germany, UK and Denmark offer helpful insights for Norway:

Denmark and Germany pioneered wind power in the 1970s and 1980s with an emphasis on creating strong industrial clusters with wind turbine OEMs and other component suppliers, and support services such as design and consulting. While the German industry grew with the help of long-term government R&D support, Denmark's was fueled by a grass-roots movement with little initial government support. By about 1980, however, the Danish government established the Energy Package and Energy Plan, which built trust among private players who later commercialized the industry.[19] Both countries have also relied heavily on feed-in tariffs, tax incentives and other market incentives to drive the shift from fossil to renewable energy generation.

The United Kingdom and Germany's push for offshore wind has yielded significant cost improvements in recent years. In Germany, recent tenders offer prices well below market for power at around 30 euros per megawatt-hour.[20] In the UK, contracts have been awarded with a guaranteed revenue of just £57.50 per megawatt-hour of electricity produced in 2022/23.[21] The two countries adopted different regulatory regimes: the UK organizes tenders to allow third parties, offshore transmission owners, to compete for the ownership and operation of offshore transmission assets. The aims include delivering cost-efficient investments and attracting capital and technical expertise. In Germany, on the other hand, offshore connections are constructed, owned and operated by transmission system operators. While the UK model is a more solid approach to cost recovery, the German model performs better on planning and coordination – crucial to the long-term development of an offshore wind network. Either way, these are successful examples of development programs.

China's installed solar power capacity, by far the world's largest, surpassed 77 gigawatts in 2016 – about 5% of the country's total power capacity.[22] China gained its first foothold in solar energy through an explosive growth in panel manufacturing fueled by Germany's decision in the late 1990s to offer businesses and homeowners financial incentives to install rooftop solar panels. China soon overtook the United States – the origin of the technology and a leading manufacturer for more than three decades. Between 2008 and 2013, China's output cut world prices by 80%, fundamentally changing solar economics. In 2013, China launched its own solar targets and subsidies, and its domestic market surpassed that of Germany two years later. China plans to invest another 2.5 trillion yuan, about $380 billion, to add 210 gigawatts of renewable capacity by 2020, of which 70 will be from solar.[23] China's deep and sustained subsidies to produce technologically advanced products and undercut foreign manufacturers included free and low-cost loans; artificially cheap raw materials, components, energy and land; and support for R&D and technology acquisitions. On the other hand, the Chinese government offered feed-in tariffs at provincial and state levels in addition to other forms of subsidies to spur local development of projects. Overall, this is a one-of-a-kind story of deep, end-to-end government support along the entire technology lifecycle from R&D to adoption.

While by many metrics, these ongoing and highly progressive campaigns to shift rapidly towards renewable energy sources have been fairly successful, certain challenges remain to move towards widespread adoption of clean, renewable power systems. More recent government programs are therefore aimed at driving adoption, based on:

- **Long-term commitments:** Since government budgets follow annual cycles, longer-term contracts can make commitments legally binding.
- **Global sourcing of ideas:** Many recent solar and wind projects began as competitive international tenders, which attracted bids from companies from all over the world on how much government support they would require. More than 35 countries now use such tenders.
- **Technology-neutral policies:** Over time, governments have shifted from subsidies based on the cost of installing a specific technology to technology-neutral tenders that create marketplaces for abatement technologies.
- **Output-focused incentives:** While feed-in tariffs and early tendering schemes can provide incentives to complete a specific project (input), more recent tendering schemes provide incentives for renewable energy generation capacity or even better – renewable energy supply (output).

Exhibit 9

Policy to support renewables adoption has evolved, from feed-in-tariffs to technology-neutral and output-focused tenders

Most common today

Maturing contracting policy →

	Feed-in-tariffs	Contract for Difference (CDF) tender	Technology neutral tender	Technology neutral tender with grid integration cost
Description	Long-term contract subsidy based on cost of generation for each technology	**Bonus** on top of **wholesale price** Incentive to **market power** efficiently	**Competitive, international** tenders Tendering of installed capacity	**Competitive, international** tenders Bidding on amount of energy to **supply in specified time period**
Long-term commitment	✓	✓	✓	✓
Technology-neutral	✗	✗	✓	✓
Output-focused	✗	✗		✓
Example	**Germany**	**UK**	**Brazil**	**Chile**

SOURCE: BNEF, EWEA, McKinsey

Other examples: biofuels, hydrogen, and ozone-depleting gases

While Norwegian industry is making only slow progress on decarbonization, there are opportunities to learn from research, development and adoption programs in other countries and other sectors for GHG abatement technologies. Three examples provide relevant insights as Norway charts a path to a low-emission industrial sector:

- **The United States is the largest producer of biofuels,** with an annual output of 400 million barrels.[24] The US owes this success to the introduction and enforcement of a renewable fuel standard in 2007 that required gasoline and diesel fuel sold in the US to be blended with increasing volumes of biofuels. The aims included reducing greenhouse gas emissions, expanding the nation's renewable or biofuel sector and reducing its reliance on imported oil. The effort was spearheaded and then guided in close collaboration with industry groups such as the Biotechnology Innovation Organization and Renewables Fuel Association. Most important, the program authorized grants worth more than $4 billion for related R&D efforts, including aiding commercial production of advanced biofuels such as cellulosic ethanol and biomass-based diesel.[25] This is an example of how consistency over at least a decade jumpstarted a sector by giving investors the confidence to build facilities. This policy has also had strong knock-on effects on other sectors such as agriculture and natural gas.
- **Japan has launched a 30-year strategy to create a hydrogen economy.** Its holistic approach covers mobility, buildings, industry and the energy system. By 2020, about 1.4 million Japanese households should be using fuel cell units to power their homes, rising to 5.3 million households, or about 10%, by 2030.[26] The nation aims to build 300 hydrogen filling stations by 2025 and serve 800,000 fuel cell vehicles by 2030. With strong government support, Toyota, Honda, Nissan and other Japanese companies are leading global developments in hydrogen technology. Some worry that export markets may prefer competing technologies such as electric vehicles,[27] but this may be a fit-for-purpose strategic and practical bet for a resource-strapped island nation, setting an example for how a unique context might require a unique approach in picking the technology and designing relevant development programs around it.
- **The world came together to reduce ozone-depleting gases** in the Montreal Protocol in 1989. Perhaps the single most successful international environmental agreement to date, this effort took into account all parties to the protocol and all of their phase-out commitments. Together, they achieved a compliance rate of more than 98% by 2016. The protocol's stable framework allowed industry to plan long-term research and innovation. Among other drivers of success were the relatively low costs of implementation – CFCs were old technology and well out of patent – and the huge, immediate benefits of compliance, such as the avoidance of skin cancers and cataracts. The treaty included a multilateral fund to help cover the cost of switching to CFC-free technologies, especially in developing countries. In parallel, enforcement mechanisms included penalties, such as trade sanctions, against products containing or, more controversially, using CFCs. This is a case example of effective adoption programs put in place and successfully executed over the originally intended timeline.

These examples demonstrate how large-scale technology innovation and adoption are possible in relatively short timeframes, even in the face of significant challenges. In each case, consistent, long-term government support was essential to set the right direction and send the right signals. Close collaboration among stakeholders was also required, including industry associations, large private sector players, universities and start-ups. Some of the examples also show that developing new climate-friendly technology can create new markets and significant opportunities for industrial players.

7. THE WAY FORWARD

Norway and its industries can work together to build a low- or zero-emission economy by 2050. This transition, if carried out wisely and at the right pace with the right investments, could generate enormous economic benefits for the Norwegian industrial sector. Substantial barriers must be overcome, of course, and without a master plan or consistent and coherent government policy mechanisms, it is hard to imagine that the private sector would venture into this complex transition and sustain the required investments.

Given the challenges and opportunities ahead, we envision a program for Norway with three elements that could drive industry decarbonization to meet the 2050 targets:

- **Develop a national transition plan that demonstrates a long-term governmental commitment:** While it is wise to urge and orchestrate as much international collaboration as possible, the plan must be pragmatic to start moving towards the 2050 objectives as soon as possible. It will serve two purposes: providing clarity around targets and goals and providing longer-term predictability.
- **Design and roll out a coherent set of policy mechanisms supporting the plan:** Effective policy mechanisms and regulations must be in sync with the targets in the plan to overcome barriers at each stage of the transition cycle. These interventions must provide the long-term certainty that the private sector requires to invest in developing and adopting abatement technology.
- **Deepen the engagement of all stakeholders:** To support the plan, Norway should facilitate information-sharing and collaboration across universities, research institutes, industry associations, and private companies. Cross-sector and cross-border initiatives, for example, should look beyond short-term cost concerns and focus on the long-term value of industry decarbonization. The financial rewards may be significant and the value of a healthy planet goes far beyond pure monetary value.

APPENDIX: METHODOLOGY AND INTERVIEWS

This report was commissioned by Enova and supported by McKinsey & Company as an external advisor. The information and opinions presented here are entirely those of the authors. In addition to close examination of the existing literature, they conducted 14 interviews with industrial companies, industry associations, research institutes and government entities. The report also builds on McKinsey's research on emission abatement and more than 25 interviews with McKinsey subject-matter experts from around the globe.

The purpose of the report is to provide a knowledge base for Enova's strategy and priorities, and the report examines the climate challenge for the Norwegian industry across four areas:

1. **Prospects for Norwegian industry in a low emission society (chapters 2 and 4)**
   - What global megatrends impact the development of Norwegian industry, and what are the implications of these trends?
   - What trends impact market developments for technology, commodities and products?
   - What new players and value chains will impact the different segments of Norwegian industry?
   - In broad terms, how will Norwegian industry look in 2030 and 2050?

2. **Drivers, barriers and risks related to emission abatement (chapters 3 and 5)**
   - What drivers exist across industry segments related to innovation, product, and technology development?
   - What industry and segment specific drivers and barriers do also impact innovation, product, and technology development?
   - What risk factors exist and impact development and choices related to innovation, product, and technology development?
   - What are plausible choices made by different industry players given the drivers and barriers?

3. **Potential for new Norwegian industries in a low-emission society (chapter 4)**
   - What must happen for new, climate-neutral and energy-efficient industries to emerge in Norway?
   - What are Norway's unique sources of competitive advantage related to renewable resources, and how will they impact potential new industries?
   - What existing industry sectors will most likely be affected by potential new industries, and what are potential consequences?
   - What are implications for Norwegian society if new industries based on renewable resources emerge?

4. **Competence, capital and financing required to deliver on the climate aspiration (chapters 5 and 6)**
   - Where are the major competence hubs across Norwegian industry, and how do they impact the direction the industry is taking?
   - To what extent do capital and the access to capital impact the choices made by Norwegian industry, particularly related to climate change?
   - What trends are driving the development of capital in Norwegian industry, and what do the trends say about developments in industry production and emissions?
   - What is the impact of financing models on choices related to innovation, product and technology development in Norwegian industries?
   - What trends are influencing financing models, and what are their implications?

The report builds on existing perspectives on Norwegian industry emission abatement, particularly from the Norwegian Environment Agency and the industry itself through the roadmaps for Norwegian industry. In addition, we used industry-specific reports, such as from the European Fertilizer Association and the Oil and Gas Climate Initiative. We used these reports as foundations to build upon rather than sources of specific facts or perspectives.

The report builds on a large proprietary McKinsey library. This includes global perspectives on each of the large industries studied in this report and also perspectives on climate change and emission abatement. McKinsey continuously researches greenhouse gas emission abatement, starting with the first global greenhouse gas abatement curve in 2007. As pointed out in this report, Norway is different from other countries in several aspects of the industry climate challenge, but where applicable we also tapped McKinsey's perspectives on industry decarbonization in other countries, such as the public report, "Energy transition: Mission (im)possible for industry? A Dutch example for decarbonization."

We also used several datasets, particularly from Statistics Norway, Rystad Energy and EIA. We studied many specific developments and events based on reports from news outlets, such as Bloomberg, Financial Times and Reuters.

Last, the authors interviewed more than 25 McKinsey subject-matter experts and leaders in 14 Norwegian stakeholder organizations, including industrial companies, industry associations, research institutes and government entities. We thank all parties who contributed to this work: Alcoa Norway, Borregaard, Eramet, Marine Harvest, Norwegian Environment Agency, Norcem, Norsk Hydro, Orkla, Pemco, RISE PFI, Statoil, Sintef, Tine and Yara.

We covered four main topics covered in the interviews:

- What fundamental trends are driving developments in your industry, and how are these trends influenced by aspirations to reach a low-emission society by 2050?
- What technologies are available or in development that could help your industry significantly reduce GHG emissions?
- What are the drivers and barriers for your industry in developing and implementing these technologies?
- What opportunities for Norwegian industry could arise from a move to a low-emission society?

At an aggregate level, six messages stand out from the interviews we conducted:

- **Norwegian industry is already doing a lot to reduce emissions and has achieved impressive results in many areas.** This is particularly true for energy-efficiency initiatives and reduction of non-CO_2 emissions, such as PFC gases from the aluminum industry and nitrous oxide from the fertilizer industry.
- **Yet the industry is not on track to deliver the required emission abatement.** While there are many potential solutions for abatement of the remaining CO_2 emissions, few are commercially viable at scale. Current technology development will not do enough to change this pattern in time to meet the 2050 goals.
- **Sustained competitiveness of Norwegian industry in global markets is crucial** to create value and good jobs – and to protect the environment, as production in Norway is typically cleaner than most alternatives. This naturally imposes constraints on investments in new technology with unclear financial benefits, and most companies invest with strict two- or three-year payback requirements.
- **Stable conditions and long-term government support will therefore be required** to move Norwegian industry towards a low-emission future. All the industrial companies that we interviewed pointed to the need for long-term financing schemes that enable investments in new technology while securing industry competitiveness.
- **The transition will unlock new opportunities for Norwegian industrial companies**. Consumer-facing companies already see customer preferences shifting towards low-carbon products, and other industrial sectors expect to see similar shifts in the mid- to long-term future. Some companies are independently developing low-carbon technologies that they expect to turn a profit, for example through licensing, but most large technology development efforts require government financing.
- **Progress will clearly require more collaboration – and leaders are eager to participate.** Most interviewees point to initiatives like the HighEFF program and the recent joint industry roadmaps as critical building blocks to solve the climate challenge for Norwegian industry. Companies and industries have a lot to learn from each other, and they will find synergies in cooperating to develop joint solutions.

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Enova works to promote Norway's transition to the low emission society. The transition will require us to cut greenhouse gas emissions, safeguard security of supply and create new values. That is why Enova works to bring the good solutions out in the market and contributes to new energy and climate technologies.

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