1. Introduction

Two features of the Norwegian economy set it apart from almost all other countries:

- a large offshore petroleum sector
- an electricity sector almost completely composed of renewables.

These two factors mean that the distribution of greenhouse gas emissions differs significantly from other countries, as shown in Table 1.

Table 1 Norwegian greenhouse gas emissions. 2021

Sector	ETS or non-ETS	Emissions (Mt CO_2 eq.)	Percent of total emissions	Percentage change in emissions, 1990-2021
Petroleum extraction	ETS	12.1	24.7	48.4
Manufacturing and mining	Mostly ETS	11.7	23.9	-40.8
Road traffic	Non-ETS	8.7	17.8	17.1
Other transportation	Mostly non ETS	7.5	15.3	40.8
Agriculture	Non-ETS	4.6	9.4	-4.7
Energy supply*	Non-ETS	1.7	3.5	405.6
Heating of buildings	Non-ETS	0.5	1.0	-80.5
Other	Mostly non ETS	2.1	4.3	-25.3
Total		**48.9**	**100**	**-4.7**

*GHG emissions primarily from fossil-based heat production, and to a small extent also waste-based and bio-based electricity production.
Note: ETS stands for the Emission Trading System implemented in Europe
Source: Statistics Norway (2023a).

This table differs dramatically from similar one's for almost every other country in three respects:

- Norway has a big offshore petroleum sector with large emissions originating from the gas turbines on the platforms, which are used to generate electricity for extraction activities.

- There are virtually no emissions associated with electricity generation; Norway's electricity supply is based on 91% hydro and 8% wind power (in 2021); see Statistics Norway (2023b).
- Hardly any emissions are generated by the heating of Norwegian buildings, which is primarily done by electricity.

Offshore extraction of oil and natural gas, which is henceforth referred to as petroleum extraction, has been a key element in the Norwegian economy since the early 1970s and has played a major role in making Norway one of the richest countries in Europe, measured in per capita GDP. The industry's share of GDP was 21% in 2021, and preliminary national account figures suggest an even higher share (36%) in 2022 due to the extremely high prices for natural gas. (In the summer of 2022, daily gross income from sales of natural gas peaked at €1bn.)

In addition to its pivotal importance, the petroleum extraction sector is also a large purchaser of inputs from other sectors of the Norwegian economy. These inputs are partly for offshore investments but also for various types of intermediate inputs. Supplying and supporting offshore extraction involves both manufacturing and service industries. The impact and significance of offshore petroleum extraction for the rest of the Norwegian economy have been discussed in several articles in recent decades, see, e.g. Eika (1996), Cappelen et al. (2013) and Bjørnald and Thorsrud (2016).

Measured by area, Norway is the sixth biggest country in Europe, and the distance from South to North makes it one of the longest, too. There is a strong political preference for ensuring that a substantial portion of the population can live in rural/semi-rural districts. Transport – by vehicle, ship, train and plane – is, therefore, a key activity from a business and social point of view. While transport plays a key role in preserving thriving districts, road, sea, and air transport also emit substantial amounts of CO_2 (see Table 1).

Greenhouse gas emissions from agriculture consist mostly of methane and nitrous oxide from livestock and the use of fertilizers. While these emissions are important, we do not discuss them in this paper as the policies to reduce them differ greatly from those designed for other sectors.

Most countries have significant emissions from electricity generation and heating buildings. In many cases, cutting these emissions is less costly than cutting emissions from other sources. As noted above, this is not the case in Norway. Therefore, in order to reduce non-agricultural emissions, Norway must reduce emissions from the first four sources listed in Table 1.

This paper will discuss Norwegian climate policy in light of current and proposed strategies to radically reduce emissions in the four sectors and achieve a low-carbon society by 2050; the latter is defined as cutting emissions by at least 95% relative to 1990. We examine the Norwegian policy for cutting emissions in the short term from an economic perspective and some of the suggested initiatives aimed at achieving radical reductions in these sectors in the long term. As will become clear from the following, the guiding principle is to obtain a low-carbon society by promoting technology switching, in particular through carbon capture and storage, the electrification of petroleum extraction and the introduction of zero-emissions transport technologies.

Although Norway is part of the EU ETS—Table 1 shows that both the emission-intensive manufacturing sectors and extraction of petroleum are covered by this arrangement—relying solely on European tradable emissions permits and domestic emission taxation are regarded as insufficient measures if the ambitious long-term target of becoming a low-carbon society is to be achieved by 2050.

2. Theory

It is widely recognised among economists that a common price on carbon emissions, through either a carbon tax or a price for tradeable emission permits, is the most important policy instrument available to cut emissions. Standard economic reasoning also implies that in the absence of other market failures, an appropriately set carbon price is the only instrument necessary to achieve an efficient climate policy. In practice, however, most countries use a variety of other policy instruments in addition to an appropriate price for carbon emissions. These include explicit or implicit subsidies to carbon energy alternatives coupled with various forms of direct regulation.

There may be several reasons for using additional instruments, some good and some not so good. Among the good reasons are the following three:

- Distributional considerations may imply that the price of carbon is set too low.
- Governments are unable to commit to a future carbon price.
- Other externalities and market failures.

In practice, distributional concerns are important in all policy settings. Even if the government intends to fully recycle carbon tax revenues, the individual voter might focus purely on the visible tax increase and have little faith that carbon tax revenue will be used in a way that compensates him or her. Moreover, some people will be more adversely affected by a carbon tax than others. This will be the case for those consuming more than the average share of fossil fuels due to their current preferences or earlier investments (e.g., they may have acquired a large house and/or have a long commute). On the production side, some industries will bear a disproportionately high share of the total carbon tax cost. Consumers who use large amounts of fossil fuels, as well as workers and owners in high-emission sectors, may lobby against a carbon tax.

By contrast, sectors that generate renewable energy or inputs into this production will benefit from subsidies for renewables and may lobby for them. Another factor worth bearing in mind is that the costs of various types of subsidies and direct regulations are likely to be less visible to the typical voter.

These arguments suggest that it might be easier to obtain political support for a renewable's subsidy than for a carbon tax. As a consequence, the price of carbon may end up being set too low to achieve the emission goal(s) set by the government. Other policy instruments then have to be used as well.

For future carbon emissions to be strongly reduced, large investments in renewable energy and other low-carbon technologies are needed. Clearly, the profitability of such investments will depend strongly on the future price of carbon emissions. If the current government were able to commit to a carbon price far into the future, this would not be a problem. However, such a commitment is not feasible in practice, which suggests that decisions relating to investments in renewable energy and other low-carbon technologies must be based on market agents' expectations about future carbon prices.

If the current price of carbon is controversial (partly because of the distributional concerns mentioned above), market agents' expectations about future prices may be biased downwards compared to what current policy makers intend. If this is the case, the incentives to invest in low-carbon energy and technology will be too low, even if the current price of carbon is set at an appropriate level. This argument suggests that other policy instruments also need to be used to generate sufficient investment in low-carbon energy and technology.

Some support for the latter policy conclusion is found in the literature. Gaure et al. (2022) show that if there is a chance that the current carbon tax is set lower than the (true) social cost of carbon, then the current government should offer R&D subsidies to climate-friendly electricity technologies. However, subsidies should only be offered if these technologies compete with fossil-fuel-based technologies for new investments in production capacities. Ulph and Ulph (2013) also analyse a two-period model with a current and a future government setting climate change policies. In their study, the two governments assign different weights to environmental damages relative to net consumer benefit. The current government cannot commit the future government and thus may use an R&D subsidy to stimulate investment in abatement technology. According to the Ulph and Ulph study, even if market expectations of future carbon prices remain unbiased, the uncertainty about these future prices may weaken the incentives for investing in low-carbon energy and technology.

There may be other externalities and market failures in addition to climate change. Perhaps some of the most obvious are various market imperfections associated with the development of new technology. These are, of course, still relevant, independent of the climate issue. However, with economies rapidly transitioning from the use of fossil fuels, the introduction of new technologies is likely to be more important than ever. Hence, appropriate policies addressing externalities and other market failures related to these, for example, the patent system, will play an increasing role.

In addition to the market imperfections mentioned above, various types of co-ordination issues may also arise in (rapidly) transitioning economies. Here is an obvious example: No one will buy an electric car if they expect there will be no charging stations, and no one will invest in charging stations if they expect there will be no electric cars. It is not obvious that an unregulated marked will manage such types of coordination in an optimal manner, see e.g. Greaker and Midttømme (2016). Hence, there are reasons for policies, in addition to imposing a price on carbon, to address coordination issues.

To sum up: A price on carbon emissions at an appropriate level (relative to the emissions goal) should be a key element of any efficient climate policy. There are also positive grounds for various other forms of policies. However, this does not mean that the more policy instruments, the better. Each additional instrument should have a proper rationale. In Section 3, we discuss some of the Norwegian policies in light of these considerations.

3. Norwegian climate goals

The most important policy goal for Norway is its commitment to the Paris agreement: Norway's nationally determined contribution (NDC) is to reduce the country's emissions by 50–55% by 2030 compared with 1990, see Table 2.

Norway also has a threefold agreement with the EU. First, it is part of the EU ETS; this covers approximately half of the Norwegian emissions (see Table 1 for details). Second, domestic emissions in the non-ETS sectors should be reduced annually towards 2030. At present, the agreement with the EU requires Norway to gradually reduce emissions so that the non-ETS emissions in 2030 are 40% below their 2005 levels. There is some flexibility in this agreement: Norway can use the EU's Effort Sharing Regulation (ESR) to cut its emissions by less than the commitment as long as it buys additional emission reductions from other EU countries.

However, the EU has tightened its emissions requirements for 2030 as part of the European Green Deal to become climate neutral by 2050. To reach this long-term target, the EU has committed to cutting total emissions by at least 55% by 2030, partly by strengthening the EU ETS and by introducing emission trading arrangements for road transport and buildings. In light of the more ambitious EU emissions targets for 2030, Norway's agreement with the EU will probably be revised. In particular, the target for cuts in Norwegian non-ETS emissions may be raised significantly.

Table 2 Norwegian climate goals and ambitions

Overall goal or ambition	Details
Paris agreement	Reduce Norway's emissions by 50–55% by 2030, compared with 1990. Formally part of the EU/EEA-wide goal.
Agreement with EU	Participate in EU ETS; Specific commitment for non-ETS emissions; Specific commitment for LULUCF.
Norwegian Climate Change Act	Norwegian emissions required to be 50–55% lower by 2030 and 90–95% lower by 2050, both compared with 1990. The Act explicitly allows for co-operation with the EU.
"Hurdalsplattformen": Goal/ambition for Norway's *total* emissions	Reduce *total* emissions (non-ETS plus ETS) by 55% by 2030 (compared with 1990).
Various sectoral goals/ambitions	Examples: All new cars should be emission-free by 2025; Reduce offshore emissions (from extraction of oil and natural gas) by 50% from 2005 to 2030; Oslo and several other municipalities have specific goals/ambitions.

The third element of the agreement with the EU concerns Land Use, Land Use Change, and Forestry (LULUCF). Like policies on emissions from agriculture, LULUCF policies are noticeably different from others discussed in this article and so are not included here.

In addition to Norway's international commitments, Norway has a Climate Change Act. This law requires Norwegian emissions to be 50–55% lower by 2030 and 90–95% lower by 2050, both compared with 1990. The Act explicitly allows for co-operation with the EU. Hence, these goals are not directly linked to emissions from Norwegian territory since flexible mechanisms like the EU ETS or EU ESR can be used.

The above goals have been set by the Parliament, with broad cross-party support.

Moreover, they relate both to the Paris agreement and Norway's agreement with the EU and involve binding international commitments. It seems likely that these goals will, therefore, have a significant influence on future policies.

Norway also has various other climate-related goals. Since these are not international commitments, they might better be described as ambitions rather than goals.

First, the previous government presented the goal that all new private cars should be emissions-free by 2025. In 2022, 79% of all purchased new cars were electric (OFV, 2023). Second, in 2021 the Government laid out additional goals/ambitions in its policy platform "Hurdalsplattformen": Norway's *total* emissions (both non-ETS and ETS) should fall by 55% by 2030. This sounds highly ambitious: As Table 1 shows, total emissions decreased by 4.7% from 1990 to 2021 (whereas there have been radical changes in the composition of emissions across sources). In order for emissions to be 45% of the 1990 level by 2030, they must fall by almost 8% annually from 2021 to 2030.

The same policy platform also announced that various sector-specific emissions targets will be introduced. The Parliament has already set a goal for the offshore petroleum sector (which is part of the ETS): emissions should be reduced by 50% between 2005 and 2030.

In addition to goals set by central government, some cities and municipalities have defined their own climate goals. Oslo, for example, aims to cut emissions by 95% from 2009 levels by 2030. An obvious question is how seriously these aspirations should be taken: Oslo's actual emissions only fell by 26% during the eleven-year period 2009–2020, i.e., by an annual reduction of 2.7%, partly because of the nationwide ban on oil-fired heating systems. To reach the 2030 goal, emissions in Oslo would have to fall by an annual rate of 24% from 2020 to 2030.

4. Norwegian Climate Policies

Approximately 50% of Norwegian emissions are covered by the EU ETS, including the petroleum extraction sector and most of the emissions from manufacturing. With few exceptions, all non-ETS emissions are subject to the general carbon tax, which is NOK 952 (about €91) per ton of CO_2 as of 2023. Because the ETS price in December 2022 varied between €84–94 (Trading Economics, 2023), the price of carbon emissions for ETS sectors and the general tax for non-ETS sectors are roughly of the same magnitude. Note that the current Parliament has approved the previous government's plan to gradually raise the non-ETS price to NOK 2,000 (about €200) in 2030 (plus an adjustment for general inflation from 2020 to 2030).

On top of the ETS quota price, there is a Norwegian carbon tax on petroleum extraction (NOK 761) and domestic aviation (NOK 649). As a result, these two sectors have a much higher total carbon price than the rest of the Norwegian economy.

An important element of Norwegian climate policy has been subsidies for electric cars. Since 1955, Norway has imposed a relatively high tax on new car purchases. For regular cars, the total purchase tax (including VAT) is about 50%, while the standard VAT for other goods and services is 25%. Electric cars are completely exempt from VAT. Electric cars are also eligible for other benefits, such as reduced charges on toll roads, permission to drive on bus lanes, and reduced, or even no, parking fee in public areas.

Approximately 25% of Norway's total emissions come from extraction of petroleum. These emissions originate from the gas turbines on platforms, which are used to generate electricity for the extraction process. As mentioned previously, Norway aims to reduce these offshore emissions by 50% by 2030. The only way to achieve this (without reducing total oil and gas extraction) is to replace the electricity from the offshore gas turbines with (emission-free) electricity. Some electrification of this type is (marginally) profitable for the petroleum companies given the high price they must pay for their carbon emissions. However, to achieve the goal of a 50% cut in emissions, the government would have to impose electrification on the industry.

5. Goals and policies in light of EU policies

The EU ETS covers about 45% of EU's emissions. The basic idea behind quota systems of this type is that total emissions are regulated by the cap, and that the quota market gives a common price of emissions so that a cost-effective allocation of emissions is achieved within the cap. Any additional policy instruments directed towards emissions from sectors within the quota system gives a reallocation of emissions away from the most efficient allocation, and should hence be avoided. In light of this, the Norwegian CO_2 tax on offshore petroleum production and on domestic aviation is hard to justify. Likewise, it is difficult to find any good reason for the emission goals and electrification requirement for the offshore petroleum sector.

Under current EU policies, it makes sense for Norway to have a uniform domestic carbon tax on non-ETS emissions. Additional goals and policies related to specific parts of the non-ETS emissions are not so easy to justify. Consider, in particular, the subsidies related to electric cars: The cost of these is obviously difficult to calculate, partly because it is difficult to calculate the decline in carbon emissions due to the transition to electric cars. The national budget for 2020 (Ministry of Finance, 2019) has made some cost calculations, and all of these suggest that the cost-per-ton of CO_2 avoided exceeds €500. This is a very high cost both compared with the EU ETS quota price and the general carbon tax applied in non-ETS sectors. Even restricting oneself to the non-ETS sectors, this suggests that efficiency gains can be achieved by increasing the general CO_2 tax and reducing some of the benefits to electric cars.

On the other hand, altering the composition of the national car fleet will take considerable time, even under ideal conditions with a 'correct' price on carbon. Moreover, this transition may face other obstacles not captured by simple economic analyses. Examples can include the co-ordination problem associated with charging stations mentioned previously and other uncertainties and incomplete information facing buyers of new cars.

The Norwegian policies encouraging electric cars must also be viewed in the light of the EU's mandatory emission reduction targets for new cars. Like most EU regulations, the rules are quite complex. The short version of this regulation is that for *all new cars* sold in the EU/EEA, average emissions of CO_2 per km cannot exceed an upper limit. This regulation applies to the aggregate sale of new cars, including electric ones, so that if one seller exceeds the limit, it can purchase additional allowances from another seller that is below the limit. This system resembles a renewable portfolio standard; see, for example, Greaker et al. (2014).[21] To illustrate this, assume that the limit is 100g CO_2 per km and that all fossil-fuel-based cars emit 150g CO_2 per km. In order to reach the average limit of 100g CO_2 per km, one-third of all cars sold must, therefore, be zero-emissions vehicles (in practice, electric vehicles).

The current limit is 95g CO_2 per km for passenger cars. As long as this limit is binding, any additional policy promoting electric cars will have no effect on the emissions from the total fleet of new cars: The policy will simply make it easier for car manufacturers to satisfy the regulated average emissions per km. In other words, subsidising new electric cars will, in fact, be a subsidy for the whole fleet of new cars since the composition of new (emission-free) cars will be determined by the regulation. This relates to a general property of renewable portfolio standards, pointed out by, e.g. Greaker et al. (2014): A subsidy for renewable energy when a renewable portfolio standard is binding is a subsidy to *all* energy. As a direct

21. An example of a renewable portfolio standard is a requirement that a specific share of all electric energy should be renewable.

consequence, the use of dirty energy will also go up. Subsidising the purchase of electric cars may increase the total number of new cars but will also increase the number of cars running on fossil fuels. Although this effect may be weak, it illustrates that the effects of subsidizing electric cars are by no means obvious.

An important element of the EU's future climate policy is the introduction of a new quota system covering emissions from road transport and buildings. As with the current ETS, quotas will be tradable across countries, the total number of quotas will be regulated by a cap, and the cap will be adjusted through a market stability reserve (MSR).

For practical reasons, the upstream actors will be required to buy quotas, and it is expected that the EU-wide quota price will be passed on to the downstream actors. If the domestic carbon price faced by the downstream actors in road transport and buildings exceeds the equilibrium quota price, then that country does not need to take part in the new quota system. This may well prove to be the case for Norway, as the general carbon tax can easily exceed the quota price; the latter is expected to be below €45/tCO_2. If so, it is difficult to see why Norway should be part of the new quota system. If, however, Norway does decide to join, then the Norwegian policies of encouraging electric cars will be even more difficult to justify. Nevertheless, additional instruments may be justified by the reasons mentioned above.

6. The transition to a low-carbon society

6.1 Introduction

In Section 3, we outlined the Norwegian climate targets, in particular, the commitment to cut emissions by 90–95% by 2050 relative to 1990. Henceforth, this target will be referred to as the transition to a low-carbon economy. The current government has announced a policy platform that provides some guidelines on how to reach these goals, see Office of the Prime Minister (2021). The most important measures include:

- Imposing industry-specific and sector-specific climate targets; these should be developed in co-operation with the industries. Currently, one industry-specific target has been announced (petroleum extraction), see Section 3
- Electrifying petroleum extraction, see Section 3
- Developing a value chain for carbon capture and storage (CCS)

- Developing a value chain for hydrogen and reaching targets for (blue and green) hydrogen production
- Investing heavily in offshore wind power
- Developing a sustainable battery industry
- Continued participation in the EU ETS framework
- All sales of new passenger cars and light commercial vehicles should be emission-free by 2025.

Before we examine some of the policy measures listed above, see Sections 7–11, we provide a short discussion of how active the state may be in ensuring a green transition.

6.2 The role of the state

Transition towards a low-carbon economy requires the phasing out of emissions and dirty technologies in some sectors and their replacement by climate-friendly technologies and green economic activities. Because the latter technologies and activities will have a long lifetime, it is vital to avoid serious mistakes. Therefore, a key question is whether the government should design a general policy package that provides industry-neutral incentives to invest in climate-friendly activities or actively invest in specific industries, i.e., pick a set of future climate-friendly industries and technologies expected to become successful and invest in these.

In standard economic theory, the economy is referred to as imperfect if there are various market failures, such as positive or negative externalities, natural monopoly, and other cases of imperfect competition. Typically, it is assumed that each market failure is corrected by separate targeted policies and that economic actors therefore internalise social costs and benefits. The role of the state is largely to correct these well-defined market failures and to ensure that property rights are respected. We refer to this as the *neoclassical* state.

An alternative view is that radical social change, like the green transition, requires a *proactive* state. The role of the state is in this case to facilitate the transition by co-ordinating various policy measures across sectors; across private actors with diverging interests; and across government bodies, each being responsible for a distinct policy field such as technology development or industry and employment, see Mazzucato (2021). According to Mazzucato (2021), 'missions' should be designed to organise and assist major social changes, like the green transition, and they should ideally have the following properties:

i. Be bold and address societal values.

ii. Specify concrete targets: you should know when you get there!

iii. Involve research and innovation to ensure technological readiness over a limited time frame.

iv. Be cross-sectoral, cross-actor, and cross-disciplinary.

v. Cover multiple competing technological solutions supplemented by rules to stop funding of R&D in technologies that do not show sufficient improvement.

It is beyond the scope of the current paper to discuss and compare these two alternative approaches. Clearly, the neoclassical state approach relies heavily on the creative nature of individuals, whereas the proactive state relies heavily on well-informed and benevolent politicians and bureaucrats. Needless to say, both are open to criticism. The policy platform of the current government (see above) is a mix of the neoclassical and the proactive state, but as a rule of thumb, priority is given to non-neutral incentives, i.e., a proactive state is called for. As a consequence, there are several sector-specific policies which we will examine in detail in the next sections.

7. Sector-specific policies: I Petroleum extraction

7.1 Introduction

Norway is a major supplier of oil and natural gas; in 2021, the country was the 11^{th} largest global supplier of crude oil, see Wiki (2023a), and the 7^{th} largest global supplier of natural gas, see Wiki (2023b). Most of the Norwegian natural gas is exported to the European market. While Russia has for decades been the largest supplier of natural gas to Europe, this ranking changed in 2022 because of radical reductions in Russian gas exports following the invasion of Ukraine. As a result, Norway became the largest natural gas exporter to Europe in 2022.

In Norway, emissions from the extraction of petroleum increased by around 50% in the 1990s, but later emissions have been relatively stable, with a small decrease in recent years. As seen in Table 1, emissions from the extraction of petroleum amounted to 25% of total Norwegian emissions in 2021.

7.2 Strategy: future offshore activities

Current emissions from the extraction of petroleum are not exactly in line with a transition to a low-carbon economy. Therefore, the government has announced that these emissions must fall by 50% by 2030 and reach net zero by 2050, primarily through electrification using emission-free electricity, e.g., offshore wind power, see Office of the Prime Minister (2021). According to this policy platform, the aggregate level of offshore activity should be stable over time, but new types of activities like (i) a value chain for CCS; (ii) a value chain for hydrogen; (iii) offshore wind power; and (iv) other offshore non-petroleum activities will be phased in. This strategy reflects that demand for petroleum may fall significantly over the next 30 years: According to WEO (2021), global demand for oil in the "sustainable development" scenario will be 50% lower in 2050 than in 2020 (p. 315), whereas demand for natural gas in Europe will be 80% lower in 2050 than in 2020 (under the same scenario). With lower petroleum-related activities, new offshore activities will have to be phased in to meet the target of retaining the current level of offshore activity.

8. Sector-specific policies: II CCS

8.1 Introduction

While prominent international organisations like the IEA and the IPCC have argued that Carbon Capture and Storage (CCS) is pivotal in ensuring a cost-efficient solution to the climate change problem, there is, to date, no market for carbon storage.

The Norwegian involvement in CCS dates back to 1996 when CO_2 emitted from the extraction of natural gas was captured and stored in order to increase pressure in the gas reservoirs. In 2007 the government launched the so-called "moon-landing project": to build a gas power plant fully integrated with facilities to capture CO_2. This project was intended as a game changer for the European gas industry: with environmentally friendly gas power, Norway could sell more natural gas, which in turn would generate more income without causing a rise in total emissions of CO_2.

The project was not the overwhelming success expected and was cancelled seven years later. In addition, because of a low ETS price (albeit only until the end of 2021), there has been little interest in CCS in the European electricity industry. Also, with radical cost decreases and various support mechanisms for renewable electricity (onshore wind power and solar PV), investment in solar and wind has proven more attractive than establishing fossil-fuel-based power plants with integrated carbon capture facilities.

8.2 Strategy: How to establish a CCS value chain?

There is, as of yet, no commercial market for CCS. This may partly reflect a standard co-ordination problem: anybody considering constructing a carbon storage site may not be willing to invest before being confident that there are enough clients with captured carbon who will demand storage services. Likewise, anybody considering investing in carbon capture facilities may not be willing to invest before being confident that reliable transport and storage facilities for the captured carbon will be available.

Typically, there are three possible outcomes in a coordination game: (i) no investment; (ii) moderate investment; and (iii) heavy investment, see, e.g., Farrell and Saloner (1986) and Greaker and Midttømme (2016). Golombek et al. (2022) study the coordination game of establishing a CCS value chain. Their study focuses on plants (with CO_2 emissions) considering investment in capture facilities and terminals considering investment in facilities to transport the captured CO_2 to a storage site. The government has a role in ensuring that substantial investments are undertaken, in addition to correcting for market imperfections, such as abuse of the market power of terminals, which are local monopolists.

A key insight from Golombek et al. (2022) is that integration of terminals and storage facilities is socially beneficial; it gives these actors the correct incentives to invest. However, as long as plants considering to invest in capture facilities tend to invest too little, and there are additional market imperfections, there still is an important role for policy: through a suitable package of instruments, the government can ensure that the first-best social outcome can be reached.

8.3 The Longship project

In 2020, the Norwegian government approved the Langskip project (Longship, named after Viking sea-going vessels) which is a government commitment to develop a value chain for CCS, see Norwegian Ministry of Petroleum and Energy (2020a); investment in carbon transport and storage will be funded primarily by the government and not private equity. Interestingly, in line with the conclusions of Golombek et al. (2022), in Longship, terminal and storage facilities are integrated into one single actor. Initially, the project is intended for Norwegian industries that lack cheap options for cutting emissions, e.g., cement or hydrogen production based on Norwegian natural gas.

Longship has two principal components. The first, which is referred to as the Northern Lights project, relates to a terminal on the Western coast of Norway and a pipeline from the terminal to an offshore storage site. In the first phase of the Northern Lights project, the annual CO_2 terminal capacity and the annual injection capacity to the storage is 1.5 Mt CO_2 (in 2021, total GHG emissions in Norway amounted to 49 Mt CO_2 equivalents, see Table 1). If phase one, which is mainly state-funded, proves successful, i.e., full utilization of the storage capacity is reached, a second phase will be initiated. In this phase, the capacities can be expanded to 5 Mt of CO_2. However, no government funding will be made available. Again, if successful, the capacities can be expanded further: Equinor (formerly Statoil) has detailed scenarios for 20 Mt and even up to 100 Mt of carbon storage on the Norwegian Continental Shelf. It is envisaged that the majority of clients will be foreign manufacturing firms that have invested in carbon capture facilities (Equinor, 2019). According to Andersen (2022), seven countries have already negotiated access to the Northern Lights' storage facilities in 2022.

The second component of Longship is government-funded investment in carbon capture facilities at a cement plant in Norway (Mongstad) and a commitment to fund carbon capture facilities at a factory transforming non-recyclable waste to energy in Oslo. The captured CO_2 will be transported by ship to the terminal in the west of Norway.

8.4 The future of CCS in Norway

There are ten existing or planned carbon capture and utilisation projects in Norway; see Engh (2021). However, none of these covers emission-intensive carbon industries such as alumina, ferroalloys or iron and steel. In these industries, only a proportion of total emissions can be captured with the current production technology, see Prosess21 (2020). According to this report, if plants in these industries want to invest in carbon capture facilities, most of them would have to change their technology. The potential of CCS in Norwegian manufacturing is around 1.7 $MtCO_2$ in 2030, see Norwegian Environment Agency (2022).

As there currently is no commercial market for captured carbon, Longship has the potential to become a game changer for CCS in Europe. However, there are challenges with respect to both demand and supply of storage services. First, even though there will be a carbon storage unit off the Norwegian coast, plants may still be reluctant to invest in capture facilities: for years, the ETS price was below €20/tCO_2, and thus investment would not be profitable. However, since November 2021, the ETS price has roughly fluctuated around €80/tCO2, which may be close to making carbon capture investment profitable. Also, the extent to which governments in Europe will provide incentives, regulations and legal requirements that stimulate investment in carbon capture facilities depends on public and political acceptance of storage of CO_2.

On the supply side, Norway may see increased competition, as Scotland, the Netherlands and Denmark also plan to develop carbon storage sites. All of these sites have high fixed costs and need to attract customers to be profitable. Competition may emerge between storage suppliers, although different geographical locations may hamper competition to some degree. On the other hand, the location effect may not be so strong because captured CO_2 is primarily transported by ship, not in pipelines, to a terminal or directly to the storage site. As ships are a flexible transport solution, more competitors in the field may lower the market price for storage services overall. On the other hand, more competitors may raise total R&D costs and some of the knowledge generated may spill over to the competitors, thereby lowering future costs of investment in storage facilities.

9. Sector-specific policies: III Hydrogen

9.1 Introduction

In addition to removing carbon from industrial processes, such as cement production, a carbon storage site may be a crucial element in establishing a Norwegian value chain for hydrogen based on natural gas. In the literature, production of hydrogen based on natural gas is referred to as "blue" hydrogen if the CO_2 has been removed and is stored. In contrast, hydrogen production based on natural gas (or coal) without carbon removal is referred to as "grey". A third category is "green" hydrogen. Here, renewable electricity is used to produce hydrogen through the electrolysis of water. For the hydrogen consumer, the colour, i.e., the environmental footprint of each "type" of hydrogen, may possibly be of little interest, as it has no impact on the quality of the end product.

Currently, hydrogen is a marginal energy carrier in Europe. Its share of the European energy mix is less than 2%. Hydrogen is mainly used by refineries and by the chemical industry to produce ammonia. Yet, hydrogen has great potential, both in the EU, see European Commission (2020a) and in Norway, see Norwegian Ministry of Petroleum and Energy (2020b). In the manufacturing industries, it can be used to produce methanol and metals, for example, alumina and steel. In transport, it can be used for heavy-duty road vehicles, to power maritime transport, and perhaps even for aviation in the long term. In the building sector, hydrogen can replace natural gas for heating and cooking. In the electricity sector, hydrogen can be used to store energy.

9.2 The first challenge of hydrogen

Hydrogen faces two main challenges. First, it is expensive. Even grey hydrogen, which is the cheapest type, is expensive, partly because of high energy loss factors, see IRENA (2020). According to European Commission (2020b), the cost of blue hydrogen is about one-third higher than the cost of grey hydrogen prior to paying for carbon emissions. For green hydrogen, the corresponding number is, according to European Commission (2020b), at least two, maybe even higher than three.

Note that these cost ratios are based on the price of natural gas just prior to 2020. The price of natural gas in Europe has fluctuated extremely since 2019. It reached a minimum price level in the summer of 2020, then started to increase slowly, and has skyrocketed since summer 2021: The price in August 2022, six months after the Russian invasion of Ukraine, was more than four times higher than 12 months previously. However, the price of electricity in Europe has also increased significantly since the summer of 2021, reflecting the high price of natural gas.

To be more specific, according to DNV GL (2019), if the price of *natural gas* is €22/MWh, then the cost of blue hydrogen is €1.5/kg H_2. In September 2022, the average price of natural gas was, however, much higher (around €200/MWh), which implies a cost of blue hydrogen at approximately €7/kg H_2. In comparison with green hydrogen: it costs approximately €5/kg H_2 if the price of *electricity* is €67/MWh; see DNV GL (2019). Again, in September 2022, the price of electricity was significantly higher than €67/MWh but varied across countries and sectors. If the price of electricity is €120/MWh, then the cost of green hydrogen is €7/kg H_2, i.e., equal to the cost estimate of blue hydrogen in September 2022.

At least in Norway, and probably in most European countries, the price of electricity in September 2022 was higher than €120/MWh for plants paying the market price, i.e., units not having a long-run, fixed-price contract. This suggests that blue hydrogen was cheaper than green hydrogen in September 2022.

The all-time high price of natural gas in the summer of 2022 will undoubtedly represent a temporary phenomenon. According to WEO (2021), in a scenario with net zero global carbon emissions by 2050, the price of natural gas in the European Union in 2050 will be slightly lower than in 2020 (p. 101), whereas in another scenario where "all climate commitments made by governments around the world [...] will be met in full and on time" the price of natural gas in Europe in 2050 will be around 50% higher than in 2020. These predictions suggest that blue hydrogen may yet be competitive in the long run.

9.3 The second challenge of hydrogen

The second challenge facing hydrogen is that there is no significant commercial market for it in Europe. To encourage a radical increase in the take-up of hydrogen, a transport infrastructure is needed, for example, by utilising parts of the existing gas transmission and distribution grids and/or by developing a hydrogen transmission network. This points to the double co-ordination problem faced by a potential blue hydrogen producer: Before investing in facilities, the potential producer must believe that there will be a storage site for the captured carbon and that there will be demand for their product. The latter requires investment in facilities designed for the transport and use of hydrogen. For a Norwegian blue hydrogen producer, the first co-ordination problem was removed when the Norwegian government launched the Northern Lights project.

9.4 Strategy: business models for hydrogen

In general, the development of a value chain for hydrogen requires suitable business models that address risk-sharing between key actors. The government, or the EU, could offer risk-sharing schemes to ensure socially correct investment incentives for private stakeholders, i.e., provide incentives that sustain socially warranted investment in the various links of a value chain. Longship provides an example of risk sharing; the government shoulders most of the risk as the value chain is developed, whereas private companies assume all of the risk in investment in transport and storage facilities if the (initial) value chain is expanded.

Without any involvement from the government, an investor in a capture facility saves an amount equal to the captured CO_2 times an uncertain future CO_2 price. If the government wants to reduce the uncertainty for private stakeholders, a possible business model could include the government guaranteeing a minimum price for all captured carbon: If the future price of carbon turns out to be lower than the minimum price, the investor obtains a transfer from the government equal to the difference between the minimum price and the future price (for each unit of captured carbon). As a result, the investor has actually saved an amount of money equal to the minimum price multiplied by the amount of captured carbon. If the future carbon price exceeds the minimum price, no transfer is received from the government.

10. Sector-specific policies: IV Offshore wind power

10.1 Introduction

Norwegian electricity supply has always been characterized by a large market share of hydropower; production consists mainly of reservoir hydro stations, but there are also pumped-storage hydro and run-of-river hydro plants.

A few onshore gas-fired power stations have been set up in the past, but one has already been dismantled, and the others are not currently online. However, over the last 20 years, there has been a steady stream of investment in onshore wind power; this technology accounted for 8% of total Norwegian electricity supply in 2021. In addition, the government recently approved offshore wind power developments in designated areas. Over time, offshore wind power supply may—in order to electrify the offshore petroleum sector—replace the small offshore gas-power plants that currently serve the extraction industry. Offshore wind power will also meet conventional electricity demand, both domestically and abroad.

10.2 Will investment in offshore wind power in Norway be profitable?

To assess whether Norway should develop offshore wind parks, we draw on Gaure and Golombek (2022a), which studies the future composition of a fully decarbonised European electricity generation sector. To this end, they minimise the total costs of investment and production of electricity plus costs of investing in storage capacity (batteries) subject to the assumption that the only available electricity generating technologies are onshore wind power, offshore wind power and solar. As they are interested in the long-term characteristics of a completely carbon-free electricity system, they impose the condition that all capacity be built from scratch.

Using spatial, hourly data for 23 European countries over ten years (2006-15), Gaure and Golombek (2022a) find that the cost-efficient capacity share of offshore wind power is approximately 20%. Due to Norway's advantageous offshore wind conditions, it is optimal that 20% of desired European offshore capacity is installed in Norway, i.e., 4% of total capacity.

10.3 Strategy: Does Norway enjoy a comparative advantage in offshore wind power?

In Gaure and Golombek (2022a), it is assumed that the cost of investment does not differ from country to country. However, because of competences gained from offshore petroleum extraction as well as the efficient supply chains serving that industry, Norway may have a competitive advantage in deep-water offshore wind power production, see Greaker et al., (2019). This strengthens the case for developing an offshore wind power industry in Norway. In particular, by becoming an early mover, Norwegian supply chains could, through learning by doing in the home market, become sufficiently competitive also to serve the same industry abroad.

On the other hand, the current cost of offshore wind power production is relatively high and far above the cost level that would make investment profitable if the price of electricity continues in the range observed between 2010 and 2020 (i.e., significantly less than 100 €/MWh). R&D and increased industrial know-how are likely to create a significant cost reduction over time; this may suggest that Norway should not be over eager to invest today but wait and learn from developments in other countries. But how long should Norway wait? If future long-term electricity prices in Europe remain relatively close to those seen in the spring/summer of 2022, i.e., after the Russian invasion of Ukraine and the radical drop in Russian gas supply to Europe, investment in offshore wind power will surely be profitable. However, due to radical structural changes in the electricity markets, future electricity prices remain uncertain; WEO (2021) provides no predictions.

11. Sector-specific policies: V Batteries

11.1 Introduction

Demand for batteries for electric appliances such as smartphones and PCs has risen radically in recent decades and may continue to do so. Furthermore, with more electrification in order to cut emissions of greenhouse gases, demand for batteries used in the electricity sector will increase.

11.2 Intermittent power and batteries

The EU aims to decarbonise electricity supply by 2050, see European Commission (2018). This will require a higher share of intermittent power, primarily from solar and wind power. Electricity supply from these technologies depends on installed capacity and the weather (in particular, solar irradiance and wind speed). In order to ensure that total electricity generation always equals the load—the system will physically break down if this is not the case—some type of flexibility is required.

One possible source of flexibility is electric batteries: in periods where total supply exceeds the load, the difference can be charged into batteries. Similarly, in periods where the load exceeds supply, electricity can be discharged from the battery. As such, a key question is: how much energy storage capacity is needed for a decarbonised European electricity market?

Gaure and Golombek (2022a) calculate the cost-efficient investment in electricity-generating technologies and batteries (to store energy) for 23 European countries, see above. They find that the optimal size of the battery corresponds to 16 average hours of consumption of electricity (5.6 TWh). However, if the technology also includes bio-CCS power (in addition to solar and wind), the optimal battery size amounts to less than one average hour of consumption.

In the Gaure and Golombek (2022a) study, gross production is far above consumption. In fact, 42% of gross production has to be curtailed, i.e., the production facilities are temporarily disconnected from the grid. Alternatively, this amount of electricity is used in other sectors or exported. Economists see curtailment as part of an optimal solution. For others, including politicians, however, it is often regarded as a waste of resources and not socially acceptable.

To illustrate the implications of not allowing for curtailment, Gaure and Golombek (2022b) use their model to study an electricity system where the *total* intermittent production in the planning period (2006-15) equals total consumption in the same period, i.e. there is no curtailment. As in Gaure and Golombek (2022a), the electricity system is based on onshore power, offshore power, solar PV, electric batteries and bio-CCS. The battery strategy is as follows: in hours when intermittent production exceeds load, the battery is charged, whereas it is discharged in hours when load exceeds intermittent production. The bio-power technology is used only if intermittent supply is lower than load and the battery is flat, i.e., bio-power is 'plan B'.

Minimising the energy battery capacity and using the same data set as in Gaure and Golombek (2022a), Gaure and Golombek (2022b) find that the optimal battery size corresponds to 15 days of average consumption (123 TWh), which is 22 times higher than in Gaure and Golombek (2022a).

To sum up, if curtailment is socially acceptable in a decarbonised European electricity market, the need for storage capacity becomes rather limited. If, however, curtailment is not allowed, the need for storage becomes much higher. If the entire demand for energy storage is serviced by batteries (not by other technologies, like reservoir hydro and hydrogen), how great is the demand for batteries in the two cases studied above?

In both Gaure and Golombek (2022a) and Gaure and Golombek (2022b), it is assumed that the lifespan of batteries is ten years, that a battery can be recharged

1,000 times, and that the price of batteries (in 2030) will be €150/kWh, see Bogdanov et al. (2019). If curtailment is socially acceptable, see Gaure and Golombek (2022a), then under these assumptions, annual gross income from battery production equals €84bn. This corresponds to the value of vehicles purchased by German households in 2020; see OECD (2022).

By contrast, if curtailment is not socially acceptable, see Gaure and Golombek (2022b), annual gross income of battery production equals €1,845bn, which is roughly 10% higher than total final consumption of households in Germany in 2020, see OECD (2022). This number (€1,845bn) is so high that the EU clearly has an incentive to find an alternative solution for the electricity generation sector.

11.3 Does Norway have a comparative advantage in battery production?

Batteries are heterogeneous products that may differ in size, loss factors and other technical characteristics. Still, batteries from one producer can easily be replaced by batteries from another. Hence, battery price, adjusted for technical elements like loss rates, is the key factor in capturing market shares. There is hardly any brand preference for batteries with respect to design nor any network externalities that might lock in customers. This suggests that there is probably not any first-mover advantage to be gained from producing batteries.

Countries with a competitive advantage in battery production, because of, for example, technical competence in related fields, should develop a battery industry. However, we are not aware of the existence of this type of competence in Norway. Establishing a competitive advantage in the short term is not simple: if the government sustains a low price for electricity to a private battery producer, e.g. via subsidies, this does not represent a comparative advantage from a national perspective, although the private battery producer may indeed make substantial profits.

12. Policy recommendations and concluding remarks

We conclude our discussion of Norwegian climate policies by listing the policy implications of our analysis.

- Norway should carefully re-evaluate its goals and policies for sectors already covered by the EU ETS: Such goals and policies tend to undermine the whole idea behind the ETS, namely setting a cap on total emissions covered by the ETS and let the market find the most cost-effective way to achieve the target.
- In particular, it seems difficult to justify the explicit goal for emissions from the offshore petroleum sector, which is covered by the ETS. This goal will only be possible to achieve with electrification that is unprofitable even with the high carbon price facing this sector.
- Although generous subsidies for electric vehicles may previously have been a good policy, perhaps the time has come to phase them out. The introduction of a new EU-wide quota system for transportation, and the strengthening of the EU mandatory emission reduction targets for new cars, are additional reasons for phasing out Norwegian subsidies to electric vehicles.
- Scaling up new "green" industries in Norway should be based on sound economic principles. In particular, it is important to avoid subsidising electricity provision to these new industries unless such subsidies can be fully justified.
- Similarly, battery production in Norway should only be considered if it can be proven that it will be profitable without state subsidies.
- The Longship project, which is mainly funded by the Norwegian government, is crucial to establishing a value chain for carbon capture and storage in Norway and may provide the foundation for a European carbon storage industry. However, the introduction of additional and expanded storage facilities in Norway should be funded solely by private equity.

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Comment on R. Golombek & M. Hoel: Climate policy and climate goals in Norway

Taran Fæhn

This comment refers to an initial draft of the article published for the peer review conference in November, 2022.

1. Introduction

This review responds to the paper by Rolf Golombek and Michael Hoel with the title "Climate policy and climate goals in Norway" presented at the Nordic Economic Policy Review Conference in Oslo on 26 October 2022. It sums up the main points of my discussion of the paper at the conference. As the intention behind involving discussants and reviewers is to encourage improvements of the original manuscripts, the final published article in this journal will expectedly have been revised. This review nevertheless offers some perspectives on Norway's climate policies that may have broader relevance and interest.

Golombek and Hoel's paper examines the Norwegian government's short-term policies to reduce emissions as well as its long-term strategies to cut emissions radically. The authors restrict their discussion to three key sectors that currently account for significant shares of Norwegian greenhouse gas emissions: manufacturing industries (24%), petroleum extraction (25%) and transport (33%). The paper starts by providing an overview of the complex Norwegian climate policy goals, instruments and strategies in the context of the country's energy and emissions situation. They highlight the following policy implications: (i) Norway should carefully reconsider its goals and policies in sectors already covered by the

EU emission trading system (ETS), (ii) carbon pricing in the non-ETS sectors should be uniform across all emission sources and (iii) establishing and expanding new "green" industries in Norway should be based on sound economic principles.

Although it is easy to concur with these conclusions on a more general level, it is not always exactly clear on what grounds they are reached. What, for instance, are sound economic principles? Indeed, ahead of their conclusions, the authors provide an economic theory section. Unfortunately, it is not sufficiently illuminating due to its generic form. The normative arguments would have been more useful if, instead, they were related directly to the discussions of the Norwegian policy instruments and strategies in the subsequent sections.

I have three suggestions that I think might tease out a closer connection between conclusions and arguments. The first concerns the status of different climate policy goals, the second and third seek to add nuance to Golombek and Hoel's presentation of some implemented and potential policy instruments for achieving the short-term 2030 targets and the long-term 2050 targets, respectively.

2. The different status of climate policy goals

By making a clear distinction between Norway's climate *commitments*, on the one hand, and the additional *ambitions* set by the government on the other, it would be easier to draw policy implications from the normative conclusions in the paper. My reasoning is that commitments must be regarded as binding, while self-imposed ambitions can more easily be adjusted in response to normative findings. Norway's commitments are established by law in the Norwegian Climate Change Act and in international agreements. The Act quantifies the maximum greenhouse gas emissions permissible by 2030 and 2050, respectively. The 2030 target was also pledged in the Paris Agreement. Moreover, an agreement with the EU (and Iceland) splits the 2030 commitments into one for emission sources covered by the EU ETS and one for sources outside the Emission Trading System (ETS). These are currently under renegotiation to accord with the overall EU targets and the updated Norwegian Paris Agreement pledge.

Golombek and Hoel treat the net-zero ambition in 2050 as a commitment. It is not: The obligation in the Act is to become a low-emission society, quantified as a 90–95% cut from the 1990 level. The cost of moving from a 90% to a 100% cut is probably very high.

Golombek and Hoel advise that some sector-specific goals should be reconsidered, including the *transformation* goal that aims to cut all Norwegian ETS-covered emissions within its own borders and not purchase emission allowances under the EU ETS. These are, however, only ambitions and can be revisited at a later date. Another ambition that could be reconsidered, but that Golombek and Hoel do not mention, is the *climate-neutrality* goal for 2030. It would be interesting to see a discussion of how it relates to the long-term low-emission commitment, let alone the net-zero ambition for 2050.

Golombek and Hoel choose to omit a discussion of the third, and probably most difficult, commitment in the EU agreement: on the net emissions from the land use, land use change and forestry (LULUCF) sector. The EU as a whole has decided to increase the overall LULUCF goal for 2030 from a previous net zero target to a net *uptake* of 310 million tonnes of CO_2-equivalents. The resulting commitments for each member state, as well as their access to flexibility mechanisms, are still not clear. However, this bolstering of the goal, along with several technical adjustments, has undoubtedly increased Norway's LULUCF challenges considerably. It will require significant reductions in land use emissions and represents a potential area of conflict with several other climate-motivated needs for energy infrastructures and installations, bioenergy production and agricultural measures.

3. Available policy instruments towards 2030

The agreement with the EU allows for several flexibility mechanisms intended to increase the cost-effectiveness of climate policies. There is, however, one severe restriction: Norway is obliged to refrain from using credit markets outside the EU. This also applies to arrangements within the UNFCCC framework, like those under the auspices of Article 6 in the Paris Agreement as well as the Clean Development Mechanism. Golombek and Hoel misinterpret the acquisition of carbon offsets from countries/agents outside Europe being used to fulfil international commitments.

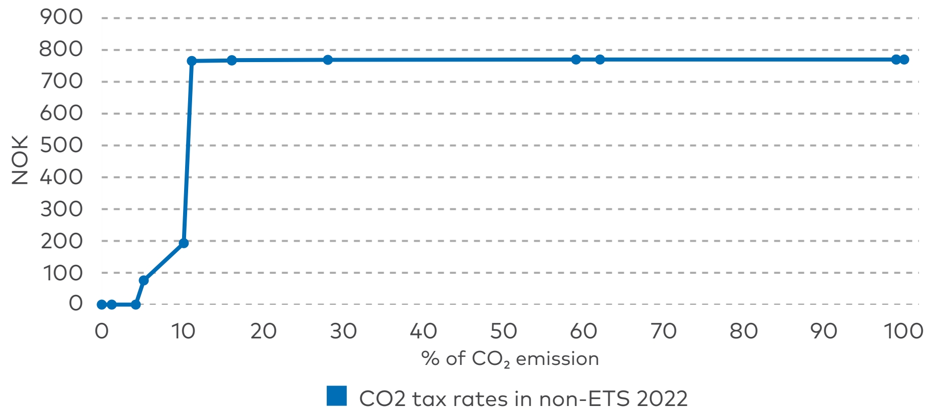
On the other hand, the EU agreement provides several new instruments. Golombek and Hoel judge a couple of the EU *fit-for-55* by 2030 initiatives as promising: The Carbon Border Adjustment Mechanism (CBAM) and the new, separate ETS for buildings and transportation are examples. Recently, details of these reforms have been agreed.

In the period 2026–2034, CBAM will gradually replace current measures against carbon leakage, the free allocation of ETS allowances and the national aid compensating for allowance costs passed on in electricity prices. This package is welcomed by Golombek and Hoel. The literature states that an ideal carbon border adjustment system would normally outperform the current system (Hoel, 1996; Fischer & Fox, 2012; Böhringer et al., 2017). However, it is important to note that the EU CBAM is not quite as recommendable in its current form. There are two main reasons: It only applies to the import side and only to direct emissions. On the export side, to the extent that the EU ETS-covered firms compete against non-regulated suppliers on other world markets, they still face the relative disadvantage of paying the ETS price. Regarding indirect emissions, no arrangement has yet been agreed for to replace the current aid designed to compensate for indirect electricity price impacts of the EU ETS. Consequently, it may make more sense for Norwegian companies to argue against the CBAM reform than Golombek and Hoel acknowledge.

As a means of reducing efficiency losses currently originating from the large variation of marginal abatement costs across borders, Golombek and Hoel's expectations for the new buildings and transportation ETS seem unreasonably high. In fact, its design is not intended to work in the same way as the current ETS under which Norway can, for instance, conveniently choose to substitute costly domestic abatement by purchasing relatively affordable allowances. Buildings and transportation are still subject to the non-ETS commitment that will be the binding target. Thus, buying allowances under the new ETS will not reduce the obligation to mitigate greenhouse gas emissions from non-ETS sources on Norwegian territory. Rather, the price established in the new ETS will work as a minimum, EU-wide tax on these emissions. This price is expected to be relatively low and has little impact on the already highly taxed fossil fuel prices in Norway.

This brings me to another claim by Golombek and Hoel that warrants discussion. They are concerned about the significant carbon price variation across the non-ETS sectors, implying an inefficient allocation of emissions. They explain this variation by "sectors being exempted from taxation and sectors being exposed to additional taxation." As a matter of fact, recent state budgets have made considerable progress toward levelling up carbon tax rates across non-ETS sectors, as seen in Figure 1.

Figure 1 CO_2 tax rates in Norwegian non-ETS sectors, 2022



Roughly 90% of the CO_2-emissions had the general full rate of NOK 766 /t in 2022. Moreover, several non-CO_2 greenhouse gas sources also face this tax rate. It is nevertheless true that other taxes apply to some of the emission sources, but these are motivated by considerations other than mitigating climate change. In particular, market intervention against the local environmental impacts of transport activities can explain the highest effective tax rates imposed on households reported by Golombek and Hoel. In general, since externalities associated with economic activities differ, it is far from obvious that sizable efficiency gains can be achieved by making the total effective rates uniform.

4. What are sound policy strategies towards 2050?

Golombek and Hoel's extensive discussion of Norway's long-term prospects for radical reductions in emissions reveals many interesting details relating to emerging green markets and technologies. The authors offer impressive insight and convincingly substantiate some of the future comparative advantages of the Norwegian economy.

The main conclusion from this section is that new green industries' expansion in Norway towards 2050 should be based on sound economic principles. Partly due to the structure of the paper, it is not always easy to distinguish between description and advice: nor is it clear what constitutes sound economic principles, nor grasp whether, in this context, *Norway* refers to the central government. It is also unclear whether an intervening state should go beyond carbon pricing. The theory section introduces the following reasons for using a more ample toolbox than carbon pricing alone: Distributional considerations, commitment problems, knowledge spillovers and co-ordination problems. A key question is posed: Should policies generate industry-neutral incentives or actively promote specific investments and industries, i.e., pick winners? However, neither the answer nor the arguments provided are clearly laid out.

A closer reading brings the following arguments to the surface: CCS and hydrogen production are examples of technological fields suffering from co-ordination challenges that can legitimise state involvement beyond just carbon pricing. The justification for subsidising electricity as a source in new green industries, including offshore wind power and batteries for storage, is less obvious in their view.

Golombek and Hoel's reflections on long-term climate policies address electrification, power generation and hydrogen production. These foci are natural given their expertise and the direction set by government through formulating its transformation ambition in terms of domestic abatement of the emissions covered by the EU ETS.

I would like to have seen a discussion of two other areas of technological development that are expected to play crucial roles in the net-zero transformation of the Norwegian, European and global economies: The circular economy and carbon dioxide removal. Establishing a circular industry will call for co-operation and co-ordination across and beyond existing value chains, innovation of products, processes and organisations and a local focus. Economic thinking is essential, and Norwegian public and private initiatives are, so far, lagging behind. Carbon dioxide removal measures span from well-known LULUCF-associated low-tech practices to intensely science-based, immature, large-scale technologies. It will inevitably form part of net-zero strategies, as gross emissions will not be eliminated by 2050.

5. Concluding remarks

My recommendation to distinguish commitments from ambitions is partly rooted in the advantages I see for a small, open country of entering into international agreements. Norway's coalition with the EU renders it among the most ambitious and serious climate policy agents in the world. There are also several valid reasons for cost savings to be expected. Beyond reducing carbon leakage when joining forces, binding agreements and other legal arrangements like the Climate Change Act decrease the commitment problem described by Golombek and Hoel.

On the downside, many targets, regulations and instruments implemented by the EU do not always naturally fit Norwegian particularities and priorities. This can generate political tension and additional economic costs. However, as Golombek and Hoel point out, many national initiatives have their own disadvantages, too.

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Comment on R. Golombek & M. Hoel: Climate policy and climate goals in Norway

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This comment refers to an initial draft of the article published for the peer review conference in November, 2022.

1. Introduction

Norway co-operates closely with the EU on climate policies, and in November 2022, following the EU lead, Norway bolstered its nationally determined contribution target under the Paris Agreement to reduce greenhouse gas emissions by at least 55% compared to 1990 levels by 2030 (previously, the target was to reduce emissions by at least 50% and towards 55%). In addition, Norway aims to reduce emissions by 90–95% by 2050. Norwegian greenhouse gas emissions have been relatively stable since 1990. In 2021, they were 4.7% below 1990 levels, although this figure does not include the effects of forestry and agriculture. This underscores the level of climate target ambitions that Norway has set itself and its continued reliance on EU co-operation to reach them.

Golombek and Hoel's article gives an overview of Norway's climate goals and the current and proposed policies to reach them. The paper starts by reviewing some key findings from the literature on carbon emissions reduction; the authors argue that carbon pricing should be the main policy instrument, and they briefly discuss why and under which circumstances policymakers could consider additional measures. This section also touches on some political economy issues related to climate policy. The following section provides an overview of Norway's climate targets and policies, placing emphasis on the period to 2030, and shows the close link between Norway's and the EU's climate policies. In the fourth section of the paper, Golombek and Hoel discuss the current government's plans and ambitions to transform the Norwegian economy into a low-emissions future, as outlined in the government's coalition agreement (the Hurdal platform). More specifically, this section presents and discusses plans for the oil and gas sector, carbon capture and storage (CCS), hydrogen and batteries.

Golombek and Hoel's paper gives readers a solid overview of Norway's current climate goals and policies, its collaboration with the EU and its overall plans and ambitions to transform the energy industry and move towards a low-emissions future. In the following, I will provide some comments on the paper and some of the topics it discusses.

2. Goals and policies towards 2030

The section of the paper entitled *Norwegian climate goals and climate policy* provides a concise overview of Norway's climate goals for 2030 and 2050 and of the key policies necessary to reach the 2030 targets. The authors deftly describe the use of carbon pricing to regulate emissions both in sectors that are part of the EU emissions trading system (EU ETS) and in non-ETS sectors. However, I would like to have seen an introduction to the third main pillar of the EU climate policy; the Land Use, Land-Use Change and Forestry (LULUCF) regulation, which commits Norway and other European countries to emissions reductions and carbon removal in the land use and forestry sectors. A presentation of the LULUCF regulation and how this element of European policy affects Norway would benefit this part of the paper.

In line with standard economic thinking, the authors argue against imposing national carbon taxes on sectors that are part of the EU ETS. To understand their reasoning, consider the case of the offshore petroleum sector in Norway, which is currently subject to a national carbon tax in addition to the EU ETS. This extra taxation forces the industry to abate more, at a higher (marginal) abatement cost than if they were solely subject to the EU ETS. However, the overall impact on total European emissions is negligible. Additional emission cuts in the Norwegian petroleum sector leave more EU ETS credits for others in the carbon permit market. If we disregard the possibility that these additional emission cuts trigger the market stability reserve mechanism (permit removal), the emission cuts in Norway's offshore petroleum sector will be offset by higher emissions from other companies and sectors in the EU ETS. Consequently, a national carbon tax, in addition to the EU ETS, will not only increase the abatement cost of the affected sector but also the total European abatement cost while having little or no impact on the aggregate emissions level.

Despite this and given the Norwegian government's stated aim of promoting the creation of value chains for CCS and hydrogen offshore, I wonder whether this could be an argument in favour of a special carbon tax on offshore oil and gas activities. Even though the effect on total emissions is limited in the short term, longer-term effects could prove positive if the higher carbon price in this sector encourages the industry to develop and implement new and improved CCS technologies. As I will return to below, some solid arguments can be made for opposing policies that try to pick winners and stimulate development in specific industries rather than providing industry-neutral incentives. However, as Golombek and Hoel discuss in the latter part of their paper there is also an argument that Norway has some advantages in the development of technologies such as large-scale CCS. Hence, the literature on second-best policies might be relevant here (see e.g. Goulder et al., 1999; Fischer et al., 2021).

An aspect that Golombek and Hoel pay little attention to is whether Norway's climate goals and ambitions are realistic. As mentioned above, Norway has thus far (as of 2021) reduced its greenhouse gas emissions by about 5% compared to 1990 levels, which is very far from the 55% reduction target for 2030. To reduce emissions in non-ETS sectors, the government has announced that it will gradually raise carbon taxes to about NOK 2,000 by 2030 in constant 2020 prices. It would be interesting if the authors could say something about whether this price path will be sufficient in itself to meet the targets or to what extent Norway will rely on the flexibility mechanism of the EU Effort Sharing Regulation (ESR), for example by buying emissions reductions from other countries that are part of the EU ESR.

3. Long-term goals and policies

In the fourth section of their paper, Golombek and Hoel present ambitious policy measures related to Norway's transition to a low-carbon economy, as outlined in the current government's coalition agreement. More specifically, they consider the part of this agreement that describes measures to actively stimulate a transition away from oil and gas and toward other offshore and energy-related activities. In addition to petroleum extraction, Golombek and Hoel discuss CCS, the production of blue and green hydrogen, battery production and offshore wind power.

In June 2022, the Norwegian government launched a roadmap that provides more detail on how they plan to promote green industries[22]. This identifies seven areas that the government will prioritise as part of the green industrial initiative. In addition to value chains for offshore wind, batteries, hydrogen, and CCS (areas discussed by Golombek and Hoel), the roadmap outlines the government's plans for a clean and energy-efficient process industry, a green maritime industry, and forestry/timber and other bioeconomy sectors. Thus, it would be possible for Golombek and Hoel to broaden the scope of their paper beyond the energy sectors by also covering these initiatives and other areas that perhaps should have been higher on the government's agenda.

In terms of policy evaluation, Golombek and Hoel raise the dilemma of whether to use industry-neutral incentives to promote climate-friendly activities or make active investments in specific industries. They recommend letting "sound economic principles" guide policy measures encouraging new green industries. It is hard to disagree, but it would have been helpful if the authors could have been slightly more specific on what this actually implies, both in more general terms and in the specific cases they discuss in this part of their paper.

While green technology investments will probably be inadequate without direct policy intervention (Greaker & Popp, 2022), many economists are sceptical of governments' attempts to pick winners in the green transition. History provides numerous examples of such failures, while the prospect of subsidies or direct public investments in projects and technologies increases the potential for rent-seeking behaviour (see e.g. Baldwin & Robert-Nicoud, 2007). However, others argue that governments trying to single out winners is a necessary policy facet to combat climate change. Meckling et al. (2022) state that in a climate change context, this approach is warranted and offer some advice on how to choose suitable projects, including recommendations for limiting rent-seeking behaviour. They present three main arguments for the importance of picking winners through public investments: (i) it is unlikely that governments on their own will implement sufficient carbon pricing to drive technological change at the required pace, (ii) some technologies have significant future emissions reduction potential, but high capital investments are needed today to drive down the cost curve, and (iii) picking winners can encourage governments to shift the balance of power from polluters to the beneficiaries of decarbonisation. Meckling et al. (2022) argue that many

22. Roadmap - The green industrial initiative, June 2022, available from: https://www.regjeringen.no/en/dokumenter/roadmap-the-green-industrial-initiative/id2920286/

governments are already (directly or indirectly) trying to pick winners, and hence, it is important that they do this effectively. They recommend that in the early stages of an evolving new technology, policymakers should pick companies or consortia that are involved in bringing them to market, and then, as the technologies mature, the shift should be towards supporting their wider deployment. They also argue that policymakers should prioritise technologies with the greatest potential for emissions reductions and that investment decisions should be rules and goals based. I believe that more specific advice on how to pick winners while minimising rent-seeking behaviour would strengthen the active industry measures discussion and provide a clearer basis for the policy recommendations offered by Golombek and Hoel.

This section of Golombek and Hoel's paper also includes a detailed discussion of calculations from previous research papers, assessing the potential scale of the (future) European battery market. While this is undoubtedly interesting, I think it receives more attention (and space) than deserved, given the paper's overall subject matter. I believe that in assessing the government's initiative to set up a battery value chain, the question of whether Norway has any inherent advantages in battery production compared to other potential producers is more important than the exact size of the market. Key factors for battery production include labour, competence and considerable amounts of available electricity. I would have preferred a discussion that focussed on some of these issues. For example: How can Norway best utilise its electricity resources, given the demands of new green projects and the ongoing electrification of society.

Finally, I am curious as to how the Norwegian government's long-term plans correlate with those of the European Union and how international co-operation can reach common climate goals in an efficient way.

4. Concluding remarks

Golombek and Hoel's paper shows that there are many climate-related aspirations, goals and policies in Norway and that the level of ambition is high. Climate policies in Norway are typically expected to deliver on far more than just climate goals, for example, by stimulating new green industries, increasing exports, creating new jobs, and boosting economic activity in rural areas. However, resources are scarce (both human and energy resources), even for an energy-rich country like Norway. It is vital to define a set of well-founded priorities and invest and implement policies based on these. Golombek and Hoel discuss some important issues related to this, with particular emphasis on the energy sector.

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