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Norway's net-zero emissions target for 2030

Too ambitious to be true?

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Abstract

Norway has positioned itself as a climate policy forerunner by aiming to reach net-zero emissions already by 2030. However, the net-zero ambition is not well-defined, not legally binding, nor substantiated by action plans. In a first, interdisciplinary, analysis we scrutinise the net-zero concept and discuss unilateral options. Second, we provide an economic analysis with a global computable model, SNOW, of the costs and macroeconomic impacts of various policy scenarios. It explores how the net-zero ambition interacts with other 2030 goals and quantifies the impacts of emphasising domestic abatement and carbon removal measures vs. paying for emission mitigation abroad. Finally, the 2030 results are revisited to assess how well they align with Norwegian and global climate targets for 2050.

The main findings are that pursuing the net-zero ambition, on top of other binding 2030 goals Norway is already committed to, will increase costs by 25-100% depending on the use of domestic measures. On the margin, domestic measures are found to have only small, uncertain, and costly mitigation potential, thus, buying international carbon credits will be inevitable. Besides being significantly cheaper, carbon trading can have the potential benefits of developing the credit markets and the individual projects' qualities. Even if domestic measures can play but a modest part in the net-zero strategy towards 2030, we identify several steps governments unilaterally can take today to expand abatement opportunities towards mid-century. We also find measures that seem cost-effective in pursuing 2030 goals but look less attractive against a global 2050 backdrop.

Keywords: Net-zero emissions; Climate change mitigation, Abatement policies; Nationally Determined Contributions; Carbon credits; Emissions trading system; Effort-Sharing Regulation; LULUCF

JEL classification: O44, O52; H23, Q54

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Sammendrag

Norge har ambisjoner om å bli det første klimanøytrale landet i verden, dvs. oppnå netto null klimagassutslipp allerede i 2030. Imidlertid er ambisjonen fremdeles ikke klart definert, den er ikke rettslig bindende eller støttet opp med konkrete tiltaksplaner. Først i denne artikkelen gjør vi en tverrfaglig vurdering av begrepet `klimanøytral´og hva som finnes av praktisk gjennomførbare tiltak mot 2030. Deretter gjennomfører vi en makroøkonomisk, numerisk analyse med modellen SNOW av noen politikkscenarioer. Analysen fanger opp samspill mellom klimanøytralitetsmålet og andre klimapolitiske mål Norge har for 2030 og sammenlikner de samfunnsøkonomiske effektene av en strategi som legger vekt på innenlandske tiltak med en strategi der kvotekjøp står sentralt. Tilslutt vurderer vi strategiene for 2030 i lys av klimamålene Norge har for 2050.

Å oppfylle klimanøytralitetsambisjonen vil kreve mer enn hva Norge har forpliktet seg til i bindende internasjonale avtaler og i landets klimalov. Vi finner at kostnadene ved klimapolitikken vil øke med 25 -100% avhengig av strategi. Innenladske tiltak vil ha et beskjedent potensial; resten må dekkes ved å kjøpe klimakvoter. Ikke bare er kvotehandel billig sett i forhold til innenlandske tiltak, det er realistisk at en ved å nytte handelsmekanismene innenfor Parisavtalens Artikkel 6 kan bidra til at mekanismene forbedres og utslippsreduksjonene blir mer pålitelige. Selv om det er lite å oppnå innenlands innen 2030, identifiserer den langsiktige analysen av det er potensial for betydelige utslippskutt innenlands innen 2050. På den annen side vil noen av tiltakene som er kostnadseffektive i et 2030-perspektiv kaste lite av seg på lang sikt.

1. Introduction

In the wake of the report on global warming of 1.5 ℃ from The International Panel on Climate Change (IPCC 2018), setting net-zero targets has gained significant relevance. The report highlighted that achieving the 1.5 ℃ goal requires global anthropogenic CO_2 emissions to be balanced by carbon removal around mid-century. However, this global necessity does not apply at the single-country level; the allocation of emissions and removals across countries would be a question of cost effectiveness, fairness, and feasibility. Nonetheless, several countries have net-zero ambitions for the next decades, usually formulated in terms of greenhouse gas (GHG) emissions. Norway is among them and stands out by having a net-zero GHG goal already for 2030. Thus, Norway is often referred to as a frontrunner in the net-zero debate.

The net-zero ambition of Norway is still not convincingly planned in the details nor well-adapted to feasibility constraints. Pursuing the fulfilment as early as in 2030 aggravates the challenge in many respects. Action has become urgent, technological mitigation opportunities are still scarce, and exploiting international carbon markets is risky due to weak regulations and lack of consensus on the operationalisation of abatement measures and accounting principles. On the other hand, these deficiencies also introduce degrees of freedom. This is particularly so in the current Norwegian case, since the net-zero ambition is unilaterally adopted, poorly defined, and not settled by law or international commitments. In this situation, it can be tempting to adapt the specifications of targets and policy measures to the country's particular capabilities.

This leads to the first research question addressed in this article: *How can the net-zero ambition, and its fulfilment, be understood and operationalised in the Norwegian case?* We address this in Section 2. The purpose is to identify legal and feasible delimitations and assess likely net-zero strategies. We approach this by scrutinising relevant national and international policy documents and political processes with an interdisciplinary approach, where political science is combined with expertise from technological science, biology and economics.

Among influential preconditions are the legal and feasible aspects of various *other* climate policy commitments and ambitions of Norway towards 2030. The interplay between the net-zero-challenge and these other commitments and ambitions is the topic of Section 2.1. Besides the Nationally Determined Contribution (NDC) of Norway pledged in the Paris Agreement, Norway is committed through agreements with the EU to targets consistent with EU's *Fit-for-55* programme.[1]

1 See https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55/.

Renegotiations are ongoing. Norway's international commitments are consistent with those fixed by law in Norway's Climate Change Act.[2] In Section 2.2, some options for interpreting the self-imposed net-zero ambition are discussed, before concluding that the government will most likely resort to existing and recommended accounting principles, implying that so will we in this analysis. Section 2.3 makes a feasibility and likeliness discussion of the different types of measures that can contribute to the net-zero fulfilment.

The second research question we pose is: *How do different feasible net-zero strategies towards 2030 compare in terms of costs and practicability?* We analyse this question numerically in Section 3 by a hybrid linking procedure of macroeconomic model results and bottom-up data. The section brings the conclusions from Section 2 into a disaggregated, global computable general equilibrium (CGE) framework. In addition to a scenario that simulates an implementation of Norway's 2030 commitments, we present two scenarios that fulfil the net-zero ambition in consistency with the feasibility assessments in Section 2 and a cost-effectiveness criterion.[3] The first net-zero scenario balances the remaining emissions in the commitment scenario by carbon credit purchases abroad, while a second gives priority to domestic abatement and carbon removal measures. A key contribution of our comprehensive macroeconomic approach is to capture the interaction of the net-zero ambition with other national commitments and the simultaneity of a wide range of measures. Multiple analyses of scenarios that reach net-zero emissions by mid-century have been published, however, the majority of these is based on global energy systems and/or integrated assessment modelling, and their focus is either on world emissions, as in IEA (2022), Meinshausen et al. (2022) and UNEP (2023), or on large emitting countries, as in van Soest et al. (2021). Quantitative single-country studies of net-zero approaches are scarce, which is unsatisfactory given that policymaking will have to take place on the national level. The frontrunner case, that is heavily reliant on existing technologies and carbon markets, is barely studied. Besides our Norwegian analysis, a handful of studies addresses the Finnish case, which has the relatively close net-zero target-year 2035.[4] As we will come back to, Finland's situation deviates from that of Norway in several respects.

In Section 4, we raise a third research question: *How can 2030 strategies be aligned with long-term targets?* The climate change challenge is persistent, and it is not obvious that a well-adapted plan for

[2] See https://lovdata.no/dokument/NLE/lov/2017-06-16-60.

[3] Note that climate change effects are kept out of the analysis as Norwegian policies would have similar impact in all the scenarios. The costs of the scenarios only differ in their direct and indirect abatement costs.

[4] See Parry and Wingender (2021), Ministry of Economic Affairs and Employment of Finland (2022) Boston Consulting Group (2022), and IEA (2023a).

2030 leads us on a sound pathway further into the future. In this third part of the analysis, we revisit the 2030 results to identify measures that appeared rational in the 2030 perspective but look less attractive against a 2050 backdrop. Vice versa, we consider actions that should start today to generate high yield in the long run even if they are found to have only small impact on emissions in the coming decade. The qualitative approach to this third research question is motivated by the large uncertainty encompassing the international development towards 2050 and its influence on the societal and economic context of Norway's climate policies. Moreover, many of the dilemmas related to timing cannot be addressed by the static numerical approach in Section 3, since they involve systemic dynamic processes.

With reference to the question: *"Is the net-zero emissions target in 2030 too ambitious to be true?"* posed in the title of the article, the main conclusions from our analysis are that the answer is: *"yes, a net-zero emissions target by 2030 is too ambitious to be true"*, if we interpret the goal as requiring domestic mitigation, only. If the intention is to allow for use of international carbon credits, the answer becomes *"no"*.

Even if we conclude that domestic measures can play but a modest part in mitigating emissions towards 2030, the government can take steps already today to expand abatement opportunities towards mid-century. Meanwhile, domestic actions need to be combined with substantial purchases of international carbon credits. We conclude that buying and cancelling allowances in the EU emissions trading system (ETS) will not be legally accountable for Norway. Carbon credits issued for mitigation projects in other parts of the world, however, will most likely be accessible. Buying carbon credits can have several potential benefits. Besides being a relatively cheap 2030 solution for Norway, such trading can facilitate low-emission transformation in countries with low capacities, transfer technology and competence to the seller countries, develop the international trading institutions, improve global collaboration, and contribute to strengthen the environmental integrity of the carbon credits. Section 5 elaborates more on the conclusions from our analysis.

2. Interpreting and operationalising the net-zero ambition

In 2008, the Norwegian Parliament passed a net-zero target for 2050 and declared that it should be expedited to 2030, provided major commitments were taken on by other industrialised countries (Ministry of the Environment 2007). After the ratification of the Paris Agreement in 2016, the Parliament stated that this precondition had been met and pushed the target closer in time to 2030 (Parliament 2016).

In the Norwegian documents, the target is named 'climate neutrality', a notion that usually describes a state in which human activities result in no net effect on the climate system. In the following we interpret the Norwegian target as a balancing of the country's metric-weighted gross anthropogenic GHG emissions by corresponding removals (not necessarily implemented within own borders). We will in the following use the more common concept for covering this, namely 'net-zero GHG emissions'; see IPCC (2018).

The decision of the Parliament has raised much dispute and uncertainty as to how the net-zero ambition should be interpreted and operationalised in the context of all the other national climate policy commitments and ambitions. Simultaneity among the various goals potentially brings complex interactions. Moreover, the international commitments embody detailed sets of rules and principles for mitigation policies, that potentially have relevance for how the net-zero emissions goal and potential net-zero actions can be operationalised.

2.1. Net-zero emissions and other simultaneous national goals

The national commitments and ambitions for 2030 are illustrated in Figure 1. Norway has international commitments within two frameworks. First, Norway last updated its NDC in November 2022 (Government of Norway 2022). The target is to reduce emissions by at least 55% by 2030 compared with 1990 levels. Second, Norway has a legally binding agreement, established in 2019, about collaboration with the EU (and Iceland) to fulfil the 2030 target (Parliament 2019). The Norwegian Climate Change Act, which came into force in 2018 and was updated in 2023, covers these elements, along with the long-run commitment for 2050 to become a low-emission society, defined as mitigating emissions by 90-95% from the 1990 level.

Despite still under renegotiation, the 2019 agreement with the EU will imply that Norway adopts the Fit-for-55 ambitions for 2030 with commitments split into three pillars: (1) The EU ETS has an emissions cap for all involved industries – including generation of *electricity*, *coal* and *petroleum* extraction, *energy-intensive, trade-exposed manufacturing*, intra-European *aviation* and *water transport*

– that corresponds to a 62% emission reduction from the 2005 level. Countries fulfil their parts as domestic companies facing the allowance price are incentivised to abate emissions or trade ETS allowances. (2) Non-ETS emissions, including those in *primary industrie*s and *commercial transport* (except *aviation* and international shipping), are covered by EU's Effort-Sharing Regulation (ESR). Here EU's Fit-for-55 goal for 2030 is a 40% reduction from the 2005 level. Moreover, it is expected that Norway will be assigned a cap for 2030 equal to 50% of the 2005 emissions level as well as quantified caps for each of the years from 2021 to 2030. (3) The EU has a 2030 target of increased regional net removal compared with a reference level of at least 310 million tonnes CO_2-equivalent (mill. tCO_2e) emissions in the Land Use, Land-Use Change, and Forestry sector (LULUCF) that will also commit Norway. The member states have been allocated their shares of how much net uptake will have to increase in 2030 compared to the average in the reference period 2016-2018. Norway is still not included, but it is expected that its national commitment will be based on similar calculations. Preliminary estimations are presented in Section 2.3.

Figure 1. **Norway's climate policy commitments and ambitions for 2030**

COMMITMENTS	
The Paris Agreement, Nationally Determined Contribution + Climate Change Act	• 55% GHG emission reduction from 1990 level
The collaboration with the EU (under renegotiation – likely result)	(1) ETS-covered (emissions in the EU Emissions Trading System): - 62% cut from 2005 level (2) ESR-covered (emissions under Effort-Sharing Regulation): - 50% cut from 2005 level (3) LULUCF-covered (forest and land): - net removal increase from 2016 -2018 average, calculated as for EU Some flexibility across time, borders, pillars
AMBITIONS	
2021 Labour-Centre Parties government coalition	• 55% GHG emission reduction from 1990 level • <u>Only</u> domestic abatement
The Parliament	• Net-zero greenhouse gas emissions by 2030 and onwards

The EU allows for flexibility in the fulfilment of all these targets, not only of the ETS-covered emissions. Within some limitations, ESR and LULUCF commitments can be fulfilled across borders. There will also be some opportunities for trading across pillars and within pillars across time.

On the other hand, the EU prohibits the use of non-European flexibility mechanisms, which implies that Norway is obliged to refrain from using these to meet the targets specified in the 2019 agreement with the EU, but not otherwise. These include all kinds of credit trading, also arrangements within the UNFCCC[5] framework, most notably those under the auspice of Article 6 in the Paris Agreement as well as the Clean Development Mechanism (CDM), which is still around and played a significant part in Norway's fulfilment of the commitments in the Kyoto-protocol periods of 2008-2012 and 2013-2020.

Finally, Figure 1 also includes another non-binding ambition established by the Labour-Centre Parties government coalition in 2021. In addition to the legally binding target in the Climate Change Act, which includes collaboration with the EU to reach the target, the government stated the ambition to fulfil the 55% GHG emission reduction from the 1990-level by domestic abatement, only (Government of Norway 2021). This ambition in principle excludes replacing domestic mitigation by buying allowances in the EU ETS market or using other possibilities to factor in other flexibility mechanisms in the climate policy collaboration with the EU. The given rationale is that heading for an ambitious medium-term mitigation domestically is expected to prepare domestic industries for the long-run transformation of the Norwegian and international economies. We will investigate the interaction between the net-zero ambition and the abstention from using flexibility vis-á-vis the EU in a sensitivity analysis in the numerical study in Section 3.3.

2.2. Principles for accounting emissions – a discussion

The net-zero target apparently extends Norway's climate policy ambitions for 2030 beyond the international commitments. However, this is not necessarily the case. Since the unilateral net-zero ambition is not legally regulated, the government can choose to be creative and widen its scope of action. Here, we discuss the legality and feasibility of alternative accounting principles and assess what most likely will be the net-zero interpretation of the government.

[5]UNFCCC is UN's Framework Convention on Climate Change – that frames the Paris Agreement.

Legality and feasibility of accounting methods

One open question related to accounting emissions is whether to include net uptake in forests and land in the net-zero emissions definition. The decision will have significant implications. In 2022, net uptake in forest and land constituted as much as 30% of Norway's (gross) GHG emissions (Norwegian Environment Agency et al. 2024). Net removals in forests, or other parts of the LULUCF sector, are not part of Norway's NDC under the Paris Agreement nor of the 55% target for 2030 settled in the Climate Change Act. A main reason is a fundamental hesitation in balancing anthropogenic emissions from firms and households against natural processes occurring in forests and land (Grassi et al. 2017). Despite, the EU switched to a net emissions definition in its recent update of the 2030 NDC. This is not a politically feasible option for Norway. First, it would violate the binding *ratchet mechanism* of the Paris Agreement demanding each update of the NDCs to increase the ambition. Second, the ambitions of Norway's ESR and ETS commitments vis-á-vis the EU will meet the NDC alone, thus LULUCF measures will come on top. These political feasibility concerns were less insistent in the EU case, as carbon removal in forests and land only constitutes 9% of gross GHG emissions (European Environment Agency 2023). For example, the net-zero-plan of Finland, an EU member with a net-zero target as early as 2035, is to balance remaining gross emissions against what their forests will likely be able to remove. This approach is consistent with EU counting principles but not Norwegian. As a consequence, analysing the Finnish net-zero plan does not to the same degree as the Norwegian rely on capturing complex interactions.

Another way of alleviating the net-zero challenge can be to choose accounting methods other than the territorial accounting principle (which allocates emissions based on where they occur). For Norway, a consumption-based perspective could have some advantages. This principle assigns all emissions in value chains to where they are finally consumed downstream (Steininger et al. 2016), and this means Norway would be relieved for the substantial GHG emissions resulting from its export-oriented *petroleum* sector (Bruvoll and Faehn 2009). Another example is that Norway has a large capacity for CO_2 storage in aquifers and depleted offshore oil and gas reservoirs. How to assign credits for carbon that originates from abroad and is stored beneath the Norwegian continental shelf is yet not internationally regulated but will be of importance to Norway.

Our assessment on likely policies

Unilaterally applying alternative accounting methods will risk errors and double counting. A main recommendation in Rogelj et al. (2021), who discuss operational criteria for net-zero targets, is to ensure that each mitigated unit of GHG is accounted for once and only once. Further, they argue that national net-zero targets should be clear on which emission sources are covered, which gases are included, how they are weighted, and the reference point for measurement. In line with these recommendations, the Norwegian Parliament has expressed concern for the quality and reliability of Norway's target and advocated that its achievement must follow standards that guarantee real and permanent emission reductions and environmental integrity.

Based on these concerns, we conclude that, most likely, definitions of GHG sources and principles for abatement accounting will be made in UNFCCC-consistent terms and, also, be kept within the legal framework of EU's Fit-for-55 strategy. Implications of these premises are that the territorial principle will be adopted, the involved GHG gases will be the seven Kyoto gases[6] weighted in relative terms by means of current GWP100-based CO_2-equivalent metrics (IPCC 2023). Moreover, to be consistent with Norway's NDC, we do not allow for using the definition of emissions corrected for uptake in forest and land.

2.3. Operationalising net-zero measures – a discussion

Rogelj et al. (2021) recommend that governments specify what kinds of measures the country will use and preferably also in what proportions. Norway's net-zero decision from 2016 is phrased relatively detailed: *"Reduced emissions can be obtained through the EU emissions market, international cooperation on emission reductions, allowance trading or project-based cooperation."* (Ministry of Climate and Environment 2016). The 2021 Climate Plan (Ministry of Climate and Environment 2021) reaffirms this stance.

Our review of relevant policy documents combined with international recommendations (Rogelj et al. 2021; van Soest et al. 2021) has led us to expect a rather cautious approach, where only well-regulated measures will be topical. Thus, in the analyses in Sections 3 and 4, only measures that are approved in the Fit-for-55 regulations or in the process of being approved, will be included. These presumptions are consistent with the conservative attitude we expect in terms of counting principles (see previous subsection). To meet the binding commitments for 2030, Norway will have to implement a large share of the mitigation measures that are feasible within that timeframe. Further mitigation towards net-zero GHG emissions will have to rely on additional measures. On the margin, remaining measures accessible for the net-zero fulfilment will tend to be relatively costly or in other respects hard to realise.

[6]These include CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3.

Measures Norway can undertake include two principal *classes* of options: (i) paying for emission reductions abroad and (ii) domestic measures. The official documents and the international recommendations tend to suggest options in class (i) as a main strategy for Norway. We systematically explore all possibilities in order to assess the impacts and likelihood of different choices.

Class (i): Paying for emission reductions abroad

There are mainly three mechanisms available for trading allowances and credits internationally. First, the cross-border flexibility mechanisms in the EU can be used. Along with the ETS market, these include access to flexibility in ESR-covered and LULUCF sectors, which imply that Norway can finance ESR and LULUCF projects in other EU member states (or Iceland) as part of own fulfilment. Second, Article 6 in the Paris Agreement offers opportunities for accessing international credits. Third, several voluntary carbon markets exist as an additional source of international carbon credits.

Legality and feasibility of options

When it comes to the EU cross-border flexibility mechanisms, virtually no trade in ESR allocations or LULUCF credits have yet been observed due to shortage of sellers, though we cannot exclude that some agreements among countries may be settled within 2030. In contrast, the EU ETS market is well-functioning, and ETS allowances are extensively traded among companies. However, buying allowances in the EU ETS market and refraining from using them, is *not* a legal option for Norway. Such emission reductions would as a default be recorded and reported to UNFCCC as EU achievements. This is because the EU ETS applies at the company level and is operated at the EU-level. Theoretically, to avoid double-counting, a separate agreement with the EU about transferring the registration to Norway could be a possibility, but this is most likely not a politically feasible solution.

The regulations under Article 6 are gradually replacing the Kyoto Protocol's flexible mechanisms (World Bank 2022a). Article 6.2. establishes the basis for a system with bilateral transfer agreements between countries, so-called Internationally Transferred Mitigation Outcomes (ITMOs). Article 6.4 concerns a new mitigation mechanism, referred to by some parties as the 'sustainable development mechanism', generally seen as taking over the role of the CDM. Unlike the CDM, there are no restrictions on which parties can host mitigation projects and on which parties can use the resulting emission reductions to fulfil their NDCs.

It is relevant here to bear in mind that the EU already in 2014 decided to stop the possibility for European firms to use international credits for ETS compliance from 2021 on, and this also legally binds Norway. It is true that the net-zero ambition is a different issue, as it goes beyond the commitments in the EU collaboration, and Norway has in its NDC secured its right to use the UNFCCC mechanisms for exceeding the commitments in the EU collaboration. Nevertheless, the EU has banned these credits for specific reasons, not least the genuine uncertainty about their environmental integrity, i.e., to what extent the credits given for the projects reflect their real emissions effect (Oeko Institut 2016). The EU also worry for impact on the ETS price and for delayed net-zero transformation of their own economies.

Monitoring and verifying real effects are difficult due to uncertainties related to additionality, permanence, and indirect impacts of the projects. The uncertainty surrounding the role of such credits has been reinforced by a lack of ability of the parties in the Paris Agreement to agree on how to operationalise the Article 6 mechanisms. Key controversial issues have been how to handle unused CDM credits with uncertain environmental integrity (Ahonen et al. 2022) and how to avoid that both sellers and buyers of credits report the same emission cuts projects. During the last couple of years, the parties have come further in solving these issues. Common verifiable and comparable accounting systems have been adopted, rules avoiding double counting have been settled, and new eligibility rules have included CDM credits generated after 2013 but excluded transactions for avoided deforestation.

No ITMOs have been transferred to date, however, partnerships have been established between some host countries and buyers, and strategies and needed processes for ITMO authorizations are under development. In collaboration with the Global Green Growth Institute, Norway aims to develop programs in Indonesia, Morocco, Vietnam, and Senegal. Another ongoing activity of Norway is in the Transformative Carbon Asset Facility program of the World Bank (Global Green Growth Institute 2023; World Bank 2022b). At present, cooperation projects on technological carbon removal like Direct Air Capture with Carbon Storage (DACCS) are hindered by insufficient UNFCCC regulations (IEA 2023b).

Irrespective of the status of Article 6, numerous voluntary markets have emerged as a response to the demand for carbon credits as attractive assets for economic entities like companies, cities and organisations wishing to compensate for emissions they generate. A question is whether these markets could be utilised by governments like the Norwegian to offset remaining emissions and meet the net-zero target. Moreover, it could be argued that carbon credits bought by Norwegian companies and other juridical entities could be regarded as domestic contributions to the government's net-zero ambition.

Our assessment on likely policies

In contrast to how the Norwegian government specifies its main net-zero strategy, we conclude that the likely situation is that the EU flexibility options are legally and practically excluded as means for exceeding Norway's commitments in the EU collaboration.

Use of the voluntary markets by governments seems rather unlikely. This would especially apply to the option of including the trading of domestic companies in the country's net-zero accounts. The markets are fragmented. Common definitions, standards, and 'due diligence' procedures for carbon credits are missing. Thus, the carbon credits have uncertain and variable quality and comparing credits across traders and markets is difficult. The risk of double counting would be high.

However, there are signs of Article-6procedures learning from the development going on in the voluntary markets. Even if the voluntary markets still are fragmented, standardisation is developing, and some proprietary standards exist. In many respects, the mechanisms resemble each other. Ahonen et al. (2022) argue that, over time, the similarities between the UNFCCC mechanisms and the voluntary markets will strengthen. They foresee further alignment of operationalisation and rules across voluntary markets and market-based cooperation under Article 6. One scenario could be that the experience from voluntary markets of developing standards and monitoring processes will inform and potentially improve the carbon trading mechanisms under Article 6. Due to the bottom-up design of the Paris Agreement, the UNFCCC mechanisms take on a voluntary character. In our quantitative analysis, we assume merging of the two systems and a harmonisation of their carbon prices. For carbon credits in the UNFCCC system, present price forecasts lie in the range from 20 to 40 USD/ tCO_2e towards 2030, while voluntary markets have expected prices between 1 and 20 USD/ tCO_2e (Carbon Credits 2024, Ecosystem Marketplace 2022, Carbon-pulse 2023).[7]

Class (ii): Domestic measures

After fulfilling the binding commitments, remaining domestic net emissions can be mitigated by strengthening *domestic* action further. Such over-fulfilment on own territory can take place in the ETS-covered, ESR-covered or LULUCF sectors and take the form of abatement measures (reducing gross emissions) or removal measures (increasing carbon uptake). We split the removal options into natural and technological measures, where nature-based removal corresponds to over-fulfilment of the LULUCF commitments. Since most available removal solutions, natural as well as technological,

[7] All carbon prices and marginal abatement costs are given in 2020-USD. The CO_2-equivalents are based on GWP100.

remove CO_2, we concentrate on *carbon* removal, even though projects that aim to remove CH_4 also exist.

Legality and feasibility of options

Some quantitative analyses of Norway's legally binding commitments by 2030 in the ESR and ETS sectors already exist, but none that study their interaction with the net-zero goal. In the project Climate Cure 2030, the Norwegian authorities assessed the potential and cost of fulfilling the commitments in the ESR-covered part of the economy by domestic measures, both from a bottom-up and a top-down perspective; see Norwegian Environment Agency et al. (2020) and Faehn et al. (2020), respectively.[8] The top-down analysis found a 2030 marginal abatement cost of 390 USD/tCO_2e for the ESR-covered sector to meet the commitment of a 50% reduction from 2005. In Norwegian Environment Agency (2022a, 2023a), their bottom-up assessment is updated. These conclude that, compared to the 2005 level, the 2030 abatement potential in the ESR-covered sector is 56%. In other words, almost all the potential they identify is expected to be emptied out to reach a domestic 50% cut.

In a global, top-down analysis of CO_2 abatement, Faehn and Yonezawa (2021) find a marginal cost as high as 660 USD/tCO_2 for meeting the committed 50% reduction in the ESR sector domestically. That study also assesses the commitment in the ETS sector and addresses the case where Norway's ambition is to fulfil its NDC through domestic measures, only (see Figure 1). Technically, we represent this ambition by assuming, *one* domestic allowance market covering both ESR and ETS emissions. The price in this common market renders 450 USD/tCO_2. As the level of ESR- and ETS-covered emissions in Norway are approximately equal, the findings indicate that there is a considerably lower marginal cost in the domestic ETS sector than in the ESR sector. Norwegian Environment Agency (2022b) assesses the ETS-covered sector by a bottom-up approach and identifies a domestic abatement potential in 2030 of 52% compared to the 2005 level. In other words, the bottom-up results do not leave sufficient room for meeting the ETS ambition by domestic abatement, alone. Then the needed abatement amounts to 62% of the 2005 level (see Table 1).

Turning to nature-based carbon removal measures, we have already argued that switching the definition of emissions from *gross* to *net* by including net uptake in LULUCF in our overall NDC target would be politically challenging. Our conservative approach to the net-zero operationalisation, thus,

[8] Top-down analysis deviates from bottom-up approaches by, first, including not only technological abatement options but also changes in the scales of production and consumption. Second, while potentials of the measures are estimated by the analyst in bottom-up analysis, they result endogenously from the level of the computed marginal abatement cost in top-down analysis. At some level, however, costs will become politically unacceptable and prohibitive in a practical sense.

excludes this possibility. This does not mean that additional actions to *increase* net LULUCF uptake is left out. These are fully legitimate measures and are also part of the existing agreement with the EU from 2019.

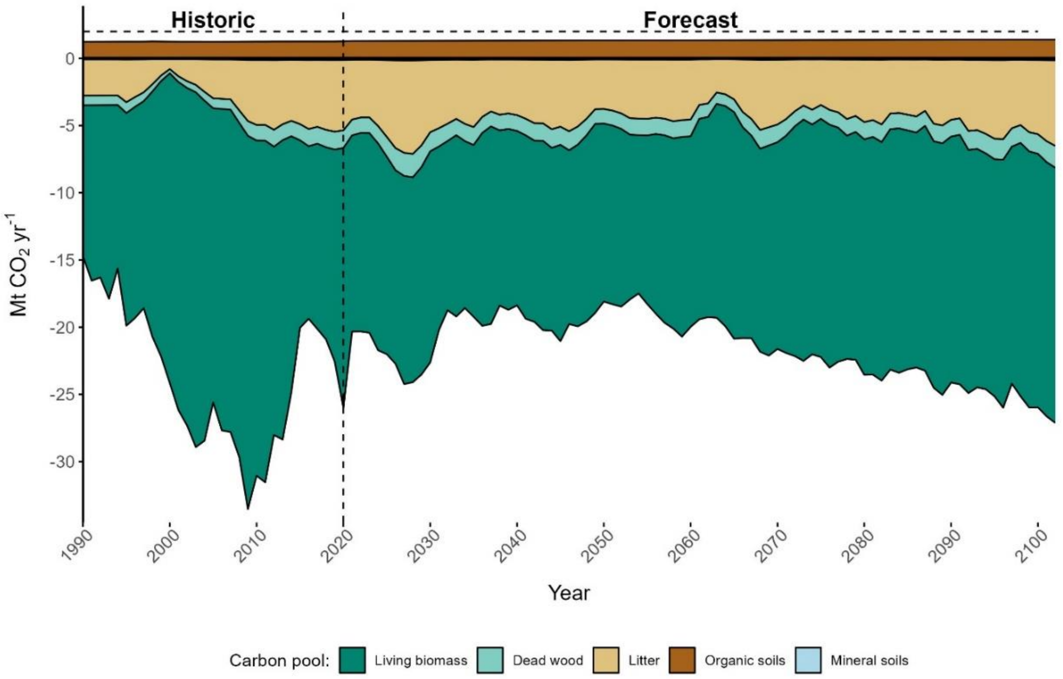
The Norwegian LULUCF sector had a net removal of 13.7 mill. tCO_2e in 2022, corresponding to approximately 30% of Norway's GHG emissions in the ESR and ETS-covered sectors. Forest land serves as the major sink in the LULUCF sector, which had net removals of 17.9 mill. tCO_2e in 2022. Figure 2 shows past and projected annual net removal of CO_2 from the forest land carbon pool, i.e., excluding non-CO_2 and storing in harvested wood products (HWP). Since 1990, net removal increased until 2010, while the more recent years have had lower levels. This is also true for the projection from 2020 to 2030 and onwards. The projected net uptake in 2030 for (all) LULUCF is estimated to 16.5 mill. tCO_2e.

While the EU has allocated its LULUCF target for increased net removal by 2030 on each of the member states, the Norwegian share is still under negotiation. Therefore, it is not clear how the target for Norway in the LULUCF sector will relate to the net removal in the projection of approximately 16.5 mill. tCO_2e in 2030. If a gap is expected, it will need to be addressed. We have made own calculations based on the same methodology as for the EU member states and arrives at a net removal target of 14.8 or 16.7 mill. tCO_2e, depending on the chosen data as input.[9] The first estimate implies that the target is lower than in the projection, while the other implies a gap of 0.2 mill. tCO_2e. We approximate the gap to 0 mill. tCO_2e in 2030. Note that Norway had relatively low net carbon removal in the reference period used by the EU (2016-2018) compared with the last decades.[10]

[9] Since Norway is not included in the EU target, it is our interpretation that Norway's 2030 target would need to be calculated as a share of a new Norway-EU target. Important elements in the calculation are the size of managed area, and average net emissions for the reference period 2016-2018. Our two estimates of the obliged net removal increase from the reference are 1.2 and 2.9 mill. tCO_2e, based on the Norwegian submission to the UNFCCC in 2020 and 2022, respectively, which deviate in their classifications and areas of managed land (14 vs. 25mill. hectares).

[10] Norway will also have quantified targets for each year prior to 2030. This analysis does not assess Norway's commitments prior to 2030. For the years 2026-2030, they seem to more or less overlap with the projected emission levels in the benchmark. Note, however, that for the years 2021-2025 the reference period (1990-2009) had on average far larger net removal, which contributes to substantially increase the challenge (Gulbrandsen 2024). There will be no trade possibilities across the two periods.

Figure 2. Norway's historical and projected CO_2 net emissions from forest land for each of the carbon pools.[a)]



a) Adapted from Mohr et al. (2022).

When no measures are needed to fulfil the LULUCF commitment, all potential measures to increase natural net carbon removal can be used to approach the net-zero goal. In accordance with the present EU regulations, natural carbon removal that can take place in ocean is omitted. We include only measures that involve managed lands (78% of Norway's land area). For our analysis we have considered the following measures:

a. Reducing deforestation would have an immediate effect of reducing emissions, and a more long-term effect in sustaining the potential for forest removals. Deforestation in Norway occurs by land-use change due to buildings, infrastructure and agriculture and currently contributes to emissions of approximately 3 mill. tCO_2 per year. We assess that an immediate halt of deforestation could increase the projected LULUCF net annual removal from -16.5 to -18.5 mill. tCO_2e by 2030. Costs of holding back on land-take is equal to the potential utility of the foregone project net of possible ecosystem services. We have no sources that assess the feasible and cost-effective potential of land-take.
b. Increasing afforestation would, in contrast, not yield significant removal by 2030. It will take time for the new forest to grow and increase carbon storage.
c. Improving forest management of the existing forest area would also have a slow impact, thus, the 2030 potential is relatively small. According to Søgaard et al. (2020), improving the

management of existing forests through increased density in planting, improved seed material from tree breeding, and pre-commercial thinning would increase net removal by around 0.5 mill. tCO_2 within ten years at a cost of around 100 USD/tCO_2. The potential is probably an overestimate for 2030, which is only six years ahead (Norwegian Environmental Agency, 2023a).

d. Carbon removal through HWP can be spurred by increasing domestic production or the lifetimes of the materials, for instance through circular use. However, Ross et al. (2023) judge that 2030 is too early to expect any effect, as it would require restructuring and innovation in the forest and wood processing industries.
e. Sequestrating biochar in soil is expected to have minor potential in 2030. We estimate 0.5 mill tCO_2 with costs around 100 USD/tCO_2, based on Hagenbo et al. (2021) and Tisserant et al. (2022).

Lastly, besides natural carbon removal, there is the possibility to implement technology-based carbon removal solutions. Bioenergy combined with Carbon Capture and Storage (BECCS) is the most examined carbon removal alternative in the literature and extensively referred to in IPCC's 1.5 °C report (IPCC 2018). This technology relies on sustainable production of biomass for energy production, efficient Carbon Capture and Storage (CCS) and efficient value chains (Torvanger 2018). Norway has some potential for BECCS provided that more biomass from forest is produced and harvested, but this resource is limited by the need for large investments in power plants, higher value associated with timber production and fibre for industry, as well as sizeable biomass extraction costs. A variant of BECCS technology is carbon capture linked to biogenic waste incineration. This is the most topical BECCS variant for Norway. Several sites are considered, and the largest at the Hafslund Celsio waste-to-energy plant in Oslo seems to be the most imminent. The Norwegian Environment Agency (2023b) estimates that the amount of CO_2 emissions from biogenic waste that can be captured will amount to approximately 0.5 mill. tCO_2 by 2030. This assumes capture at half of the Norwegian waste-to-energy plants. For 2030, the literature cites a BECCS cost between 40 and 400 USD/tCO_2 (Fuss et al. 2018). A review of cost estimates of CCS for Norwegian waste-to-energy plants indicates a best estimate of 200 USD/tCO_2 with a range of 95-285 USD/tCO_2.[11]

DACCS is a less mature technology and has a high cost per tCO_2, due to large investments in machines that can absorb CO_2 from air and large electricity requirement. CO_2 concentration in air is about 300 times lower than in, e.g., exhaust from waste incineration plants. For DACCS, recent cost estimates lie between 65 and 1000 USD/tCO_2 (Al Juaied and Whitmore 2023). Norway has a few

[11] The review is a result of a workshop on potential Norwegian business models for CCS from waste incineration in Arendal in 2022 with Norwegian experts from Aker CC, Bellona, CICERO, Lyse, Zero, Sintef, and CCUS Norway.

active pilot projects today. The Norwegian Environment Agency (2023a) estimates a potential of 1 mill. tCO_2 by 2030 at a marginal cost in the range of 360-660 USD/tCO_2e.

Our assessment on likely policies

The previous studies of mitigation of ESR- and ETS-covered emissions referred to above indicate that the 2030 abatement potentials domestically, that can contribute to move emissions from Norway's committed targets to net zero, are minor: In the ESR- covered sector, another 6 percentage points reduction compared to 2005 levels is feasible and practically accessible (corresponding to 8% from benchmark in our quantitative analysis; see Table 5), while in the ETS sector there is already deficient measures for meeting the committed target. However, in the ETS-covered sector, there is also the opportunity to buy EU ETS allowances to meet the commitments. If the ETS market is exploited, the over-fulfilment potential in the domestic ETS-covered sector would increase correspondingly – to 11% from benchmark according to Table 5).

The ETS price facing Norwegian firms can be regarded as fixed and determined by the trading outside of Norway. Note that all the previous studies assess that the ETS price is significantly lower than the marginal cost of domestic fulfilment. Main explanations are that Norway already has renewable *electricity* supply based on hydropower, so the relatively cheap option of facing out coal- and petroleum-based *electricity* production is absent. Moreover, the ETS-covered *energy-intensive, trade-exposed manufacturing* industries are traditionally power-based, with relatively little potential for reducing fossil-fuel input. Finally, Norway has large GHG-emissions that are costly to abate in the *petroleum* industry.

When comes to the potential nature-based carbon removal measures, carbon sequestration and storage in terrestrial ecosystems, as well as in HWP are the major options. Biochar sequestration in agriculture is another option. One can also think of increased carbon storage in ocean (Macreadie et al. 2019). However, since solutions in ocean lack international regulation, we exclude them from our considered measures.

We have been able to quantify a small potential by 2030 for increased net carbon removal in the LULUCF sector. Table 5 sums up the information. Costs and potentials for certain forest management measures and for sequestrating biochar are included in the quantitative study. Together, these potentials correspond to 6% abatement from the benchmark used in our quantitative analysis – see Table 5. The politically feasible potential is probably larger. However, many of the measures have been impossible to quantify within the scope of this analysis. In Section

3, we elaborate on the choices of measures we make for the quantitative net-zero 2030 analysis and in Section 4, we come back to the mid-century relevance of the measures.

Table 5 also sums up the potential we take into consideration for technological carbon removal in the numerical analysis of 2030. The EU is currently not approving technological carbon removal projects, but we assume that some removal options that are in the process of being approved will be available within 2030, specifically carbon capture linked to biogenic waste incineration and DACCS. Together, their potential is estimated to 6% from benchmark.[12] We assess 2030 is too close for realising removal options like carbonate-based building materials or enhanced weathering in Norway. Depending on advances in technologies and changes in policy regulations, more carbon removal alternatives will be interesting in a 2050 perspective.

[12] As benchmark for technological removal options, we use benchmark emissions in the ESR sector.

3. Quantitative study of macroeconomic impacts and abatement costs of various 2030 scenarios

3.1. Method and design of the analysis

The global, regionalised CGE model SNOW, where Norway is a separate region, is the central tool in our quantification of national abatement costs and macroeconomic impacts of Norway's climate policies towards 2030. The analysis assesses different policy scenarios and compare them with a SNOW-simulated benchmark scenario. The underlying input-output tables of production and consumption together with bilateral trade flows and energy-related CO_2 emissions are from GTAP 9 (Aguiar et al. 2016). International trends towards 2030 for GDPs, energy use and emissions are developed to 2030 by means of the reference case in The International Energy Outlook from the US Energy Information Administration (EIA 2017).[13] For Norway, the benchmark scenario mimics the projection in the Norwegian National Budget for 2022, which is based on international trends similar to those in the EIA reference case (Ministry of Finance 2021). The SNOW model does not specify the LULUCF sector, so benchmark net emission removal in this sector is added, ex post, to the computations.

We analyse three policy scenarios for Norway. In the first, the commitment scenario (**COMM**), Norway fulfils its international commitments, only, not the net-zero-ambition. The 2030 commitments involve targets for all three pillars in a renegotiated agreement with the EU. SNOW is used to simulate the impacts of the ETS and ESR commitments. As shown in Figure 1, these amount to relative reductions of at least 62% and 50% compared with the 2005 levels of ETS- and ESR-covered emissions. When it comes to the LULUCF pillar, the rules and the renegotiated agreement are still not settled and uncertain, and we have calculated a most likely 2030 target for Norway.

[13] For more details on the benchmark, see Böhringer et al. (2021).

Table 1. Norwegian emission mitigation targets in the COMM policy scenario, 2030

Emission sources	**Policy targets** (see Section 2.1)	**Change from the model benchmark**
ETS-covered sector	-62% from 2005	-49%
ESR-covered sector	-50% from 2005	-32%
ETS+ESR-covered	-55% from 1990	-41%
LULUCF sector	-1.2 to -2.9 mill. tCO_2e from 2016-2018 average	0%

The benchmark emissions are, obviously, crucial for how challenging the targets in 2030 will be. Table 1 translates the targets Norway is committed to in the three pillars into percentage changes *from the 2030 benchmark*. The commitments will bring Norway's emissions (i.e., for the ETS and ESR-covered sectors together) 55% lower than in 1990, which coincides with Norway's NDC. As also reflected in Table 1, the likely 2030 target in the LULUCF sector, as calculated in Section 2.3, implies no net emission reduction from the benchmark. Thus, Norway's net commitment for 2030, i.e. including the LULUCF commitment, is equal to the gross commitments for the ETS and ESR-covered sectors. Note, however, that since land use is not reflected in the SNOW model, there are potential interaction effects on land use of implementing the ETS and ESR measures that will not be accounted and that could make the LULUCF goal more challenging.

The costs and mitigation potentials of measures that are not integrated into the SNOW model are accounted for by a hybrid linking method. Iteration procedures are used to integrate compatible bottom-up information from external sources with the model simulations. This is done for natural and technological removal options as well as for CCS. The downside of such *ex post* inclusion of information is that indirect impacts of repercussions and interplays are lost.

In the **COMM** scenario, the rest of the regions are assumed to fulfil their unconditional NDCs as interpreted in UN (2021). In addition, the EU will meet its Fit-for-55 targets for the three pillars, ETS, ESR and LULUCF, within 2030.[14] We let all regions (and pillars) comply in a manner that ensures a cost-effective implementation. In the SNOW model, this is mimicked by solving the model for

[14] Specifically, the EU will cut 62% and 40% from the 2005 emission levels in the ETS and ESR-covered sectors, respectively, and obtain a net removal of 310 mill. tCO_2e emissions in its LULUCF sector. Combined, these fulfilments will ensure that EU's NDC of a 55% net-emission cut from the 1990 level is met.

endogenous uniform carbon prices within each region, and in the EU and Norway cases, also within each pillar.

Besides **COMM**, we analyse two policy scenarios where Norway *adds* policies to those in **COMM**, in order to meet the Norwegian 2030 net-zero ambition.[15] The first, the Net Zero Carbon Credits (**NZCC**) scenario, assumes that international carbon credits will be purchased to neutralise the emissions remaining after all commitments are fulfilled. Besides the direct costs, the credit trade will have some indirect impacts, via the fixed current account and public budget.[16] The second policy scenario with a net-zero ambition is the Net Zero Domestic (**NZDO**) scenario. As opposed to **NZCC**, it assumes that domestic options, both in terms of abatement and removal measures, are prioritised. The abatement in ETS and ESR can be simulated in SNOW, while the carbon-removal measures are not explicitly modelled. Thus, their costs and abatement impacts are added from external sources to the model results. To the extent that a mitigation gap still remains, international carbon credits must be purchased in the **NZDO** scenario to offset remaining GHG emissions.

Recall from Figure 1 in Section 2.1 that besides the net-zero ambition, the government also has the non-binding ambition of refraining from using the cross-border flexibility mechanisms in the EU collaboration as a way of meeting its commitments. We disregard this ambition in the **COMM**, **NZCC**, and **NZDO** scenarios since it is not binding the government. However, at the end of the analysis we present sensitivity-tests of the results of scenarios with such a self-imposed restriction, referred to as **COMMX**, **NZCCX**, and **NZDOX**.

3.2. The numerical model SNOW

SNOW builds on general equilibrium theory that combines behavioural assumptions about rational economic agents with analysis of equilibrium conditions. The main virtue of the CGE approach is its comprehensive micro-consistent representation of price-dependent market interactions in a setting with various existing public interventions. Besides Norway, the EU (also including the rest of EFTA) is a separate region.[17]

For the industry disaggregation in this analysis, see Table 2. We distinguish between the following energy carriers: crude oil and natural gas (produced in the *petroleum* industry), *coal*, *refined oil*

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[15] Note that no other countries introduce net-zero ambitions by 2030, and the climate policies are kept as in **COMM** for the rest of the world.

[16] Rebalancing takes place by non-distortive transfers in the model, thus indirect impacts will be kept relatively low.

[17]The remaining 15 regions are United Kingdom, China, Japan, South Korea, India, Canada, USA, Brazil, Russia, Australia and New Zealand, Middle East Regions, African Regions, Other American countries, Other Asia, and Rest of the World.

products and *electricity*. This disaggregation is essential in order to distinguish energy goods by CO_2-intensity and degree of substitutability.

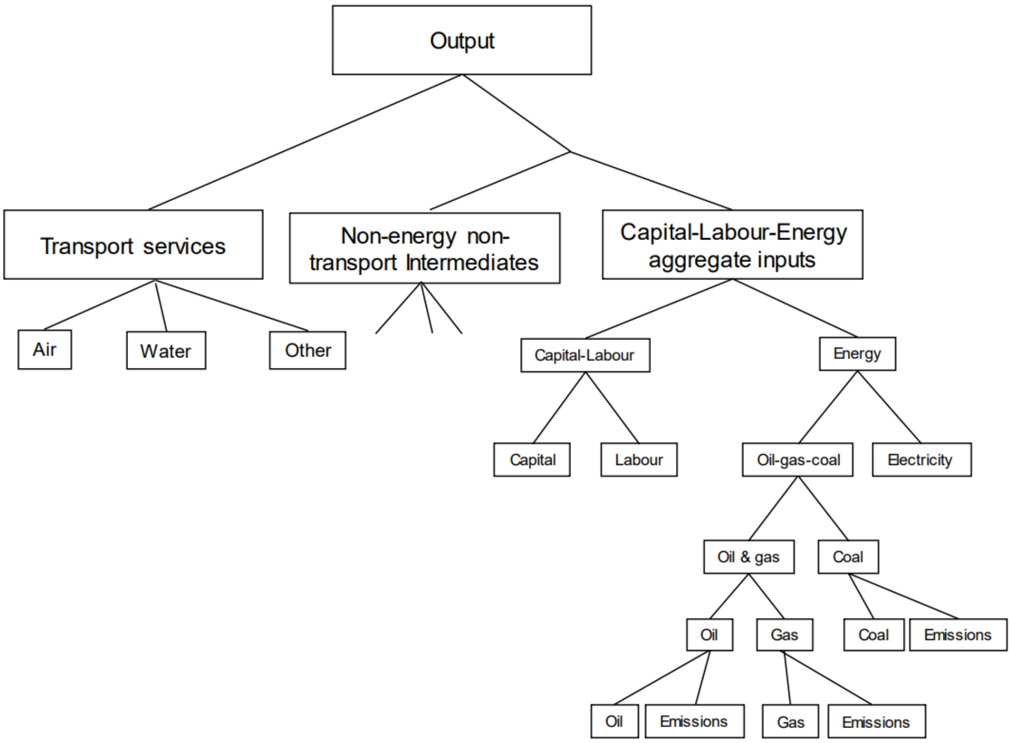
Table 2. Industries in the model

Industries (goods) in the *ETS set***
Coal
Petroleum (crude oil and gas)
Refined oil products
Electricity
Energy-intensive, trade-exposed manufacturing
Aviation ***
Industries in the *ESR* set**
Commercial transport (land and water)***
Primary industries
Other manufacturing
Other services

* Industries covered by the EU Emissions Trading System, ETS.
** The remaining industries, covered by the Effort Sharing Regulation, ESR. Note: Households' emissions are also covered by the ESR.
***Only emissions that are territorially accountable for Norway. Note: The recently included European shipping activity is not subject to ETS in the model.

The production of commodities is captured by nested constant elasticity of substitution (CES) functions that describe the price-dependent use of capital, labour, energy, and intermediate inputs; see Figure 3. Labour and capital are mobile across industries within a region but immobile across regions. Natural resources are a third type of production factor. These resources are industry and region-specific and used by the fossil fuel extraction industries (*petroleum* and *coal*). In addition to the nesting illustrated in Figure 3, these industries have a natural resource factor added at the top of the nesting. Household demand is also modelled as CES functions quite similar to those in Figure 3. Investment and government spending are modelled as Leontief production functions, and in this static setting they are exogenous in real terms. The data underlying the elasticity estimates are based on the pertinent econometric literature. The GTAP database provides substitution possibilities in production between primary factor inputs. The fossil fuel supply elasticities used as basis for the elasticities of substitution in the fossil fuel extraction industries are 4 for coal and 1 for petroleum products (crude oil and natural gas); see Graham et al. (1999) and Krichene (2002). Bilateral trade is specified using the Armington's differentiated goods approach, where domestic and foreign goods are CES composites distinguished by origin (Armington 1969). Armington elasticities are also taken from the GTAP database. A balance of payments constraint incorporates a trade deficit/surplus for each region.

Figure 3. Nested CES structure of production technology in SNOW industries



CO_2-emissions are linked in fixed proportions to the use of fossil fuels, with CO_2-coefficients differentiated by the specific carbon content of fuels. Other GHGs are not included. Under carbon policies, emissions abatement takes place in the model by fuel switching (inter-fuel substitution), energy efficiency improvements (fuel/non-fuel substitution) and downscaling of emission-intensive production and final consumption activities. We also allow for some abatement potential not represented in the original model. Specifically, investments in CCS technologies, possibly combined with hydrogen and ammonia production, are expected to take place in some of the ETS-covered SNOW industries if the marginal abatement cost exceeds 160 USD/tCO_2 (Norwegian Environment Agency 2022b). If relevant, we introduce these as reductions in the respective emission coefficients, solve for the marginal abatement cost iteratively, and add their total cost to the model-computed abatement costs, *ex post*.

3.3. Analysis

Fulfilling Norway's international commitments

We first map the 2030 outcome of the **COMM** policies, i.e., of fulfilling international commitments. The Norwegian target for ESR-covered emissions implies a reduction from the benchmark level of 32%; see Table 1. As mentioned, in praxis no mechanisms for European cross-border flexibility exist, and we assume that the entire commitment will have to be fulfilled by domestic measures. As reported in Table 3, the resulting marginal abatement cost in this sector renders 410 USD/tCO_2. For meeting the ETS commitment, Norway and the EU participates in the European ETS market. The ETS carbon price renders 210 USD/tCO_2; see Table 3. It is primarily determined by the demand for allowances in the EU member states; Norway's impact will be negligible because of its size. In the cost-effective equilibrium, the ETS carbon price will equal the marginal abatement cost in the ETS-covered sector. The domestic abatement in the ETS-covered sector is substantial, amounting to 38% of the benchmark emissions. The remaining 11 percentage points reduction from benchmark to reach the reduction target of 49% (cf. Table 1) is fulfilled by ETS allowance purchases. Finally, recall that no LULUCF measures are needed from the benchmark.

The total abatement cost in **COMM** in 2030 amounts to 2740 mill. USD. Besides the purchase cost of ETS allowances at the EU ETS allowance price, the total abatement cost includes the cost of domestic abatement in the ESR and in the ETS-covered sectors, which can be approximated by:

$ABM_i \times {MAC_i}/{2}$, i=ESR, ETS,

where ABM_i is the amount of emissions abated while MAC_i is the marginal abatement cost in sector *i*. The approximation assumes linear marginal abatement cost curves in both sectors.[18] See also Table 6 for a decomposition.

[18] As explained above, abatement resulting from CCS projects that are assessed to be cost-effective given the computed marginal abatement cost in the ETS-covered sector, is included by an iterative process and incorporated in ABM_{ETS}.

Table 3. Emissions and macroeconomic results for Norway, COMM scenario, 2030

Emissions and emission prices	**Results**	**Units**
ESR-sector: marginal cost (emission price)	410	USD/tCO2
ESR-sector: emissions	-32	% from benchmark
ETS-sector: marginal cost (emission price)	210	USD/tCO2
ETS-sector: emissions	-38	% from benchmark
ETS-sector: purchases	-11	% from benchmark
LULUCF-sector: emissions	0	% from benchmark
Economic activities		
Abatement cost	2740	mill. USD
ESR-sector: output	-1	% from benchmark
ETS-sector: output	-2	% from benchmark
GDP	-2	% from benchmark
Household consumption	-5	% from benchmark

Other economic results include a drop in GDP and household consumption of 2% and 5%, respectively. Note that the abatement cost is only one of several elements in the total social cost, which can be approximated by the consumption change. The 2030 consumption reduction is, first of all, reflecting a substantial terms-of-trade loss for Norway related to changes in the international markets in the wake of all other countries' fulfilment of their 2030 pledges in the Paris Agreement, incl. the EU's Fit-for-55 implementation.

Table 4 shows emissions and output changes by industry. In terms of output, the ETS-covered sector is more severely hit than the ESR-covered despite its access to allowances in the ETS market that contributes to keep marginal costs down. First and foremost, *petroleum* production declines sharply, by 10%. This reflects reduced global demand. This industry constitutes the largest source of domestic CO_2 emissions. Its downscaling contributes significantly to carbon mitigation and also implies access to cheaper labour and capital for other export industries, most notably, the *energy-intensive, trade-exposed manufacturing* industries, which gains and expands somewhat in spite of significant CO_2 emissions. The electrification of the Norwegian economy stimulates *electricity* supply, as does increased demand from the European markets. This reflects that Norwegian *electricity* is almost exclusively renewable hydropower, and it is expected that new capacity towards 2030 will also be renewable (hydro, wind and solar). CCS is also part of the technological transformation of the ETS industries, both in the *petroleum* and *energy-intensive, trade-exposed manufacturing* industries.

In the ESR-covered sector, the dominant source of benchmark emissions is transport. Considerable electrification takes place both in the commercial (all industries) and private transport niches (households). Substitution of *electricity* and biofuel for district heating is among the cost-effective measures; it is reflected in the abatement in *other services*. Domestically oriented ESR-covered industries, as *other services* and part of the *primary industries*, are mainly hit in indirect ways rooted in lower domestic demand. *Other manufacturing* is stimulated by demand from the export markets.

Table 4. Industry-specific results, for Norway, COMM scenario, 2030

	share*	output**	emissions**
ETS-covered industries			
Petroleum	29 %	-10 %	-43 %
Energy-intensive, trade-exposed manufacturing	16 %	2 %	-41 %
Electricity	4 %	16 %	-28 %
Aviation	5 %	0 %	-4 %
ESR-covered industries			
Other commercial transport	24 %	3 %	-41 %
Primary industries	5 %	-1 %	-25 %
Other manufacturing	2 %	3 %	-25 %
Other services	4 %	-1 %	-26 %
Households (ESR-covered)	11 %	-5 %	-19 %

* % of total emissions in benchmark
** % change from benchmark

Adding the net-zero ambition

Based on the discussions in Section 2, Table 5 sums up the available strategies for moving beyond the commitments in the **COMM** scenario in order to reach net-zero emissions by 2030. It summarises information on sources and, if the model results need to be supplemented, provides best available estimates on marginal costs and mitigation potentials for Norway (relative to benchmark in 2030) of different measures.

Note that among the options that rely on paying for emissions reductions abroad (class (i) options), the use of EU cross-border flexibility mechanisms is excluded based on the assessment in Section 2.3. Thus, the class (i) options left in the **NZCC** scenario are the UNFCCC mechanisms of Article 6 and the voluntary carbon markets. Based on the hypothesis of Ahonen et al. (2020) described in Section 2.3, we assume that the prices of these international carbon credits will tend to approach each other in the near future and use a marginal cost in the middle of the price estimates drawn from the literature for these two types of credits, i.e., of 30 USD/tCO_2; see Table 5.

In Scenario **NZCC**, the cost of the purchases necessary to reach net-zero emissions by means of carbon credits amounts to 680 mill. USD. This adds to the cost of commitments, resulting in a total abatement cost of 3420 mill. USD; see Table 6. In other words, obtaining net-zero emissions by buying carbon credits in **NZCC** is 25% costlier than limiting the ambition to the binding commitments, only, in **COMM**.

Table 5. Norway's net-zero options in 2030; estimates of marginal costs and potentials

	MARGINAL COST			POTENTIAL FOR NORWAY		
	In background literature	In our analysis	Source for our analysis	In background	In our analysis	Source for our analysis
(i) Paying for emissions reductions abroad:						
Flexibility mechanisms in Art. 6, UNFCCC	20-40 USD/t	40 USD/t	Carbon-pulse (2023)	abundant	simulated (endogenous)	SNOW model
Voluntary carbon markets	1-20 USD/t	20 USD/t	Carbon Credits (2024); Ecosystem Marketplace (2022)	abundant	simulated (endogenous)	SNOW model
(ii) Domestic measures:						
Overfulfilling abatement (Effort-Sharing Regulation-covered)	390-660 USD/t	simulated (endogenous)	SNOW model	+8% from benchmark	+8% from benchmark	Norwegian Env. Agency (2022a) and own calculations
Overfulfilling abatement (European Trade System-covered)	n.a.	simulated (endogenous)	SNOW model	+0% from benchmark	+11% from benchmark	Norwegian Env. Agency (2022b) and own calculations
Overfulfilling net removal (Nature-based/LULUCF-covered)	100-2500 USD/t	100 USD/t (weighed average)	Søgaard et al. (2020); Hagenbo et al. (2021); Tisserant et al. (2022)	+2-7% from benchmark	+6% from benchmark	Søgaard et al. (2020); Norwegian Env. Agency (2023a); Hagenbo et al. (2021); Tisserant et al. (2022)
Technology-based net removal	40-1000 USD/t	350 USD/t (weighed average)	Al Juaried and Whitmore (2023); Fuss et al. (2018);	+0-14% from benchmark*	+6% from benchmark*	Norwegian Env. Agency (2023a)

* Percentage technology-based net removal numbers are relative to the benchmark's ESR-covered emissions.

In the **NZDO** scenario, where domestic abatement and removal measures are assumed to take place, we find clear indications that domestic action will not be able to eliminate all emissions still remaining in the **COMM** scenario. A first indication is that, as reported in Section 2.3, the Norwegian Environment Agency (2022a, b) concludes that if the Norwegian commitments are to be met exclusively by domestic measures, a small potential for over-fulfilling would remain in the ESR-covered sector, while the abatement potential in the ETS-covered sector will be completely emptied out. Translated to shares of benchmark emissions, and allowing for ETS purchases as in this study, the extra abatement potentials amount to 8% and 11% of the benchmark emissions in the ESR and the ETS-covered sector, respectively; see Table 5. A second indication is that we have simulated a 90% cut in domestic emissions with the SNOW model and find clearly prohibitive costs of going this close to a net-zero solution. The marginal abatement cost exceeds 20000 USD/tCO_2, while household consumption drops with as much as 30% from the benchmark in 2030, which stands out as politically infeasible.

Based on these indications, we have chosen the more realistic approach for the **NZDO** scenario of using the abatement options in the ESR and ETS-covered sectors identified by the Norwegian Environment Agency (2022a, b) and reflected in Table 5. We supplement these abatement potentials with identified carbon removal potentials. Their 2030 potentials and costs are added by an iteration procedure similar to how we include CCS technologies not represented in the model. Based on the assessments in Section 2.3, Table 5 sums up the marginal costs and potentials of the included nature-based and technology-based removal m1easures, respectively.

Table 6 shows that the total abatement cost in the **NZDO** scenario is 5850 mill. USD, which corresponds to more than a doubling of the cost of meeting national commitments in the **COMM** scenario. The extra abatement in the ESR and ETS-covered sectors, as well as some removal measures, help approaching the net-zero solution but are not able to eliminate all emissions. The remaining will, thus, have to be balanced by buying international credits. We assume the same credit mix as in the **NZCC** scenario, implying a price of credits of 30 USD/tCO_2 and a cost of 590 mill. USD. Even if both the analysed net-zero strategies, **NZCC** and **NZDO**, involve substantial purchases of international credits, the **NZDO** scenario have 70% higher costs, indicating that the extra domestic measures are expensive. Table 6 reports an increase in the simulated marginal abatement cost in the ESR-covered sector from 410 to 530 USD/tCO_2 and in the ETS-covered sector from 210 to 440 USD/tCO_2.

Table 6. Marginal (USD/tCO_2e) and total (mill. USD) abatement costs in the policy scenarios (COMM, NZCC, and NZDO)

	COMM		NZCC		NZDO	
	Marginal	**Total**	Marginal	**Total**	Marginal	**Total**
ESR-sector: abatement	410	1 170	410	1 170	530	1 900
ETS-sector: abatement	210	1 070	210	1 070	440	2 510
ETS-sector: purchases	210	500	210	500	210	500
LULUCF-sector: net removal	0	0	0	0	220	80
Technology-based net removal	0	0	0	0	240	350
Other international credits	0	0	30	680	30	590
SUM		**2 740**		**3 420**		**5 850**

Sensitivity analysis

We discuss uncertainty in a long-term perspective in Section 4. In the shorter 2030 perspective, a main uncertainty is associated with which strategy the government will choose to fulfil its commitments. We have allowed for the use of EU ETS allowance trading in our main cases, **COMM**, **NZCC**, and **NZDO**. In sensitivity simulations, we examine the impact of fulfilling the entire mitigation commitment within own borders, thus, refraining from buying ETS allowances. As explained in Section 2.1, this is a self-imposed ambition of the current government. The abatement cost results in these scenarios, **COMMX**, **NZCCX**, and **NZDOX**, are shown in Table 7 as deviations from the main scenarios, **COMM**, **NZCC**, and **NZDO**.

Table 7. Abatement costs when refraining from ETS allowance purchases; sensitivity scenarios as deviations from corresponding main scenarios (mill. USD)

	COMMX-COMM		NZCCX-NZCC		NZDOX-NZDO	
ESR-sector abatement	+	0	+	0	+	0
ETS-sector abatement	+	1 440	+	1 440	+	0
ETS-sector purchases	-	500	-	500	-	500
LULUCF-sector net removal	+	0	+	0	+	0
Technology-based net removal	+	0	+	0	+	0
Other international credits	+	0	+	0	+	80
SUM	**+**	**940**	+	**940**	-	**420**

Table 7 shows that the abatement cost in **COMMX** is 940 mill. USD, or 34%, higher than in **COMM** (shown in Table 6). While ETS allowance expenses are reduced to zero, the abatement in the ETS-covered sector will have to increase accordingly and causes more than a doubling of the marginal abatement cost in that sector. This inflated cost of abating more in the ETS-covered sector is also carried over to the **NZCCX** scenario.

Surprisingly, however, the **NZDOX** scenario renders 420 mill. USD, or 7%, less costly than **NZDO**, despite that significant parts of the mitigation commitment are moved home. The explanation is that, irrespective of how the commitments are met, the fulfilment of the net-zero goal in **NZDO** involves the realisation of all feasible abatement and removal measures domestically. In other words, domestic actions, including both abatement and removal, are eventually the same in **NZDOX** and **NZDO**. The only difference is that relatively expensive ETS allowances in **NZDO** are replaced by a similar amount of cheaper international carbon credits in **NZDOX**. This conclusion hinges on the precondition that even if Norway would be willing to carry out as much as possible domestically, there would, simply, not be many feasible abatement nor removal measures to take on towards 2030. If, on the other hand, the net-zero society were reachable with domestic measures, only, buying ETS allowances as well as other international carbon credits would be out of the question in the **NZDOX** scenario. Like in **COMMX**, domestic implementation would turn out more expensive than exploiting the ETS market.

The substitution of carbon credits for EU ETS allowances also hinges on two restrictions on using offsets: first, the EU ban on using international carbon credits to fulfil the fit-for-55 commitments and, second, the restriction on buying and cancelling EU ETS allowances as an offset strategy to reach net-zero emissions. Combined with the expectations that international carbon credits will be cheaper than EU allowances, costs will be saved by this swap.

4. The net-zero society towards 2050 – global conditions and Norwegian options

Norway's long-run goal is to become a `low-emission society´ by 2050. The Climate Change Act specifies the goal as limiting GHG emissions to a level 90-95% below that of 1990. Here we discuss what Norway's climate policy options towards 2050 will be and revisit the 2030 solutions simulated above in the light of prolonging the horizon until 2050.

This part of the analysis is qualitative. The model framework we use is not fit for a dynamic analysis. First, it solves only for one year and is calibrated to 2030, which is the target year for Norway's net-zero ambition. Second it does not include key dynamic mechanisms, for instance it lacks innovation systems that can quantify the timing and impacts of technological developments and biological systems that can quantify the timing and impacts of LULUCF measures.

4.1. External conditions towards 2050

In a 2050 perspective, the global conditions in which a small, open country like Norway will need to choose its climate strategy, will certainly change considerably. The longer the time horizon, the larger the uncertainty. Decisions will have to be made without being able to influence these conditions to any significant extent. As a background for our discussion, we choose a global scenario meant to represent typical middle-case scenarios developed in the literature; see, e.g., UNEP (2023), IPCC (2023), IEA (2022) and the updated Shared Socioeconomic Pathways (Iconics, 2023).

The most decisive factor is the implementation of climate policies in the rest of the world. The 2030 analysis assumes that the current NDCs are met by all Paris Agreement signatories. The Paris Agreement also commits the partners to regularly strengthen their voluntary NDCs (the *ratchet mechanism)*. There are reasons to believe that the EU with its Green Deal plan[19] will have a relatively determined progress towards ambitious 2050 goals, even if there surely are social and political challenges, given the latest geopolitical developments and increasing abatement costs that have to be paid by the member-state inhabitants. The EU already has key climate policy plans beyond 2030 in place. A binding EU target to reach net-zero GHG emissions by 2050 was adopted and included in the European Climate Law already in 2021. In a middle-case scenario, we also assume that several other OECD countries will pursue the fulfilment of their 2050 net-zero pledges, in accordance with, e.g., UNEP (2023). However, as is evident from the global stocktake in Dubai in 2023, limiting global

[19] See https://www.consilium.europa.eu/en/policies/green-deal/.

warming to well below 2 °C would require that the pace of mitigation is forced considerably for the world as a whole. Slow and complex international negotiations lie ahead, and we assume a global setting for Norway's 2050 strategy where the OECD countries more or less will comply, while the rest of the world will lag seriously behind.

The sketched middle-case scenario is consistent with the following implications for Norway:

- Norway will have access to new climate-friendly and sustainable technological solutions originating from a moderate pace of research and development taking place abroad, primarily in the Global North.
- Diffusion of technologies to the Global South also takes place but at a slower pace and only to the extent that it is paid for by the Global North.
- Commodity prices mirror international climate policies, rendering consumer prices of fossil fuels and emission-intensive goods and services relatively high and producer prices relatively low.
- Natural resources like energy sources, minerals, metals, and land increasingly come under pressure because of economic growth, increased demand for inputs to green industries and technological investments, and increased demand for nature-based carbon removal.
- Marginal abatement costs, which differ considerably across industries, countries, and measures today, will slowly converge, particularly in the Global North.
- Some progress will be attained in the development of global climate institutions, including more specified international standards, definitions, and accounting rules.
- Global warming increases and stabilises at about 3 °C in the long run. [20]

4.2. Revisiting the 2030 analysis to align mid-term efforts with the 2050 goal

In a scenario towards mid-century with moderate global climate mitigation efforts and significant global warming, as described above, we take a critical second look at the mitigation strategy of Norway onwards. Three main issues discussed below are:

A. How will the international development towards 2050 affect Norway's options and willingness to choose a domestic mitigation strategy versus one that allows for cross-border flexibility?

[20] This is based on the UNEP (2023) scenarios where unconditional NDCs are fulfilled by 2030 and net-zero pledges are fulfilled by some countries by mid-century (using the report's "strict criteria").

B. Are there measures and strategies in the 2030 analysis that should be moderated or left out when assuming a 2050 perspective?

C. Are actions with a view to 2050 that should be initiated already today, omitted from the plans and implementations in the 2030 analysis?

A. Domestic strategy versus using cross-border flexibility

The Norwegian 2050 target of 90-95% reduction from the 1990 emissions level does not specify whether this concerns domestic emissions, only, or also allows for cross-border flexibility. The 2030 analysis substantiates that it is far-fetched to approach a low-emission society, let alone a net-zero society, by means of domestic measures, alone. Norway will have to resort to buying credits from abroad. To what extent a domestic mitigation strategy is feasible and attractive by 2050 will depend on the cost and other barriers involved relative to international trading of allowances and credits. The abatement cost of a domestic strategy will, *inter alia*, depend on how external drivers affect the industrial pattern of Norway through changes in comparative advantages. Increased profitability within GHG-intensive productions will, *ceteris paribus*, hamper abatement and vice versa.

One likely feature of a mid-case scenario as sketched above, is that Norway's *petroleum* production, which today is the largest emitter, can be expected to fall significantly along with declining resources and demand (Norwegian Offshore Directorate 2022; IEA 2022). When it comes to other changes driven by international conditions in the industrial pattern and associated emissions, these will largely hinge on the collaborative atmosphere across countries and regions and are difficult to foresee. A related question is how profitability of R&D and innovation activities will be affected by international comparative advantages and politics. We come back to possible Norwegian green innovation strategies below. In a mid-case scenario for the next decades, it seems likely to assume that European countries will continue to be close trading partners and political allies. Coordinating the green transition with that of the EU will, thus, be a realistic option.

In addition to the impacts of exogenous drivers on Norway's comparative advantages, the attractiveness of a domestic vs. an internationally flexible strategy will depend on the costs of abatement abroad. Relative to the EU, our 2030 analysis shows that the marginal abatement costs are likely to be higher in Norway for mitigating ETS-covered, ESR-covered and LULUCF emissions. The EU Green Deal documents express a favourable attitude towards internal flexibility. Access to EU flexibility mechanisms is one argument for continuing the climate policy collaboration with the EU. However, Norwegian and EU marginal abatement costs will probably converge towards 2050, and arbitrage possibilities will diminish over time. Even in this situation, EU collaboration appears as an attractive strategy for Norway, not least since a binding and stable international agreement with a forerunner like the EU will make the climate targets more reliable. This is crucial for incentivising domestic abatement measures with long planning horizons and lifetimes. Coordinated climate policies across countries will also reduce the risk of loss of industry competitiveness and carbon leakages to regions with less ambitious climate policies.

When it comes to international carbon credit markets as the Article 6 instruments, the middle-case global 2050 scenario we have sketched implies a gradual standardisation of accounting and reporting rules and improvement of the incentives for actual and permanent emission reductions in countries of the Global South. We cannot exclude the possibility that the EU continues its ban on Article 6 options towards 2050. However, given that the Article 6 instruments and institutions gradually improve, we can expect more confidence in international carbon credits as a means of facilitating abatement in countries with less capacities of their own. If the EU decides to approve the use of these mechanisms, the demand for carbon credits can be expected to increase. Over time hopefully also the quality of the carbon credits will increase. So will their prices. It is not unlikely in a mid-case scenario, however, that by 2050 their prices – even per real and permanent emissions reduction – will still be lower than the marginal cost of Norwegian and European abatement.

To sum up, in the 2050 scenario we consider close collaboration with the EU, and use of the flexibility within EU legislation, as a beneficial strategy for Norway. We also see few reasons for excluding the use of international carbon credits (Article 6), *ex ante*. The relative emphasis on domestic vs. cross-border abatement should be based on cost-effectiveness considerations.

B. Measures and strategies in the 2030 analysis that should be moderated

Biofuel blending mandates as abatement options call for careful considerations in terms of aligning 2030 and 2050 policies. At present, such mandates are extensively used in Norwegian transportation and are mainly dependent on imported resources. In 2023, the biofuel-share for road transportation was 17% and it is assessed that it can technically be increased to 30% by 2030 (Norwegian Environment Agency 2022a). In our computations, biofuel blending in transportation constitutes one of the endogenous abatement solutions that substitute for fossil fuels. While biofuels are regarded as interesting alternatives in the short run, their abatement potential is restricted because they are blended with fossil fuels, prices are high and land areas under pressure both domestically and internationally.

The large-scale electrification of the *petroleum* industry resulting from the 2030 analysis, is another time alignment issue. Land-based hydro and wind power is intended to replace natural gas as the main energy source in *petroleum* extraction and *refining*. In the model analysis, 10% of the abatement in 2030 was related to the *petroleum* industry, and in the sensitivity case where no allowances were purchased from the EU ETS, the electrification in *petroleum* contributed to a 14% GHG emissions reduction in Norway. This *electricity* use from the grid implies that less will be available for the green transition in other domestic industries and for renewable *electricity* export to other European countries. This leads to higher *electricity* prices and distributional concerns. The expensive electrification of the *petroleum* industry is not expected to yield emissions cuts in the long term since fossil fuel extraction will be phased out due to diminishing resources and reduced producer prices (Norwegian Offshore Directorate, 2022). The state and other *electricity* consumers than the *petroleum* companies will bear a large share of the costs due to considerable public investments in grids.

Several obvious examples of measures with potentially conflicting impacts on the 2030 and 2050 goals appear in the LULUCF sector. Reduced logging can for instance yield an immediate carbon removal effect. However, the subsequent accumulation of mature and old forest in the longer run will reduce long-term carbon removal. In the 2050 perspective, therefore, reduced logging should be left out despite some removal potential in the 2030 perspective.[21]

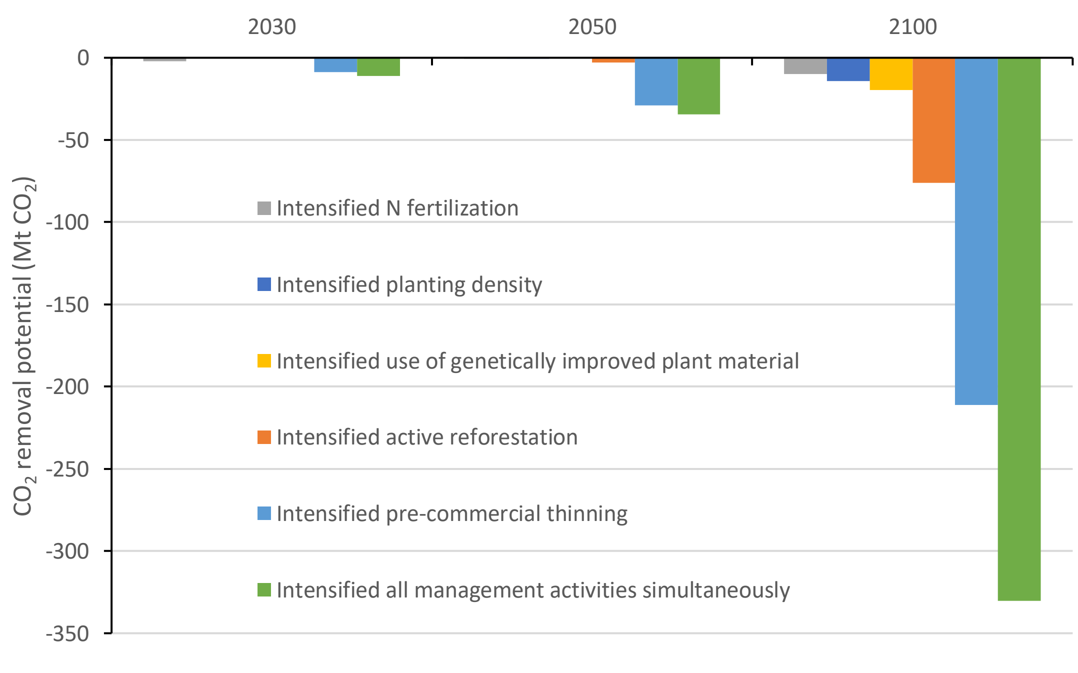
If rapid abatement is required, as in the 2030 simulations, deployment of existing technologies can be necessary instead of waiting for new and more effective solutions to be introduced in the global markets. This is reflected in the 2030 analysis, where most of the abatement taking place results from deploying existing low-emission solutions. This can cause a lock-in for several decades and delay investments in improved technologies fit for fulfilling long-run targets. A related issue is that it is tempting for governments to support deployment of existing climate-friendly technologies even if the economic arguments for this are generally weaker than for developing new technologies. Policies to meet short-run emission targets would typically imply too much technology deployment and too little innovation when seen in a 2050 perspective.

[21] Recall, however, that despite some potential, the 2030 analysis did not include this measure because of scarce data on costs and potentials.

C. Actions omitted in the 2030 analysis that should have been initiated

While a relatively small potential of net carbon removal through improved forest management was identified by 2030 due to the biological inertia of forests, Sevillano et al. (2025) demonstrate that intensifying forestry practices in Norway could enhance CO_2 removals by 2100, offsetting over six times Norway's 2022 GHG emissions. They recommend prioritising pre-commercial thinning and active reforestation after felling, followed by genetic improvement, planting density, and fertilization as key climate mitigation measures (fig 4). Assuming a long-term perspective will also reduce marginal cost. Management improvements should, in other words, be initiated in a larger scale than the 2030 analysis indicates. For afforestation, the argumentation is rather similar. Such measures were excluded from the 2030 analysis due to no – or even negative – removal impact, however, has the potential of increasing CO_2-removal significantly in the longer run (Bright et al. 2020). Carbon sequestration in HWP is another cost-effective way of increasing uptake beyond 2030, which we assessed to have negligible impact in the short run, as large investments in new plants and value chains would be necessary.

Figure 4. **CO_2 removal potential (Mt CO_2) for selected forest management activities 2030 – 2100**



Source: Sevillano et al. (2025)

The 2030 analysis reflects a significant increase in the demand for *electricity* that is met by increased supply of renewable hydro, solar, and wind power. Over the next decades, forecasts indicate the need for an even faster capacity-building within intermittent and balancing, non-intermittent power, power transmission from neighbouring countries, and energy efficiency improvement (Ministry of

Oil and Energy 2023). Thus, with a post 2030 horizon in mind, investments today should be both larger and more correlated.

The 2030 analysis does not take into account innovation policies and the impact of climate policies on technological development. When the time perspective is limited to 2030, this is not an important omission. When extending the time horizon to 2050 and increasing the domestic mitigation ambition, further improvements of the efficiency and robustness of climate-friendly technologies will be essential. Innovation processes will take time and need to start today under considerable risk. Where to expect breakthroughs and what policy incentives to introduce are challenging issues for a small economy that will need to make a selection. Norwegian know-how and resources can be relevant within different segments of research and development, including offshore floating wind turbines, energy-efficient equipment, green shipping, and hydrogen.

A priority area for domestic innovation is CCS, which is assumed to come into use in moderate scale already in the 2030 policy scenarios, but at high abatement cost. A prerequisite for wider use is to reduce costs, both in Norway and abroad. It seems that CCS could be a mitigation technology with comparative advantages for Norway given its long history of full-scale CCS-projects in the *petroleum* industry, the experiences with the Mongstad CO_2 capture test centre since 2012, along with the new ‘Langskip’ CCS project. `Langskip' includes full-scale CO_2 capture at two Norwegian industry sites, new infrastructure for CO_2 transportation and storage and, last but not least, considerable storage capacity for CO_2 under the North Sea seabed.[22] Technological development of CCS solutions in Norway could also form a basis for initiatives within carbon removal technologies like BECCS and DACCS. Moreover, hydrogen production from natural gas can emissions-free with CCS (blue hydrogen).

[22]See https://ccsnorway.com/the-project.

5. Concluding remarks

This net-zero analysis for 2030 is based on an interdisciplinary and broad quantitative approach in order to consider and integrate many simultaneous policy measures and capture interactions across measures, economic agents, and economic resources. The analysis investigates the balancing of domestic and cross-border options within a common framework, facilitated by a hybrid approach where model simulations are integrated with external quantitative bottom-up information.

It also explores the trade-off between a medium and long-term perspective on climate policies. The conclusions from the discussions in B. and C. above are summed up in Table 8, first and second column, respectively. This part of the analysis is qualitative, as the model framework is not fit for a dynamic analysis. First, it solves only for one year and is calibrated to 2030, which is the target year for Norway's net-zero ambition. Second it does not include key dynamic mechanisms, for instance innovation systems needed for quantifying technological development and biological systems needed for the timing of LULUCF measures.

Table 8. Measures with horizon-dependent mitigation potentials

Measures for mainly realising medium-term (2030) potential	Measures for mainly realising long-term (2050) potential
- Biofuel blending - Electrification of the *petroleum* sector - Reduced logging - Deployment of existing technologies	- Forest management improvements - Afforestation - Carbon storage in wood products - Investing in renewable power and transmission - Investing in innovation and R&D

Our question in the title: "*Norway's net-zero emissions target for 2030 - too ambitious to be true?"* can be answered by both *"yes"* and *"no"*. It is clearly too ambitious to be true if the ambition is to fulfil the goal with domestic measures, only. The international commitments of Norway by 2030 are almost emptying out the abatement potentials. Subsequently, Norway will have to use considerable amounts of carbon credits to reach net-zero emissions. The need for carbon credits increases if the government pursues its current ambition of refraining from purchasing EU ETS allowances to fulfil its commitments. This is a dilemma, as EU ETS allowances are acknowledged for having considerably higher environmental integrity than other international carbon credits. Moreover, this strategy would double the cost of fulfilling the ETS commitments.

Having said this, Article 6 of the Paris Agreement has a promising potential. By engaging in Article 6 projects, Norway could contribute to improving their environmental integrity. Experience can make the way for standardising and institutionalising the rules and monitoring procedures. Trading can facilitate true mitigation in countries with less capacities of their own, and technological and competence transfer can benefit the seller country. It is urgent to accelerate the low-emission transition pace of the Global South, which is a prerequisite for curbing global warming as decided in the Paris Agreement. Carbon credit purchase by countries like Norway is a way of funding this transition. The Article 6 negotiations so far has been hampered by disagreement about whether the seller or the buyer should be credited for the abatement. Combining development aid or other funding with carbon credit purchases will share the credit between the seller and the buyer. One conclusion in the 2030 perspective is, thus, that operating carefully and consciously in the international carbon credit markets may benefit both buyers and sellers as well as the climate of future generations. The same conclusion can be drawn when the perspective is prolonged: trade in allowances/carbon credits should not be restricted. Abatement projects in the Global South may be cheaper for decades ahead, but it can be expected that as time goes by and more countries pursue net-zero emissions, considerably fewer carbon credits will be for sale and their prices will approach marginal abatement costs in the Global North.

The discussion on challenges of aligning the 2030 abatement strategy with long-run targets towards 2050 emphasises the large uncertainty involved in long-run climate strategy planning. Most likely, several measures that look sensible when focussing on net-zero achievement by 2030 should be given lower priority if the actions today are seen in a 2050 perspective. These include electrification of oil and gas extraction, biofuel blending and some measures for carbon removal in forests. Reversely, we also identify actions that due to inertia should start today even if they only have small emissions impact in the first decade. The inertia is rooted in long investment periods or slow biological processes before return in terms of mitigation can be expected.

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