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The CO_2 compensation scheme in Norway

An analysis of the incentives and potential environmental effects of the 10 GWh threshold

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Acknowledgements

This thesis marks the end of my five years at NMBU. It has been a challenging process, and I am happy that I have been able to use what I have learned these past years to address something that I care about – economic policies that might have environmental impacts. This is the reason to my choice of studies and university, and I have never regretted my choice.

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I take full responsibility for potential unclarities or mistakes in this thesis.

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Jenny Alice Krogstad

Abstract

The EU Emission Trading System's goal is to put a price on carbon to internalize the external costs of emissions. In Europe, non-renewable resources still constitute a large share of the inputs in electricity production. The cost increase of utilizing non-renewables is thus transferred to the electricity prices. The CO_2 compensation scheme, or the indirect cost compensation regulation, is a voluntary scheme that countries can adopt to support carbon leakage exposed sectors to avoid carbon leakage due to climate policies. Norway is one of the countries who have decided to do so, and the payments are expected to surge within the coming years. The compensations are calculated based upon the production level or electricity consumption level and EUA prices, and to be eligible for compensation the electricity consumption must exceed 10 GWh per year. The thesis looks at the effects of this threshold on businesses' decision to increase electricity consumption to become eligible for compensation. By assessing the compensation's share of the cost increase linked to increased electricity consumption, I find that, for all but one eligible industry category analyzed, the compensation makes up between 16 % to 105 % of the cost increase under different EUA prices. The evidence shows that, in most approaches, the compensation scheme can be beneficial for Norwegian businesses moving up to the threshold, and that the compensation scheme might incentivize increased electricity consumption. I also discuss that the Norwegian electricity system, who is largely characterized by high shares of renewable electricity consumption, in combination with the compensation scheme might lead to unintended effects on competition and emissions across the European Economic Area.

Sammendrag

EUs kvotesystem har som mål å sette en pris på karbon for å internalisere de eksterne kostnadene knyttet til utslipp av klimagasser. I Europa utgjør fortsatt ikke-fornybare energikilder en stor del av innsatsfaktorene brukt i produksjon av elektrisitet. Dette gjør at kostnadene knyttet til bruken av slike ressurser smitter over på prisen for elektrisitet. CO_2 kompensasjonsordningen, eller reguleringen for kompensasjon av indirekte kostnader, er en frivillig ordning land kan velge å implementere for å støtte industrier som er særlig utsatt for karbonlekkasje. Norge er ett av landene som har valgt å gjøre dette, og utbetalingene er forventet å øke kraftig i takt med økningen av kvoteprisen i EU de neste årene. Kompensasjonen beregnes ut fra produksjonsnivå eller elektrisitetsbruk og prisen på kvoter, og for å kvalifisere til kompensasjon må elektrisitetsforbruket overskride 10 GWh per år. Denne oppgaven ser på hvilke effekter dette terskelnivået har på bedriftenes beslutning til å øke strømforbruket for å kvalifisere til kompensasjonsutbetalinger. Jeg finner at kompensasjonen utgjør mellom 16 % og 105 % av kostnadsøkningen under forskjellige kvotepriser for alle unntatt én industrigruppe. I de fleste scenarioene viser resultatene at kompensasjonsordningen kan være veldig fordelaktig for norske bedrifter, og at ordningen kan oppmuntre til økt elektrisitetsforbruk for å kvalifisere til kompensasjon. Jeg finner også at det norske strømmarkedet, som i stor grad karakteriseres av høy andel fornybar energi, kombinert med kompensasjonsordningen, kan ha utilsiktede konkurranse- og klimaeffekter i det europeiske økonomiske samarbeidsområdet.

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1. Introduction

The EU Emission Trading System has been an important policy measure to reduce CO_2 emissions in the EU, as well as serving as an inspiration to other parts of the world to increase their efforts in reducing their emissions. The intention of the system is that the tradable quotas should be reduced over the years, which will decrease the total emissions in the area and incentivize abatement and technological progress to decrease environmental effects further. In this scheme, the emission-intensive trade-exposed (EITE) sectors have been allocated free allowances to avoid carbon leakage. Carbon leakage occurs when firms relocate their activities from areas with more strict climate policies to areas with less strict policies, and thus avoiding emission reductions. This is particularly relevant for EITE industries, as they are more sensitive to increases in carbon prices.

To protect EITE industries and avoid carbon leakage, the EU has also implemented a voluntary rebate program compensating indirect emission costs. This thesis will look at the incentives provided to Norwegian EITE industries by the 10 GWh electricity consumption threshold in this program, hereby referred to as the compensation scheme. The application of the compensation scheme is voluntary for the member states, and the costs of the scheme accrue to the state that chooses to implement it. The compensation in Phase IV (2021-2030) will be based upon the electricity used or production level in each firm, the price for allowances in the ETS, an estimated emission intensity factor of electricity consumption, and a measure of aid intensity. The compensation scheme has been utilized in Norway, and the payments made by the government are significant. Given the expected increase in EUA prices, the payments are also expected to increase rapidly in Phase IV. Estimates made by the government and Refinitiv suggests that total payments in Phase IV will be in the range between 50 and 85 billion NOK (Miljødirektoratet, 2021b). This is a significant increase compared to the payments of 6,7 billion NOK in the previous period.

The compensation scheme and the design of the free allowances within the EU ETS is now under debate as the EU Green Deal has proposed a possibility of implementing carbon border adjustment mechanism (CBAM) to replace the previous arrangement. The suggested CBAM will initially only include direct emissions, and not indirect emissions through electricity usage. This means that the free allowances will be discontinued and replaced by CBAM, while the compensation scheme might be continued – at least initially. The issues that are raised in this thesis regarding the incentives provided by the compensation scheme will therefore continue to be relevant despite the changes in the EU ETS, as the compensations could still influence the financial, environmental, and competitive performance of the industries

This thesis aims at investigating the incentives provided by the CO_2 compensation scheme for Norwegian EITE industries by looking at the 10 GWh threshold – the electricity consumption level needed to be eligible for compensations. The analysis will be looking at the costs of increased electricity consumption and production capacity relative to the compensation payments. Data on production value and electricity consumption for industries by their NACE categories, EUA prices, electricity prices and compensation payments under different price scenarios is used in the analysis. This data is used to find the compensation's share of the cost increase under different scenarios and price structures. The thesis will discuss how the compensation might prevent the industries of reducing their emissions by disincentivizing investments in abatement efforts and incentivize increased electricity consumption through the payments that are being made.

The main research question to be answered is

How does the 10 GWh threshold in the CO_2 compensation scheme affect the incentives of EITE industries in Norway?

In addition to this, there are several sub research questions to be answered to address the main research question, namely

1. *Does the 10 GWh threshold affect the electricity consumption of Norwegian EITE industries?*
2. *Can the compensation scheme lead to increased electricity consumption and, thus, increased indirect emissions?*
3. *Given that Norway has an extraordinarily high share of renewable electricity and low electricity prices, are the industries being overcompensated given the carbon leakage risk and the small environmental impact of electricity consumption?*

Chapter 2 will provide the relevant background information and some literature review on the EU ETS, the energy market in Norway, and the compensation scheme in Norway and the EU.

In chapter 3 the relevant theory to understand how the energy market and electricity trade in Norway works, how the EU ETS works and affect the energy market in Norway, and how this is linked with the compensation scheme is presented. In chapter 4 the methodology and data will be presented, as well as the decided model. The results will be presented and discussed in chapter 5 and 6, before the conclusion in chapter 7.

2. Background

2.1 Brief history of energy-intensive industries

Norway has a long industrial history dating back to the times of the industrial revolution. The employment in the industrial sector, including mining operations, rapidly increased in the last half of the 1800s, peaking at almost 80 000 in 1890 (Hovland and Nordvik, 1997). The imports of machines exploded in the late 1800s to the 1910s, until the recession in the 1920s. Industrial production maintained an important position even after the two world wars. In the late 1960s, Norway became the largest aluminum producer in Europe, with the rapid development of hydropower after the second world war leading to the still present competitive advantage of cheap energy supply (Lange, 2005). This development also led to a sharp increase in other energy-intensive industries in the 50s and 60s, contributing to Norway having one of the world’s highest levels of electricity consumption per capita. This was largely made possible through financial instruments facilitated by the government, with an aim to promote “efficient and profitable businesses and expandable industries.” (Lange, 2005)

Today, the manufacturing industry employs about 25 000 people, with a value creation of around 1,5 million NOK per employee. This is higher than the average for Norwegian businesses, which is at approximately 1 million NOK per employee. (Prosess21, 2021). The turnover is about 200 billion NOK per year, with exports at around 168 billion NOK. The exports from the manufacturing industry in Norway accounts for about 18 % of total Norwegian exports, and the industry’s productivity is 50 % higher than the average for the rest of the Norwegian industries.

In 1990, Norway’s electricity system, as the second country in Europe, was liberalized through the Energy Act. This meant that electricity production and distribution was liberalized, whereas the transmission system retained its monopoly structure. In effect, market prices were established, and investments were based upon private efficiency and profitability assessments (NOU, 2019: 16). The characteristics of the Norwegian energy system has been an important facilitator in the industrial development of energy-intensive industries, with the abundance of cheap hydropower being one of the most important inputs ensuring a competitive advantage in the industries. Accounting for 32 % of total consumption in 2020, the industries are the largest electricity consumers in Norway. Of the total energy usage, electricity constituted 64 % in the same year, with aluminum production's dependency of electricity being one of the main drivers of the high electricity share (Energifakta Norge, 2021). Large electricity consumers, such as energy-intensive industries, usually operate with long-term contracts with the producers or through futures. Such contracts usually last for 8-15 years and helps ensuring availability and predictability regarding quantities and prices for the industries. Of the 40 TWh electricity the industries are consuming yearly, about 75 % is delivered through long-term contracts (Prosess21, 2020). The energy-intensive industries in Norway, therefore, have excellent conditions to be and remain competitive, even throughout the process of Europe reaching climate-neutrality by 2050.

The emissions from manufacturing industries in Norway were at 11,5 tonnes CO_2e in 2019, which is about 23 % of total emissions in Norway. This is 41 % lower than in 1990, despite very limited reductions in the 2009-2019 period. The relatively low carbon intensity of production in Norway is due to the use of renewable energy. The manufacturing industries consume about 1/3 of the renewable energy produced. The value creation in the industry has increased with 56 % since 2005. (Prosess21, 2021)

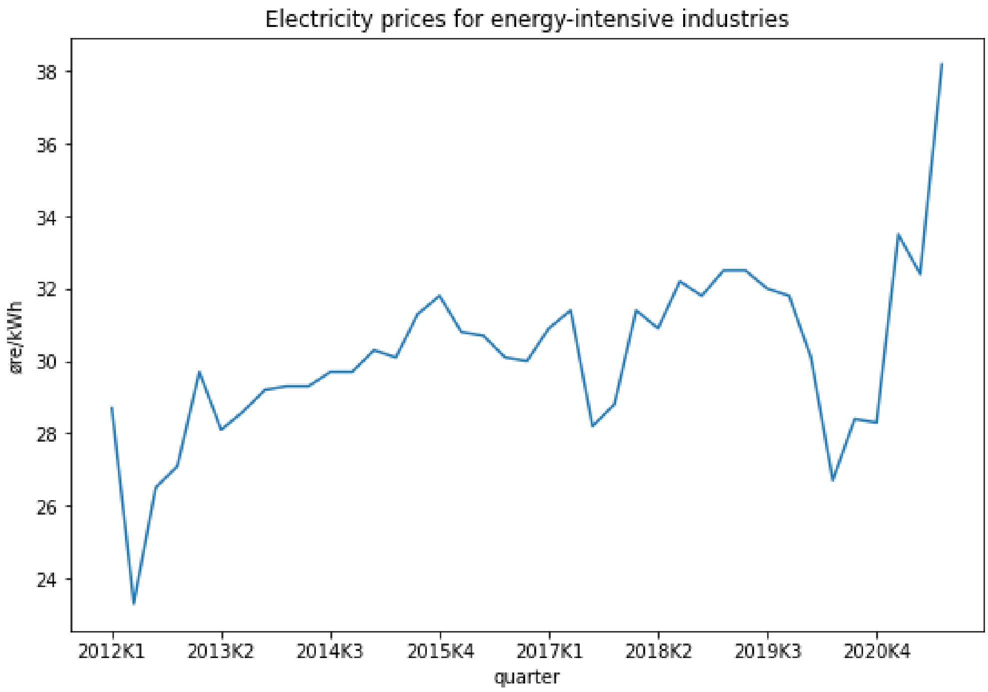

Figure 1: Electricity prices for EITE industries in Norway.

2.2 Norway's energy system

Hydropower has been an important energy source throughout history in Norway. The topography in the country with an abundance of rivers and waterfalls has made power production easily available, causing Norway to have been almost exclusively using renewable energy. In 2020, the hydropower plants produced 136,4 TWh, making Norway the seventh largest hydropower producer in the world (Olje- og Energidepartementet, 2021). Across the country, there are over 1681 functioning power plants, and Norway holds over 50 % of the reservoirs in Europe with more than 1000 water reservoirs.

Norway is a part of the Nord Pool Spot exchange together with Sweden, Denmark, Finland, and the Baltics, licensed by the Norwegian Water Resources and Energy Directorate (NVE) and the Ministry of Petroleum and Energy (OED). This is, therefore, a regional market, in which the system price is decided (Nord Pool, 2022). In Norway there are five separate bidding areas, which means that the prices within the country can differ. Historically, there has been some trade between mainly Sweden and Norway, but in the later years, with more transmission cables, trade with more European countries has been facilitated. These countries have a larger fraction of non-renewable primary energy sources used in power production than Norway. If there was full transmission capacity and "endless" trade possibilities, there would be only one price both in the regional market and between the bidding areas. However, this is not the case, and this constraint and the following price difference is often referred to as congestion rents, or "bottleneck" rents.

In Norway, the largest fraction of the energy mix stems from hydropower. In fact, hydropower has made up over or about 95 % of the total energy supply in all years (Breitschopf, 2016). This means that in and of itself, the Norwegian energy price should not be very affected by the EUA price, since there is little to no emissions linked to the energy production. However, with the interconnection to mainland Europe and other countries with a larger share of non-renewable primary energy sources, there will be a price convergence due to trade, causing the EUA price to affect the Norwegian price.

Why and how should Norway, who predominantly produce hydropower, compensate its industries for emission costs when hydropower per definition does not include carbon pricing in its productions? The compensation scheme is intended for indirect emission costs, which relates to the importing of energy and the carbon pricing following in the country of origin of said electricity. When importing from countries who use non-renewables in electricity production there will be CO_2 linked to electricity consumed in Norway. NVE (2022) estimates that the emission intensity of electricity consumed in Norway was 17, 8 and 11 gCO_2e/kWh in 2019, 2020 and 2021 respectively. Trade causes the price effect of the CO_2 cost entering the Norwegian market, which in turn, as goes the argument, harms Norwegian industries. Brenna (2021) reports estimates conducted by Thema, suggesting that a 1 € increase in the EUA price leads to an increase of Norwegian electricity prices by 0,3-0,4 €/MWh. The EU assumes a higher price effect through their estimated carbon factor. I get back to this in chapter 2.5. The development of EUA prices, coal prices and electricity prices in Europe is shown in Figure 2 below.

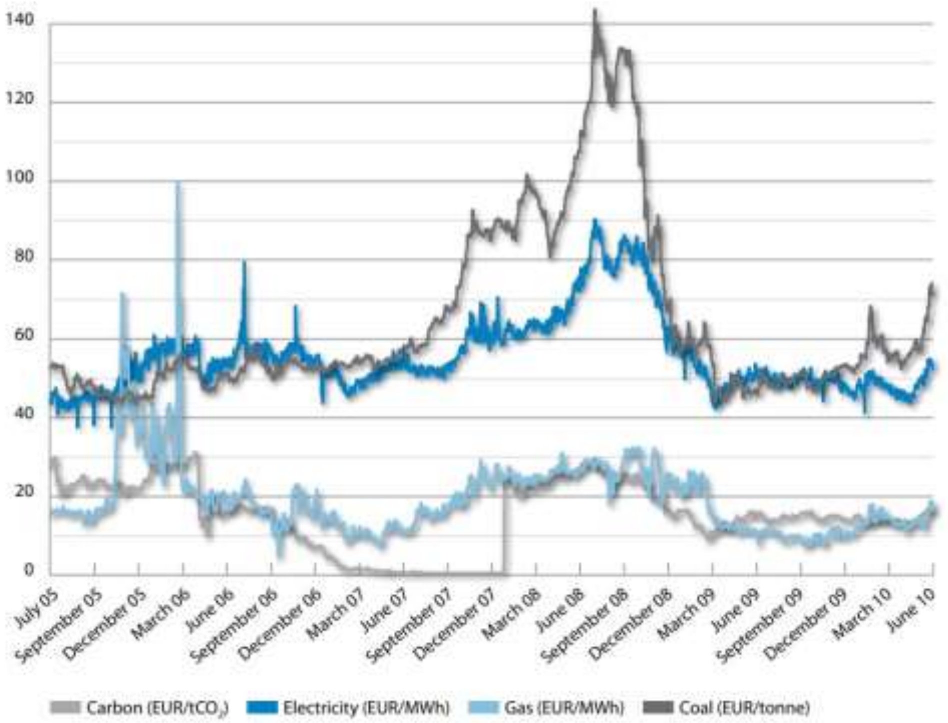

Figure 2: Carbon-, electricity-, gas-, and coal prices in Europe 2005 to 2010. Source: OECD NEA (2011)

2.3 Global climate policies

Since the 1990s, there has been an increased focus on climate change and climate policies worldwide. The United Nations Brundtland Commission and the Brundtland Commission Report which was published in 1987 (UN, 2022) has in many cases been seen as the start of the era of sustainability and what contributed to highlighting its importance globally. Since then, there has been more public focus on climate change. International agreements have been initiated and enacted, at differing successfulness, such as the Kyoto protocol of 1997 and the

Paris Agreement of 2015, both of which has aimed at developing a framework in which countries should work towards limiting their environmental impacts and emissions (EC, 2022a). The Paris Agreement of 2015 was the first global, legally binding international treaty on climate change, with the goal of limiting global warming to 1,5-2 degrees (UN, 2022). One important difference from previous agreements is that countries decide their own contributions, known as NDCs (Nationally Determined Contributions). The EU and its member states have committed to reducing domestic emissions by at least 55 % by 2030 compared to 1990 levels (European Union, 2020). Norway's updated NDC state that they are to reduce their emissions by at least 50-55 % (Climate Change Act, 2017). This goal is to be reached through cooperation in the EU ETS, and in joint fulfillment with the EU. The EU has been at the forefront globally when it comes to climate policies and emission reductions, with the EU ETS being "the world's first and largest regional cap-and-trade system for greenhouse gas emissions" (Martin et al., 2014b). Norway is a part of the EU ETS framework by law through the EEA agreement. The national goals of Norway and the cooperation with the EU are established by law in the Norwegian Climate Change Act which came into force in 2018 (Climate Change Act, 2017).

2.4 The EU ETS

The EU ETS is an emission trading scheme which was initiated in 2003 and came into effect from 2005 (EC, 2022b). It is a tradable permit system in which firms can trade emission permits among themselves according to their relative abatement costs. It covers the emissions of CO_2, N_2O and PFCs from more than 10 000 power production, manufacturing industries and airlines, with a total coverage of about 40 % of total European GHG emissions (Marcantonini et al., 2017; EC, 2022b). It is a market-oriented demand-side policy, in which the price of emissions is determined in the permit market. This causes a cost-efficient solution in which agents with lower abatement costs can sell permits to higher abatement cost agents, causing the least-cost abator to abate more. Allowances are either auctioned or allocated free of charge. Auctioning causes the firms having to internalize the costs of carbon, which internalizes the emission costs and affect the production costs. The free allocation also leads to internalizing, but with different effects on the production costs as the EUAs work as an implicit production subsidy. 50 % of the auctioning revenues are to be used for climate and energy purposes. In 2013-2019, that share was 78 % in the EU (EC, 2022b). The "main rule" is that EUAs are to be acquired through auctioning. In 2013, the auctioning share was at about 40 % in Norway, having increased since (Miljødirektoratet, 2019). Manufacturing industries still receive a large share of free allowances, 80 % in 2013, which were to be reduced by 30 % by 2020 (Miljødirektoratet, 2019). Industries deemed at significant leakage risk can still receive allowances up to 100%. The EU ETS has consisted of three Phases so far, now moving into Phase IV (2021-2030). In each of the Phases there has been differing ambitions to emission reduction targets, and the first two Phases were largely defined by low allowance prices (EUA prices) and reductions not being at the level at which it was intended. There were too many permits in circulation, which caused the costs of emission to become too low compared to the EUs reduction targets. This was further enhanced with the financial crisis of 2008/09, in which the demand for permits was severely reduced due to the overall reduction in demand in the economy, which further depreciated the EUA prices. The development of the EUA price from 2008 to today can be seen in Figure 3 below.

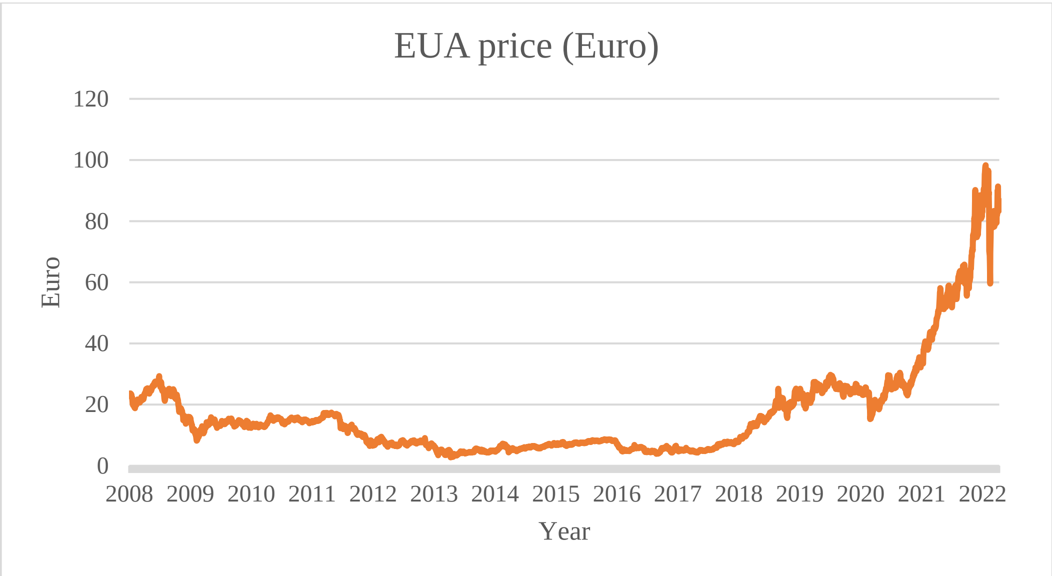

Figure 3: EUA price from 2008 to today. Data source: Energi og Klima (2022)

This has caused the scheme to undergo many changes and alterations throughout the years, with the latest ones being the application of the Market Stability Reserve (MSR) and now the Green Deal. The MSR was implemented to avoid the banked allowances pushing prices down, as there has been a significant link between the surplus in the EU ETS and the EUA prices. This limits the supply of allowances as the banked allowances will be deleted when reaching a certain level. Since then, the EUA prices have increased rapidly, and the price reached almost 97 € February 8th, 2022 (Ember, 2022).

The changes it has undergone have mainly been focused on its long-term goals but which GHGs and sectors that are included have also changes. Today, the GHGs included, with examples of productions, are shown in TABLE XX. For a full list of activities and GHGs in Norwegian industries that are covered by the EU ETS, see Appendix A (in Norwegian).

GHG	*Sector/production*
CO_2	- electricity and heat generation - energy-intensive industry sectors including oil refineries, steel works and production of iron, aluminum, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals, - commercial aviation within the EEA
N_2O	Production of nitric acid, adipic and glyoxylic acids and glyoxal
PFCs	Production of aluminum

Table 1 GHGs and activites in Norwegian industries.
Source: Miljødirektoratet (2022)

Within the covered activities, there are some exemptions. For instance, in some sectors there is not a requirement to participate unless the installation is above a certain size, some small installation can be exempt if the domestic regulator have other instruments or measures that reduces emissions by an equivalent amount, and for the aviation sector the ETS only applies to flights between airports within the EEA. (EC, 2022b)

The EU ETS Directive (Directive 2003/87/EC) is the legislative framework in which the ETS is founded upon. According to Article 10a §11, the allocation of free allowances was to be reduced throughout the Phase III, leading to a free allocation rate of 30 % in 2020. In carbon leakage exposed sectors, the share of allowances allocated free of charge is still high. The definition of which sectors are exposed to carbon leakage is defined by Article 10b §1, as

"(..) the ratio between the total value of exports to third countries plus the value of imports from third countries and the total market size for the European Economic Area (annual turnover plus total imports from third countries), by their emission intensity, measured in kgCO_2, divided by their gross value added (in euros), exceeds 0,2 (..)"

Such sectors are to be allocated free allowances up until 2030 at 100% of the quantity that is determined in Article 10a. Throughout the Directive, there are multiple exemptions and notes of caution relating to carbon leakage and the protection of energy-intensive sectors. The effects of the exemptions can be seen in Figure 4 below, showing that the emissions reductions in industrial sectors have been close to absent during Phase III relative to the power sector, whereas reductions in the latter have been significant.

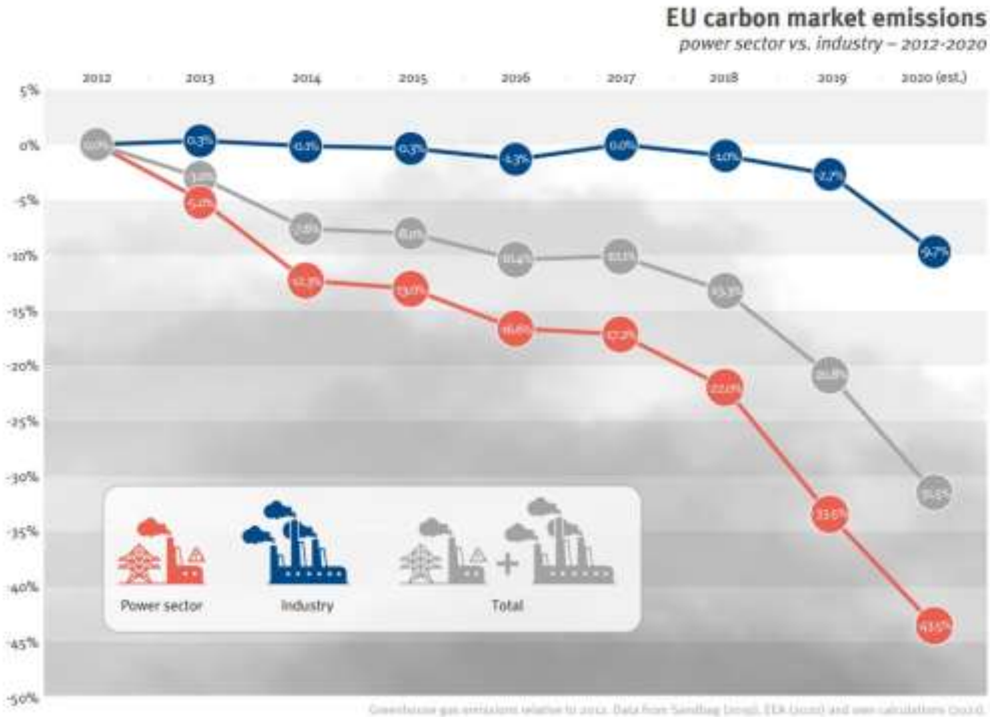

Figure 4: CO_2 emissions in ETS covered sectors. Source: Carbon Market Watch (2021)

2.5 The compensation scheme

The argument of the exemptions in the EU ETS is that the ETS can reduce the competitiveness of such industries through increased costs, which in turn can lead to carbon leakage (de Bruyn et al., 2020). This is due to such industries also being trade-exposed, meaning that the businesses have a high elasticity in demand, which leads to reduced (or increased) market shares if there are price differences faced by consumers. By increasing the costs of inputs through carbon pricing, this can harm the industries' competitiveness, causing them to move their operation to areas with less stringent climate policies. This can increase global emissions. To avoid this, in addition to the allocation of free allowances, the EU has enabled member states to implement a CO_2 compensation scheme in which EITE industries can receive compensations for their indirect costs. Indirect costs are costs due to carbon pricing on non-renewables used in electricity production, meaning that there are carbon costs and indirect emissions linked to the electricity consumption. Electricity prices increase with increased EUA prices as non-renewable resources are being used in electricity production within the EU. Norway is one of the relatively few states that has implemented this compensation scheme.

In Article 10a §6 in the EU ETS Directive (Directive 2003/87/EC), the CO_2 compensation scheme has its legislative foundation, stating that carbon leakage exposed sectors are affected by “significant indirect costs” that are passed on in electricity prices. The paragraph also states that the financial measures applied to such industries are to be in accordance with State aid rules and should not distort competition in the internal market. The regulation states that payments should not exceed 25% of the auction revenues for allowances, but with possibilities of exceptions. §6 also defines how the compensation is to be calculated, including that the level of protection should be based upon benchmarks for the indirect emissions of CO_2 per unit of production. These benchmarks should be calculated for each sector as “the product of the electricity consumption per unit of production corresponding to the most efficient available technologies and of the CO_2 emissions of the relevant European electricity production mix.” In Norway, these benchmarks are presented in the Regulation on CO_2-compensation for the industry (Forskrift om CO_2 -kompensasjon for industrien, 2013). (Directive 2003/87/EC)

While the allocation of free allowances has been regulated by the EU centrally, the application of the compensation scheme is voluntary, and the costs of the scheme accrue to the state that chooses to implement it. The compensation scheme has been utilized in Norway, with significant payments made by the government. In the period 2013-2020, the total payments added up to 6.7 billion NOK and were made to businesses who fulfilled certain criteria. The criteria are that they must produce within a NACE category that is eligible, which is decided by the EU, and the electricity consumption must exceed 10 GWh. They must also conduct an energy mapping and implement one out of three requirements. One of the requirements states that the business must ensure that at least 30 % of the electricity consumption stems from renewable energy sources, meaning that all Norwegian businesses will fulfill this requirement. In the coming period, the compensation is proportional to production level and the EUA price, which is multiplied with an energy efficiency standard, aid intensity and the carbon factor. The three latter are decided by the EU, with the aid intensity being stated as a maximum allowed level. Norway has decided to opt for the maximum level at 0,75 for the entire 2021-2030 period. For productions without efficiency standards, the compensation is proportional to electricity use and the EUA price, multiplied with an alternative standard, aid intensity and the carbon factor. The alternative standard is not decided yet, but the carbon factor is 0,53 from 2021-2025. The EUA price is therefore crucial in the calculation of compensations. Given the expected increase, and the increase that has been seen in Phase III, in EUA prices, the payments are also expected to increase rapidly in the coming period of 2021-2030. Estimates made by the government and Refinitiv suggests that total payments, under different scenarios, will be in the range between 50 and 85 billion NOK. This is a significant increase compared to the previous period, as shown in Figure 5 below. Those payments will be made to 50 to 60 Norwegian businesses, which means that there are a few industries that receive large payments by the government. The regulations also come with a set of EU recommendations. In 2020, the compensations in Norway added up to 232 % of the Norwegian auction revenues, which is much higher than the recommended amount (Miljødirektoratet, 2021b).

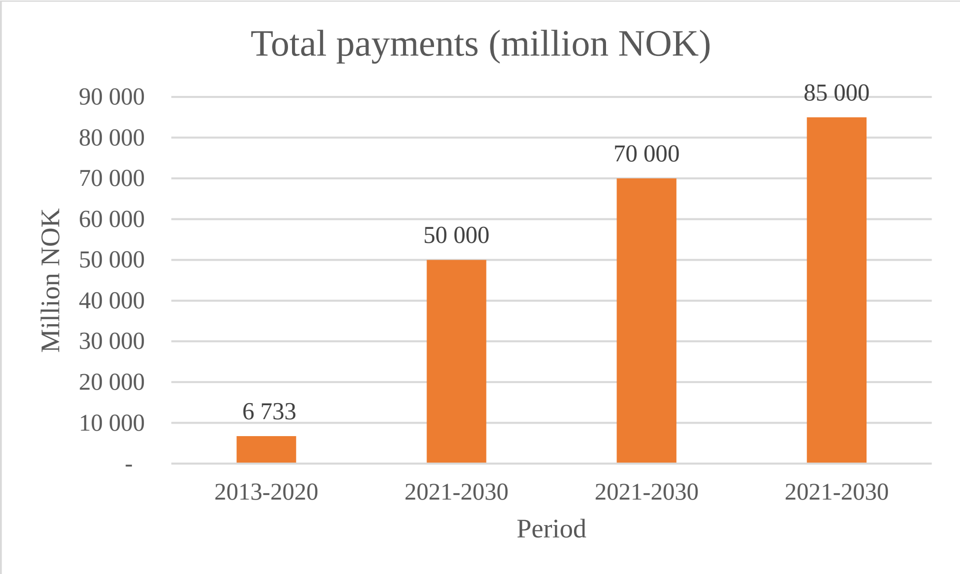

Figure 5: total compensation payments 2013-2020 vs. possible payments 2021-2030. Data source: Miljødirektoratet provided upon request and Miljødirektoratet (2021b)

Thema (2020) conducted an analysis of the compensation regime on behalf of the Norwegian Environment Agency, looking at whether the compensations contributed to reducing the risk of carbon leakage. By conducting interviews with many of the largest recipients of the payments, they were able to investigate what the industry themselves found to be important with regards to the compensation scheme. Among other things, they were able to point out that the low energy prices in Norway is and has been an important advantage for the industry. With the increasing energy prices through the increase of the EUA prices, they state, the CO_2 compensation is important to keep the competitive advantage linked to the low energy prices. The compensations have, in many cases, been used by the businesses when conducting investment analyses. The results show that the payments have been important in the decision to make further investments in Norway. This is largely linked to the reduction of the overall uncertainty of the investment due to the compensation scheme – despite uncertainties regarding the continuation of the regime. However, there is also some evidence of such investments being made in improvements and reinvestments rather than new investments. They find that the new investments to a larger extent are made in countries with lower energy prices and no carbon pricing regime. The authors point out that it is difficult to conclude whether these results would be different without the CO_2 compensations but conclude that it is likely that the compensation scheme has contributed to counteracting carbon leakage. (Thema, 2020)

The Norwegian Regulation was valid from 2013 to 2020, i.e., during Phase III of the EU ETS. A new Regulation for the 2021 to 2030 period has not yet been amended. The results from the hearings and the suggested new Regulation must be approved by EFTA Surveillance Authority (ESA) before coming into motion, most likely during the fall of 2022.

2.6 EU Green Deal

The EU is continuously working towards reaching and enhancing its goals for emissions reductions, both short-term (55 % reductions by 2030) and longer-term (net-zero by 2050). To do so, the EU Green Deal was presented in December 2019. The objective of the Deal being that the EU is to become the first climate neutral continent by 2050, which also includes the energy-intensive industries (de Bruyn et al., 2020). To reach this goal, it must tackle obstacles within many sectors – including the energy sector. In the EU, energy use alone accounted for 75 % of total man-made emissions in the area in 2020 (Eurostat, 2021). Electricity is one of the main inputs of the energy- and emission-intensive industries, meaning that there will have to be some changes in the terms for these industries as the EU goals become more ambitious.

The EU Commission has suggested to discontinue the allocation of free allowances to EITE industries and instead replace the regime with a Carbon Border Adjustment Mechanism (CBAM). The goal is to gradually reduce the free allowances starting from 2026, and the potential discontinuation of the compensation scheme depending on the ambition level and what type of emissions are to be included over time. (Commission proposal 2021/564). The reasoning behind both the allocation rules and the compensation scheme was to reduce the risk of carbon leakage and thus keep EITE industries covered by the EU ETS competitive on the international market.

2.7 Previous studies on the effects of the EU ETS on EITE industries

There has been conducted multiple studies looking at the environmental effects of the EU ETS and how it has changed firms' behaviors, investment decisions and possible improvements of the system. Ferrara and Giua (2020) has, for instance, looked at the effects of the EU ETS on firms' outcomes. The aim of the report is to investigate how the aid affect firms' economic outcomes and whether it leads to competition distortion. Carbon leakage in the medium-long term can discourage investments and reinvestments within the firms, and overcompensation can distort the markets because of the subsidizing effect of the compensation. When using difference-in-difference estimation looking at aluminum firms across Europe who receive compensations, and similar firms that do not, they find that the aid has not had significant effects on the average relative competitiveness of the beneficiaries. They do find evidence suggesting that the recipients perform worse than firms operating in countries which has not adopted the scheme when looking at certain factors. This reduction in performance could lead the firms receiving compensation being at a higher risk of carbon leakage – which is the opposite of the intended effect. When only looking at the beneficiaries, there is evidence that higher compensation payments lead to better performance, suggesting the opposite – that it may have contributed to counter carbon leakage. However, there might be other factors that also come to play, such as systematic differences between the countries who have chosen to implement the scheme and those who has not. This portrays one of the key issues found in the literature of the effects of the EU ETS and support to EITE industries, namely that the results can vary a lot according to the choice of models and assumptions.

Martin et al. (2014b) uses a similar approach by looking at the level and value of free allowances to EITE industries under the EU ETS. Their results shows that the industries are being overcompensated given their carbon leakage risk. The authors also question the motivation of said policies, as it directly contradicts the polluter-pays principle and the given framework of the EU ETS. They found that the relocation risk differed widely between different eligible industries, which further emphasized their notion of how the exemption of entire industries might be very inefficient. The reduction in the risk of carbon leakage could have been obtained with "just a fraction of the amount of permits that will be handed out for free." (Martin et al., 2014b, p. 2485) This points in the direction that there is already an inefficiency factor within the EU ETS for EITE industries, which might be further enhanced by the favorable compensation scheme for indirect emissions. A better way of allocating allowances, the authors point to, would be to allocate to the firms where the marginal reduction of relocation risk is largest, thus maximizing the welfare effects and minimize the number of the free allowances. This has not previously been discussed as a possible solution in the allocation debate.

Carbon leakage is a concept that has been investigated through different approaches. Some estimates carbon leakage rates and leakage risks that are necessary to implement efficient policies (Wingender and Misch, 2021; Martin et al., 2014b), other studies look at the potential effects of border carbon adjustment mechanisms (Larch and Wanner, 2017; Fischer and Fox, 2012), or the suggested CBAM in the EU (Zhong and Pei, 2021; Bellora and Fontagnè, 2021; Assous et al., 2021). Others focus on the overall effects on carbon leakage of the EU ETS and its design (Verde, 2020; Naegle and Zaklan, 2019; Marcantonini et al., 2017). The results vary from conclusions such as "leakage rates vary between countries" (Wingender and Misch, 2021) to finding no evidence that the EU ETS causes carbon leakage (Naegle and Zaklan, 2019), to concluding that there is no evidence of carbon leakage, but that there are some important limitations in the available data to make a "general conclusion." For instance, that data used is mostly from the first two Phases, and that the long-term effects on investment leakage or firm dynamics are not sufficiently explored (Verde, 2020). The free allocation of allowances has been estimated as overly generous by some studies, with evidence pointing towards overcompensation given the carbon leakage risk (Martin et al., 2014b). Studies have also found that there is no strong evidence for the EU ETS affecting the competitiveness of the regulated industries, in addition to free allowances most likely being allocated to installations who were not in risk of relocating and evidence of pass-through of carbon costs for industrial sectors (Marcantonini et al., 2017). The latter would indicate that the absence of free allocation would not harm the competitiveness in the industrial sector. Klemetsen et al. (2020) finds similar evidence indicating that Norwegian businesses, on average, will not be negatively affected if more allowances were auctioned. They also find evidence that emission intensities have not been affected by the EU ETS in all Phases, while there is a tendency of some emissions reductions.

With regards to the suggested CBAM, Bellora and Fontagné (2020) finds that, under a limited ambition level in the EU and under the assumption that no other country implements any climate policies, the effect of CBA on carbon leakage is limited. Even though the policy can reduce the sectoral leakages, the overall leakages are not reduced to a significant extent. They conclude that CBA will only reduce sectoral leakage to a significant extent if it is based on foreign emissions, and that this is very difficult to implement. The very real possibility of retaliation by trading partners is also a point of concern.

There is limited research looking at the effects of the EU CO_2 compensation scheme on EITE industries' incentives and environmental performance. Mostly, as shown by the examples above, the research is focused on firms' response to the allocation of free allowances and beneficial exemptions. Martin et al. (2014b), Klemetsen et al. (2020) and Ferrara and Giua (2020) are examples of papers with said focus. These largely refers to investment decisions and how it affects the profits of the firms, and thus whether it helps to counteract carbon leakage or not. The decision of making reinvestments could be a signal of a willingness to become more energy efficient, but – as pointed out by Thema (2020) – it could still be that the agents are more inclined to make new investments in other areas without as strict climate policies. The long-term effects are therefore uncertain.

Increasing EUA prices, higher renewable energy shares in Europe, increased climate focus internationally and the developments within the EU ETS are all highly relevant issues that will affect the effectiveness of the EU ETS, the compensation scheme, and the actions of firms within the EEA in the coming years. The scope of this thesis is to investigate the incentives provided by the CO_2 compensation, the effects on electricity consumption and the following possible environmental effects, and the effects on competitiveness for recipients in Norway. Due to the limited available research on this topic as well as the changes of the EU ETS, in addition to the predicted costs of the scheme being very high, this topic should be of high policy interest and -importance.

3. Theoretical framework

3.1 Externalities and market-based approaches

An externality is either a positive or negative unintended effect, for instance emissions, which thus are not included in the investment or production decision. If a negative externality is not accounted for in the production costs, the production level will exceed the socially optimal level. The goal of policies targeting such externalities is to reach the socially optimal level by integrating the external cost in the marginal costs of production to reduce production, or in the market price such that the demand for the good will decrease. There are two main ways to account for such effects, either through "conventional" command-and-control methods, or market-based approaches. Command-and-control methods might, for instance, be technology standards. This can affect businesses asymmetrically due to the heterogeneity of producers. The EU ETS is an example of a market-based approach to tackle the externalities of emissions, based upon a cap-and-trade framework.

Internalizing externalities in the production costs is the goal to account for externalities. The carbon tax as it is known today is based upon the theory of the Pigouvian tax (Pigou, 1920). The tax is set equal to the marginal external cost level at the Pareto-efficient output level. Carbon tax in an example of a market-based approach. Tradable permits are an alternative market-based approach reaching the same optimal solution. The underlying idea of which, and the vast theoretical framework that exist, is based upon what was developed throughout the 1980s and 90s (Hahn and Stavins, 1992).

Ellerman (2003) defines a tradable permit as a "transferable right to a common pool resource." He also points out that, given the structure of how tradable permits are allocated and dealt with, there is an implicit understanding that some levels of emissions are "ok" and might not be harmful. The cap-and-trade system of allowance trading is unique in that the cap is set, and businesses and industries must adapt accordingly – making the allowances essential inputs into the production. The regulator sets the cap, which means that the "acceptable level" of emissions must be defined, and rules on how the trading should work has to be determined. In the case of the EU ETS, the EU sets a cap, and the market will respond by the lower-cost abators abating more than the higher-cost abators, causing a cost-efficient abatement level. An EU cap on emissions will have the same effect as a corresponding Pigouvian tax under given strict assumptions. The difference between them being that the market sets the price for emissions based upon their relative marginal abatement costs, the cap, and the following trade in permits.

To find the optimal emissions reductions, there is a need for information regarding marginal abatement costs and marginal damage costs. The optimal abatement level will be where $MAC = MD$. For unilateral climate policies, the abatement level will be determined based upon the abatement costs of the agents and the marginal damages. For the EU, with many different countries involved, it might be difficult to obtain detailed information regarding abatement costs for all agents. The information can be based upon firms reporting on their own abatement costs, which can create incentives for the businesses to overestimate their abatement costs (Martin et al., 2014b). This can cause an issue with asymmetric information and cause the optimal abatement level to be hard to discover. This can lead to a sub-optimal solution.

The optimal emission reductions level in Figure 6 is from e^o to e^*, with total costs of abatement being the colored area. To reach this abatement level, there could be a carbon tax

= w^*, or the cap can be set such that the price of allowances will be w^*. How the firms will respond to a cap-and-trade system depends upon the allocation method, which will be covered in more detail later. When opening for tradable permits, $MACs$ will differ from agent to agent. Therefore, if there is free allocation of permits, the firms with higher MAC will buy permits and firms with lower MAC will sell permits, up until the costs of abatement are the same for all agents. If the permits are auctioned, the firms will buy permits up until the targeted reduction level. The cap-and-trade system is therefore based upon the quantities of emission reductions rather than externally setting the price of emissions – as with a tax. The markets will lead to a price discovery of carbon.

In the first Phase of the EU ETS, the total allocation of EUAs probably exceeded the optimal level, and the EUA price fell to zero. This caused the relative marginal damages to exceed the costs of abatement or abatement reductions. This leads to an efficiency loss as $e^{cap} \rightarrow MAC < w^* < MD$ whereas the optimal e^{cap} should be such that $MAC = MD = w^*$ with emission reductions at e^* and an optimal carbon price at w^*.

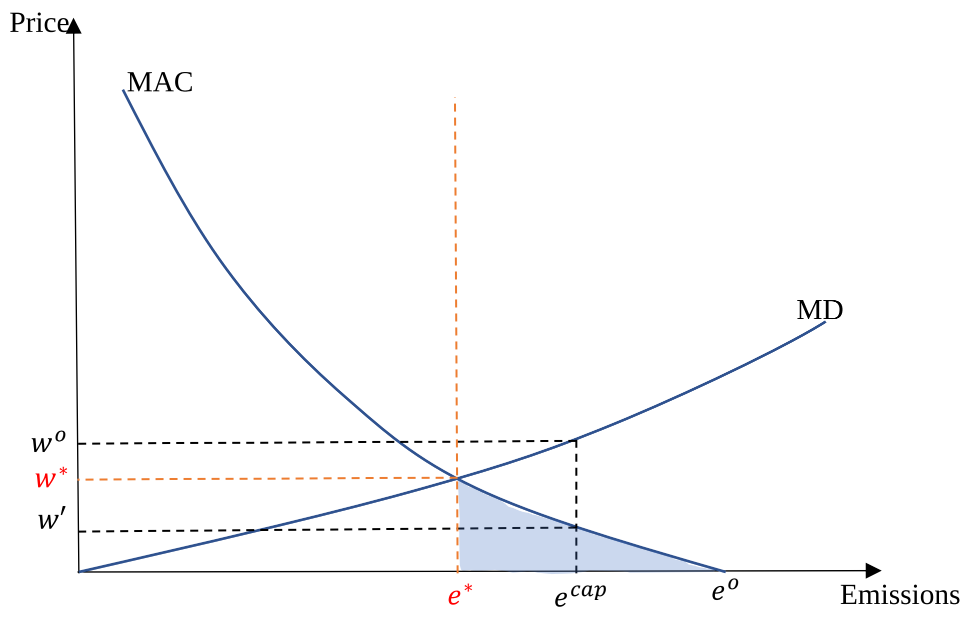

Figure 6 Optimal emission reductions framework

In addition to the cap serving as a tool to reduce emissions, it also yields an incentive to improve abatement technologies because of the possibility of arbitrage. Since the lower cost abator can sell permits, this constitutes a possibility of profit earnings for the lower cost abator and an incentive of cost reductions for the higher cost abator. In a cap-and-trade framework, technological development can lead to a reduction of the MAC and thus lead to the optimal cap being reduced accordingly.

3.2 Carbon leakage and CBAM

3.2.1 Carbon leakage and its effects

The issue with carbon leakage arises when there are benefits to be achieved for the businesses by leaving the market in which there are climate policies affecting production costs and move the production to areas with less strict climate policies. IPCC (2007, p. 81) defines carbon leakage as

$$(1)\ \frac{increase\ in\ CO_2\ emissions\ in\ countries\ not\ taking\ mitigation\ action}{reduction\ in\ emissions\ in\ the\ countries\ taking\ mitigation\ action}$$

which tells us that the leakage rate, which is part of the determination of the allocation of free allowances, can be defined as

$$(2)\ \frac{\Delta(foreign\ e)}{-\Delta(domestic\ e)}100\%$$

Ferrara and Giua (2020) argue that a relocation would lead to leakage exposed firms to contribute to maintaining high levels of global emissions, and that it can harm businesses and cause job losses in the EU.

Wingender and Misch (2021) identifies three reasons as to why carbon leakage remains an important point for climate policy discussions.

i) Carbon leakage will undermine the effectiveness and intention of unilateral climate policies, such as the EU ETS,

ii) carbon leakage can lead to reduced competitiveness of domestic businesses, and thus harm the domestic economy, and reduce the global market share if production costs increase, and

iii) carbon leakage is at the core of the discussion regarding border carbon adjustment mechanisms, which is highly debated.

The theoretical literature on carbon leakage is largely model-based, and the empirical literature has not reached a consensus on the relative leakage rates, or even their signs. The results are arguably very sensitive to the underlying assumptions, and recent empirical studies have subsequently failed to find much evidence of carbon leakage (Wingender and Misch, 2021).

The effects of carbon tariffs and carbon taxes on carbon leakage is a research area studied by many researchers. Larch and Wanner (2017) conducts an analysis of the trade, welfare, and emissions effect of carbon tariffs, i.e., a tariff levied on imported goods that have not been subject to carbon pricing, in a multi-sector and multi-factor model based upon previous studies. They identify three effects for total emissions from production in multiple tradable and non-tradable sectors, namely

i) the scale effect,
ii) the composition effect, and
iii) the technique effect.

Using this framework looking at the implications of carbon pricing on trade, welfare, and emissions, they conclude that the effectiveness of carbon tariffs on carbon leakage comes at the cost of lower trade flows and lower welfare especially for developing countries. By implementing carbon tariffs that equalizes the tax differentials between countries, trade decreases, welfare is reduced in mostly all countries, it leads to some reduced carbon leakage. They also find that the world carbon emissions reductions that occur are primarily driven by the composition effect – that the increase of average energy cost is positive and proportional to the increase in energy share (Larch and Wanner, 2017).

Energy-intensive industries are at risk of carbon leakage due to many of them also being trade-exposed. A relative cost increase will thus make them less competitive at the international market and reduce their market shares if they do not relocate. Unilateral climate policies, such as the EU ETS, will have effects on the competitiveness of the firms, but especially the trade-exposed sectors. This effect can be seen in Figure 7 . By carbon pricing increasing the production costs, the trade-exposed producers’ supply curve will shift inwards, causing a negative shift in the total supply curve, the price increases and quantity consumed decreases, and the output and emission abroad increases. The size of these relative changes depends upon the trade intensity, the transportation costs, the relative substitution between domestic and foreign goods, and the emission intensities of the production domestically and abroad. A production process with low emission intensity will be less vulnerable to increased carbon pricing.

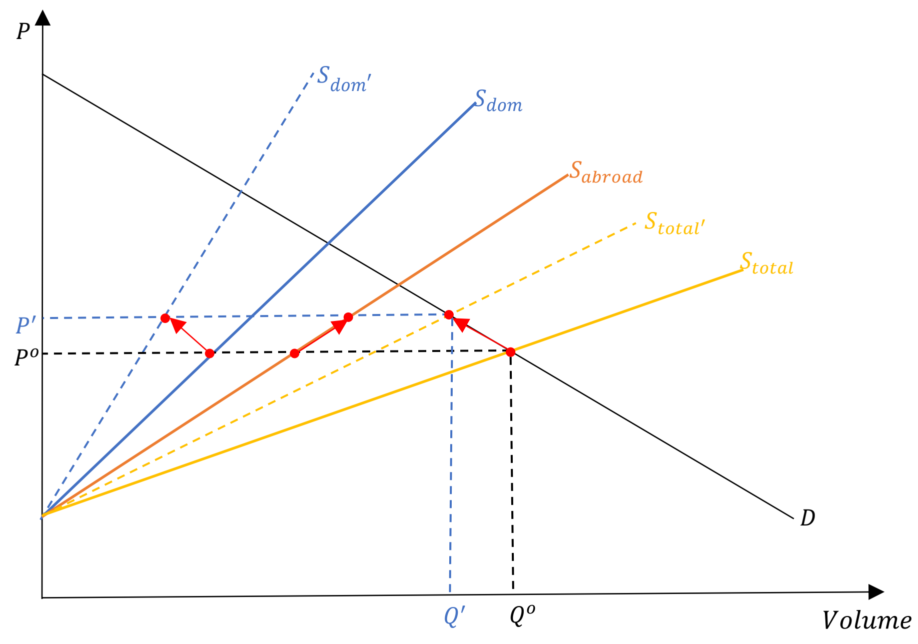

Figure 7 Competition effect of domestic climate policies

Energy-intensive industries are also prone to carbon leakage because of fossil fuels' importance in power production. The reduced domestic use of fossil fuels for electricity production by the increased costs through carbon pricing depress the demand for fossil fuels, the prices decrease and the consumption in other countries increase. The magnitude of this effect depends on the price responsiveness of demand and supply, and how integrated the energy markets are. The movements are similar to the ones portrayed in Figure 7 , but on the demand side rather than the supply side. The effects of carbon pricing on energy-intensive and trade-exposed sectors are therefore manyfold and can lead to a significant risk of carbon leakage through both demand and supply.

3.2.2 Allocation methods

Allocation of permits are of crucial importance in the design and efficiency of the EU ETS, and an important policy tool in countering carbon leakage. The Coase theorem states that the efficient outcome will be reached through negotiations regardless of the allocation of property rights, given perfect information, competition, and low transaction costs (Regan, 1972). However, with many firms, the transaction costs increase, and the efficiency will decrease. Previously, grandfathering was the method that was primarily used when allocating allowances in the EU ETS. Grandfathering is when the allocation of permits is based upon historical emissions during a given period (Knight, 2013). The expected growth in emissions is then considered to adjust the allocation accordingly.

Benchmarking is similar to grandfathering, in that both provide allowances free of charge, with the difference being that benchmarking is based upon standards rather than historical estimates. This is the method that is used today to determine how many free allowances that are distributed in the EU ETS. The motivation behind benchmarking as the allocation rule is to avoid carbon leakage. The benchmarks are determined based upon the average carbon intensity calculated based on the 10 % most carbon-efficient installations in each sector and their production method, making it an output-based allocation method (EC, 2022). This leads to all installations within the sector to receive free allowances up until the benchmark level, which serves as a subsidy for production due to reduced production costs. In Figure 7 this would lead the domestic supply curve to shift outwards, causing the domestic producers to reclaim market shares, and avoiding carbon leakage.

Auctioning is separate from grandfathering and benchmarking, as it implies that the operators need to purchase the allowances according to their emissions. This causes the carbon costs to be internalized in the production costs of the producers and can lead to the shifts shown in Figure 7. Auctioning can therefore, especially for EITE industries, can lead to carbon leakage.

The incentives provided by the different allocation methods differ. Grandfathering and benchmarking can be viewed as subsidies to the polluters, which causes issues in and of itself. However, there is an opportunity cost to the permits even though they have been acquired free of charge because the established carbon price determines a value of the permits. A higher carbon price increases the opportunity value of the allowance, and thus the value of the subsidy increases accordingly. A lump-sum transfer, as grandfathering, does not directly affect the incentives of the allowance holder. Benchmarking, on the other hand, will provide incentives to achieve best practice in carbon efficiency in the sector without limiting production. In the case of EITE industries, the allocation of allowances has largely shifted towards benchmarking.

Auctioning is different due to the costs it entails. The costs of purchasing allowances will thus be internalized in the production costs, affect the marginal costs of production which in turn affects the equilibrium production. There will therefore be an incentive of the firm to reduce the production costs, which can be done by reducing their marginal abatement costs. As explained previously, the investment in new technology and reduction in MAC because of carbon pricing and the increasingly stringent cap is a key element in the EU ETS. The increased share of auctioned EUAs constitutes a portion of this element.

3.2.3 CO_2 compensation rules

The CO_2 compensation scheme is a voluntary scheme in the EU ETS designed to further reduce the risk of carbon leakage in EITE sectors. The carbon costs embedded in the electricity prices that producers face serve as an additional cost which can lead to the same movements as shown in Figure 7, causing increased carbon leakage. The effect of the carbon price on electricity prices is referred to as indirect emission costs, with indirect emissions therefore being the emissions stemming from electricity production. Given the free allocation rule, the CO_2 compensation scheme serves as an additional benefit for exposed industries.

There are some requirements for a production to be eligible to receive compensations. The business must be part of the industry NACE codes that are defined as carbon leakage exposed, or that it can be proven equal risk of carbon leakage and trade exposure, and the electricity consumption must exceed 10 GWh per year to be eligible (Miljødirektoratet, 2021a). NACE is the statistical classification of economic activities in the European Community and is provided on different digit levels depending on how refined the division of activities are. At the 2-digit level, it will refer to the main activity – for instance Mining of coal and lignite (05), at the 3-digit level it will be slightly more refined, for instance Mining of hard coal (05.1) etc.

The 10 GWh threshold poses interesting possible incentives for the industries. Given that there is a threshold level of electricity consumption, businesses might be incentivized to increase their consumption to receive payments from the government. The energy efficiency standards for different products are set based upon benchmarks for the most efficient available production technology in the EEA. For alumina, for instance, this standard was set at 0,225 MWh/tonnes of product in 2013-2020 (Forskrift om CO_2-kompensasjon for industrien, 2013). For some production processes, there are no such standards, and then an alternative standard is used. The alternative standard, therefore, shows the fraction of the carbon factor and electricity consumption that is compensated before accounting for aid intensity and EUA price. In the previous Phase, this was set at 0,8. The calculation rule for a product in which there is an existing standard is

$$(3)\ Comp = CO_2\ factor * energy\ efficiency\ standard * production * aid\ intensity * P^{EUA}$$

Whereas the calculation rule for a product in which there is no efficiency standard is

$$(4)\ Comp = CO_2\ factor * alternative\ standard * electricity\ used * aid\ intensity * P^{EUA}$$

Therefore, for the productions with efficiency standards, the compensation works as a production subsidy, whereas for productions without energy efficiency standards, the compensations work as an electricity subsidy.

In the proposed regulation for the 2021-2030 period, the CO_2 factor is set at 0,53 and the aid intensity is set at 0,75 – the highest possible level. In the coming period, the compensation will be based upon actual production or electricity consumption, meaning that the compensation is proportional with electricity consumption or production. This might lead to businesses

a) Increasing their production,
b) Increasing their electricity consumption, or
c) Increasing both their electricity consumption and production.

The compensation can incentivize increased production when there are energy efficiency standards, whereas it can incentivize increased electricity consumption for productions with the alternative standard. The most plausible alternative would be to increase both consumption and production, option c), through new investments in real capital. In effect, this will lead to higher payments made by the government, higher electricity consumption and more production, which in turn can lead to an overall increase in the supply of energy-intensive goods.

The possible effects of the compensation scheme can be portrayed in Figure 7. We have already defined the compensation as a subsidy which is proportional to either production or electricity consumption. For the productions in which there are no energy efficiency standards, it is an electricity subsidy. Electricity is an input that directly affects the production decision and thus supply. In Figure 7, the compensation would have the opposite effect. It would lead to a positive shift in Norway's supply curve $S^{dom'}$. Whether it would shift all the way to S^{dom}, or even further, would depend upon the size of the compensation. With the possibilities for compensations by reaching the 10 GWh threshold, Norwegian producers can increase its capacity through new investments which lead to both increased electricity consumption and production, option c). Given the compensation scheme's voluntary design, this effect will benefit Norwegian industries relative to other EU industries. It can thus become a competition distorting framework impacting EU and EEA countries asymmetrically.

The compensation scheme, given its structure of being either a production- or an electricity subsidy, can thus affect the businesses' production and investment decision. The goal of the compensation scheme is to enable domestic (EU) producers to keep producing under the same competitive conditions as producers in countries who have not initiated as strict climate policies. If the incentives are sufficient such that supply from EU producers keep their original share of total supply, it will help counter carbon leakage. The production by other EU producers might also decrease because of the relatively reduced competitiveness by the compensation scheme. However, the problem related to carbon leakage is the avoidance of increased emissions. If, because of the compensation scheme, the compensated businesses become relatively more profitable, takes on a larger market share, and in turn increases total supply, the total energy usage for energy-intensive goods might also increase. Given the EU electricity generations' reliance on fossil fuels, and energy-intensive industries' processes requiring large amounts of electricity, total emissions within the European Economic Area can, ceteris paribus, increase. If total emissions within the EEA increases, and if foreign producers continue to produce at the original level, global emissions might increase. In which case, the compensation may work against its intention – to counter carbon leakage, which is a problem due to increased global emissions. However, the design of the EU ETS might also prevent the increased emissions by increased activities from EITE industries.

Previously I defined the free allocation rules as a production subsidy due to the recipients not having to buy the permits. The compensation is an additional subsidy, either a production subsidy for productions with efficiency standards, or electricity subsidy for productions without an efficiency standard. This further enhances the stimulation of domestic production within the EU ETS area.

However, since this is a voluntary scheme and considering that few member states have adopted it, the effects will disproportionately affect the producers within the EU ETS. The compensated producers will increase their production relatively more than the producers in non-compensation countries, which can impact the competition between countries within the ETS. The competition effect of the compensation scheme will differ depending on whether the countries have or have not adopted the scheme. Carbon leakage, however, will be reduced. If a producer in a non-compensated country decides to move their operations to a country who have implemented the compensation scheme, the production will still be within the EU ETS, and there will still be a relative increase in the domestic supply – meaning that carbon leakage is, by definition, avoided.

3.2.4 CBAM

The Carbon Border Adjustment Mechanism (CBAM) was introduced in the EU Green Deal as an alternative to the free allocation and potentially the CO_2 compensation scheme to counter carbon leakage. Border Carbon Adjustment is a largely theoretical approach on how to tackle carbon leakage as it has not yet been implemented many places. The CBAM will be applied as a tariff on imported goods, and thus depress the foreign supply at home, ensuring competitiveness for the climate policy exposed energy-intensive sectors within the EU area. There are many design possibilities for such a tariff, and important aspects to include is whether it should be uniform or company specific and whether it should be based on direct or also include indirect emissions. In July 2021, the EC adopted a proposal for the CBAM, stating that the mechanism should work as follows; the EU importers will have to buy carbon certificates which corresponds to the carbon price that would have been paid if the goods had been produced under EU regulations. If the producer of the good can document that the good has undergone equivalent carbon pricing in a third country, the entire cost can be deductible. The argument for why and how this can reduce carbon leakage is by suppressing the foreign imports, and by incentivizing countries outside the EU to improve their production processes (Commission proposal 2021/564 final, 2021).

In practice, such a mechanism will serve as an import tariff equivalent, which will depreciate the foreign supply in the domestic market. In Figure 7 , this can be shown through a negative shift in the supply abroad curve, as the import tariff equivalent will increase the domestic price of the good and thus reduce the domestic demand for the foreign good, which in turn reduces the foreign supply. The total supply curve will therefore also shift inwards, increasing the price. This ensures that the domestic producers despite undergoing carbon pricing will remain competitive relative to foreign producers.

3.3 NPV analysis

Assessing the incentives a business is faced with by the compensation scheme can either be done through profit maximization methods or net present value calculations of an investment decision. Profit maximization can be defined as “the difference between the revenue a firm receives and the costs that it incurs.” (Varian, 1992 p. 24) If we are to assess the profits of a firm, we need to know all its costs. This requires detailed information that is not easily accessible. Another way one can assess the profitability of investments, is through net present value analysis of an investment decision. This is commonly used in investment analyses as well as cost-benefit analyses. A NPV analysis calculates the present values of both the costs and revenues (benefits) of a project. This method also requires information about the revenues and all costs related to the project. It can be defined as

$$(5)\ NPV = -CF_0 + \sum_{t=1}^{n} \frac{NCF_t}{(1+r)^t}$$

Where $-CF_0$ is the initial capital investment occurring in time 0, NCF_t is the net cash flow (revenues minus costs) in time t which would include compensations, production value and increased electricity costs, and r being the discount rate (Boardman et al., 2014).

Looking at the business' different choices to reach the 10 GWh threshold, there are a few factors that can help to explain the decision-making problem. First, profitability needs to be investigated. This can be done through a net present value (NPV) analysis of the capital investment, increased electricity costs and increased revenues, i.e., the net cash flow. The investment data is not easily obtainable on the firm level or detailed (higher digit) NACE industry group level. Another alternative could be to use the production value and the possible increase in production value as a proxy for the lacking detailed investment data. Looking at the electricity costs in relation to the production value can be useful to assess how much the compensation and electricity costs make up the production value. If the share is high, the businesses will have higher incentives to reach the 10 GWh threshold, because the profits and NPV will increase with the compensation payments.

3.4 Energy markets and trade

Despite Norway not using fossil fuels for electricity generation and the carbon price thus not being directly embedded in the electricity price, the trade with European countries leads to the carbon price more increasingly affecting Norwegian electricity prices. This is the foundation for the implementation of the CO_2 compensation scheme in Norway, as an increase in electricity prices can weaken the competitive advantage of low electricity prices in Norway if EUA prices and trade increases.

3.4.1 Features of the energy system

The design of the energy system is of importance for the supply and price of inputs for energy-intensive industries. One of the most prominent characteristics of the electricity market is the natural monopoly. Transmission grids and power lines are such natural monopolies which are commonly run and regulated by agencies or businesses owned by the state. A natural monopoly is defined as “an industry in which multifirm production is more costly than production by a monopoly” (Baumol, 1977). It is characterized by large capital costs up front, with a falling average cost (AC) curve, i.e., economies of scale. This is only a sufficient and not a necessary condition of defining a natural monopoly. A firm exhibiting economies of scale at the output level can still exhibit increasing average costs in production (Depoorter, 2000). Natural monopolies can therefore be further divided into two kinds of monopolies – a strong natural monopoly, which is when the AC is always above the MC curve, and a weak natural monopoly where the MC is increasing at a certain production level (Depoorter, 2000). The pricing for a natural monopoly is different than in a market with perfect competition. The monopoly power will lead to prices above MC, which is a source of inefficiency in the market through a deadweight loss as prices are higher than equilibrium prices. The reduction of this deadweight loss is why transmission grids and power lines often are operated by the state or state-owned companies.

In the Norwegian context, about 1/3 of the electricity bill paid by end consumers is allocated to “grid rent” (NVE, 2021). That is a payment to the distribution system operator (DSO) or distribution network operator. The DSO is responsible for distributing electricity from the transmission system, which is the high-voltage part of the electricity grid, to the final consumer. For energy-intensive industries, the costs can be divided into the same groups as for households, but the distribution within these groups look quite different. Energy-intensive industries do, for instance, pay less grid rent, and benefit from other discounts and exemptions from other fees. Pöyry (2019) finds that, when comparing to other EU countries, Norwegian energy-intensive industries pay the least not just in end prices, but that the fees and taxes are also lower than other countries at about 0,5 €/MWh. In Belgium, having the highest fees and taxes, that amount adds up to 22 €/MWh, in comparison. The countries listed in the report have all – except for Sweden – implemented the CO_2 compensation scheme initiated by the EU. The authors also find that the average trade-weighted wage cost per hour in Norwegian industries are 29 % higher than of the countries included. The natural monopoly structure, along with the many exemptions, the free allocation of allowances and CO_2 compensation are all sources of beneficial structures for Norwegian EITE industries.

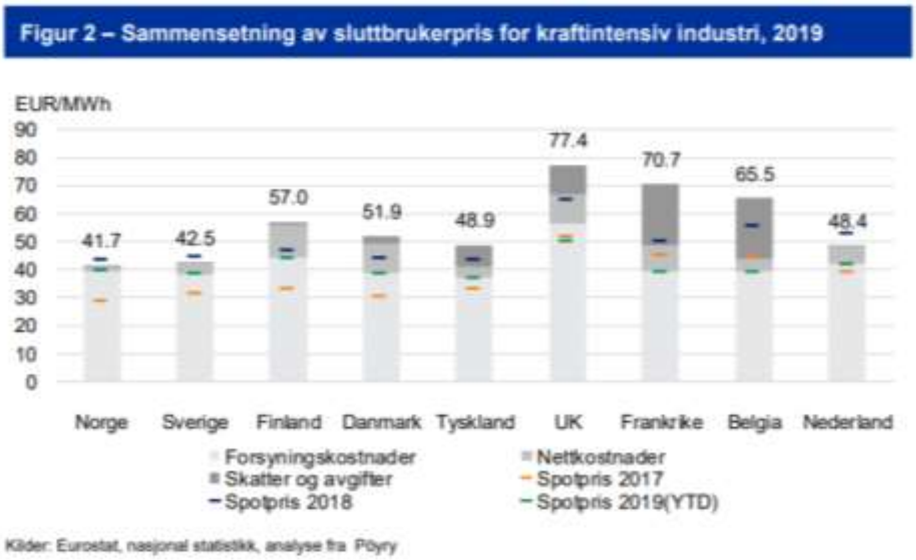

Figure 8 Comparison of end prices for energy-intensive industries in several European countries. Source: Pöyry (2019), p. 2

3.4.2 Trade in electricity and the impact of EU ETS on Norwegian electricity prices

Hu et al. (2015) found that in 2013, the industry accounted for 43 % of energy consumption in Norway, of which 29 % was due to power-intensive manufacturing. This is a significant share of the total consumption in Norway. However, hydropower made up 96 % of the energy mix in that same year, with the remainder consisting of wind power and thermal power. Therefore, very little of the energy consumed in Norway stems from non-renewable primary energy sources and has thus not been subject to carbon pricing. Hydropower is characterized by extremely low marginal costs of production, causing Norwegian prices to be relatively low compared to other countries. This has been a source of competitive advantage for the energy-intensive industries.

However, with increased trade in electricity, the indirect costs of carbon pricing will become more apparent as non-renewable primary energy sources still constitutes a significant portion of the electricity production in mainland Europe. Eurostat (2022) reports that 43.6 % of total electricity generated in the EU in 2019 came from non-renewable fossil fuels, which is a decrease from 52.5 % in 2009. By enabling more trade, more of this carbon generated electricity will flow into the Norwegian transmission lines and distribution, which can lead to an increase in the carbon factor of Norwegian electricity in the coming years. Carbon factor in electricity is the relationship between CO_2 equivalents in electricity consumption for end users, calculated as gCO_2e/kWh. In 2019, the carbon factor for Norwegian electricity was 17 gCO_2e/kWh, in contrast to the EU-27 average of 253 gCO_2e/kWh (NVE, 2022; EEA, 2021).

Trade theory states that countries will trade with each other if there is a possibility of arbitrage (Appleyard and Field, 2017). In a free trade situation, the countries with the lower domestic prices will sell to countries with higher domestic prices up until the relative prices in all countries equates, which then is the established world price for said good. If there was a possibility of free flow of electricity, the prices in all countries would then be the same. Energy markets and trade in energy has interesting features due to its restrictions of transmission capacities, which sets a physical boundary to how much can be traded, and thus how much the prices can converge. With more transmission to mainland Europe, the possibility of trade will affect the price of electricity and the domestic production decision, which in turn will impact energy-intensive industries' production costs.

The effects of the trade in electricity between Norway and other countries can be shown in a simplified, two-country equilibrium framework. In a situation where the domestic price in Norway is lower than the EU price, Norway will export to the EU up until the capacity. If the capacity constraint is higher than the demand for electricity transport, the constraint is not binding. In which case, the prices would be the same between both markets. If the capacity is below demand, there will be trade up until the constraint, making it binding. This will depend upon the relative prices and the demand in that moment, and the transmission capacity between the trading partners. If there is a constraint, the prices will converge, but the price in the importing country will still be higher than in the exporting country. In "conventional" trade theory, there is usually one country that is the importer and one that is the exporter. In the case of trade in electricity, the roles shift depending on the domestic prices. When Norway is the exporter, meaning that the domestic price in Norway is lower than in the EU, relatively clean electricity enters the European market from Norway. Vice versa, if Norwegian prices are higher than the EU price, Norway will purchase electricity from the European market. Given that the primary energy sources used in power production in the EU still consists of non-renewables, this leads to "dirtier" electricity entering the Norwegian market, and – thus – indirect emissions. The carbon pricing of the EU ETS leads to increased electricity prices in the EU. In the case where Norway is the importer, this leads to increased prices relative to the prices without regulation, as the price reduction from importing becomes smaller. It also pushes the prices up within Norway even when being an exporter, as the difference between the EU and Norwegian price increases, causing the domestic price in Norway to increase more compared to a situation without regulation. The effects can be seen in Figure 9 below.

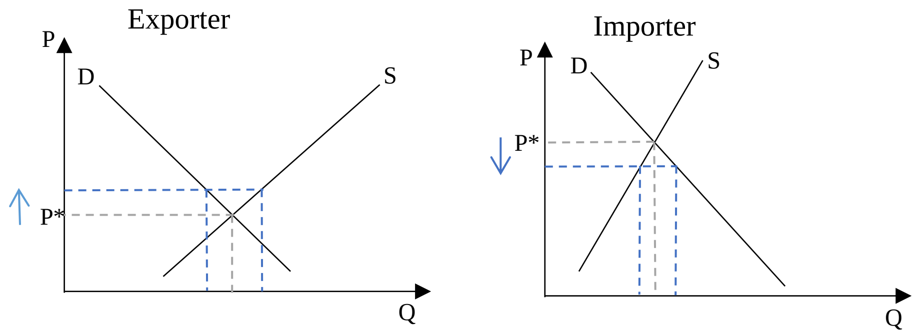

Figure 9 Two-country framework showing the effects of trade in electricity.

In addition to the scenarios mentioned above, the electricity market is a highly dynamic market in which demand varies over time. Typical patterns can be seen throughout the year, month, and day. Peak hours are usually in the morning and afternoon and higher demand when the temperatures being very high or very low. Such demand patterns will affect the demand for trade in electricity and affect the prices in between the trading partners – which in turn will depend on whether the capacity constraint is binding or not. These patterns will also affect the production decision, as the relative value of producing in one period can be lower than in another period. The relative value of producing electricity is referred to as water value for hydropower systems. The water value will affect the decision whether to produce for export, which in turn would affect the movements in Figure 9 and the domestic prices.

The relationship between Norwegian electricity prices and the EUA price will as explained above vary according to many aspects. The relative price difference of electricity in Europe and Norway will have an impact, the transmission capacity between the markets and the EUA price, meaning that the impact will vary over time. An analysis conducted by Thema for Europower in 2021 (Brenna, 2021) estimated that a 1€ increase in the EUA price will lead to an increase of 0,3 to 0,4 €/MWh of the electricity price in the Nordics – the equivalent of roughly 3 to 4 NOK/MWh depending on the exchange rate. In the CO_2 compensation scheme, the carbon intensity factor in Norway has been set at 0,53, meaning that a 1€ increase in the EUA price will, not accounting for the other fractions of the calculation equations, lead to an increase of compensation payments of 0,53 €/MWh, or 5,3 NOK/MWh.

Norway is increasingly connecting to the European market through investment and construction of new transmission lines. With the transmission capacity increasing, and increased trade possibilities, the effect of the EU ETS on Norway's electricity mix and price will increase. Much like hydropower, the marginal cost of using a transmission line is very low, with large capital costs up front. The natural monopoly structure of operating such systems can lead to further increases in prices due to congestion rents throughout the supply chain. Increased trade will also lead to more carbon-intensive electricity entering the Norwegian market. All these effects will in turn affect energy-intensive industries, their climate performance and competitiveness.

4. Data and method

4.1 Description of data

The goal of this paper is to investigate how the industry responds to the compensation scheme by looking at the 10 GWh threshold, whether it can incentivize increased consumption and production, and the potential climate impacts of the responses. To do so, data is required on each industry. I will use the relevant NACE codes to identify production value, investments, and other relevant factors. The ideal method of choice would be to conduct a NPV analysis of an investment decision. However, given the lack of detailed data this has proven difficult.

Recall equations (3) and (4) in chapter 3, showing the two alternatives of calculating the compensation. We have already established the carbon factor and aid intensity through the suggested Regulation (see chapter 3.2.3). The EUA price will be based upon existing estimates that I have adjusted accordingly to today's situation with a low, medium, and high-price estimate, as described in chapter 5.1. The alternative standard is also established at 0,8. The unknowns that remain to be able to estimate the compensation is the electricity usage, energy efficiency standard and, where there are efficiency standards, the production level.

Production

The eligible businesses must report their production to the Norwegian Environment Agency. The data provided by NEA is stated as MWh/tonne produced good. Assessing the electricity usage per tonne produced good for the compensated businesses can be beneficial to address the possible differences in energy efficiency level between compensated and non-compensated businesses. If there is a difference, this might signal something about the incentives the compensation scheme provides. The data for the compensated businesses has been made available upon request by the NEA. Detailed data for all productions in Norway within the categories are, however, not available.

Investment data

Investment data is relevant as it can tell us how much the industry is investing, which in turn can increase production and energy consumption. As mentioned, detailed investment data is difficult to obtain at the firm level. At the main industry level, there is available data, which is too "raw" to use. Investment is defined by Statistics Norway as "all procurements of new, lasting fixed assets with a usage time of 1 year or more. (…) Value added tax is calculated as net, meaning that refunded tax is not included, whereas not refunded tax is included." (Statistics Norway, 2022) The available investment data is provided by Statistics Norway in million NOK. To be able to conduct a NPV analysis, a complete image of both costs and investments would be required. Detailed data grouped in NACE categories are, however, not available, and the data at hand will be too raw to be transferrable for the analysis in this thesis.

Production costs

Costs related to all aspects of the production would be necessary to conduct a NPV analysis. Fixed costs for buildings and infrastructure, variable costs linked to employment, inputs such as raw materials, etc. Such a nuanced cost structure is difficult to obtain for all production processes, and will vary according to products, and between each production facility.

Production value

I seek to assess the profitability of increased electricity usage, and production value can give an image of the possible increased capacity in production when investment data is not available. Production in tonnes, for instance, might not be comparable between the products. By using production value, I will get comparable results between the products and industries without having to make alterations in the data. It is also more detailed than the available investment data, as it is possible to extract data on the 3-digit level NACE code for all industry groups – except for 07.1 Mining of iron ores, as will be shown later in chapter 4. Production value is the operating revenue minus the changes in the inventory of goods, goods that are used in the production, and goods and services purchased for resale. The values provided by Statistics Norway separate between businesses and companies. A business is defined as a "functional unit within a delimited area who mainly engage in activities within a specific industry group." (Statistics Norway, 2022) A company is the legal entity. A company can thus include multiple businesses, which in turn can include multiple production processes, which is spread across multiple areas. The business will be the physical entity in which the production is happening. For this thesis, and through conversation with representatives from

Statistics Norway, I have chosen to use the values provided for the businesses. The data is provided in million NOK for the years 2008 to 2019.

There has been a change in the reporting of the data from 2017, with businesses and companies being included in the same database while still being separated. Up until 2017, the data was provided in separate tables. Given the information provided for the databases, I will assume that this has not caused any changes in the way the values are calculated, and that there is no need to alter the data.

Electricity usage

There are requirements of reporting on electricity usage for the purpose of calculating compensations. Electricity usage is highly necessary in the assessment of the 10 GWh threshold and is useful to see the relative developments throughout the compensation period. In the analysis, electricity usage is used to calculate production value/GWh, which can tell something about the energy efficiency developments or development of the competitiveness for Norwegian businesses – for instance. However, detailed information regarding electricity consumption is difficult to obtain for all firms because of confidentiality and competition issues. There is, however, available information through Statistics Norway on electricity usage on the 3-digit level NACE group, provided in GWh and on purchased electricity from 2003 to 2020. For NACE code 19.2 Production of refined petroleum products, there is only available data from 2013 – which is the first year of the compensation scheme. The data on electricity usage is used to calculate the production value/GWh in each sector, which is then used to estimate the production value in each scenario – production at 8 GWh and at 10 GWh.

Electricity cost

Electricity cost is useful to assess how much an increase in used GWh and compensation make up of the production value. Electricity costs are provided by Statistics Norway in million NOK, and I have narrowed it down to purchased electricity, as this is the type of electricity costs that is eligible for compensations. Electricity costs will vary between the businesses due to different contracts with the suppliers of electricity. The data is reported yearly and is available at the 3-digit level for most productions from 2003 to 2020. For NACE code 19.20 Production of refined petroleum products, the same limitation as in electricity usage applies for electricity cost as well. In the decided analysis method, electricity costs are assumed to be included in the total costs, while accounting for the cost increases due to increases in the EUA prices under the different scenarios.

Electricity prices

Electricity prices vary between each business, due to the structure of long-term electricity contracts that will differ between firms. In the analysis, I have based the electricity prices used in the analysis on estimates by NVE long-term power market analysis (2021), adjusted for the increased EUA price.

4.1.2 Data used in the analysis

The list of relevant data above relates to the ideal NPV assessment of increased electricity consumption to reach the GWh threshold. Given that we do not have sufficient data regarding investments and costs, some simplifications and assumptions are necessary. While electricity usage and costs per NACE category is interesting and relevant for further discussion, it does not include all relevant nuances that are needed to get the full picture of an investment decision. Therefore, the values that are being used for the decided approach in this thesis, are the production values/GWh, EUA prices, electricity prices and production, and the other given factors for the calculation of the compensation. The production at 10 GWh is calculated based on the energy efficiency standards for the 3-digit group. 3-digit level of the NACE classification of economic activities is the second least refined division of the industries, but the most detailed level I can get to given the availability of data. Production value is used as a proxy for total costs, which are assumed to be equal to or lower than production value and includes electricity costs and production costs.

4.2 Industry categories

The data is reported on the 3-digit level NACE code. This has shown to be the level of which I am able to obtain the most detailed information, which I believe to be necessary to assess the incentives provided by the compensation scheme. To test the robustness of my results, I will conduct a sensitivity analysis for some of the productions – the exclusion criteria and details will be presented in chapter 5. Below follows a short description of the industry categories in which there is available data, and a rough explanation of the relevant data for each category. The NACE code is reported as the 2nd revision first, and the code that was applicable for the 1st revision in parentheses due to data being reported in both versions. Not all eligible industries are included in the description below or in the analysis. NACE group 07.1, Mining of iron ores and 19.2 Production of refined petroleum products are examples of industry groups in which there is too little information to be analyzed. I have included 07.1 in the description due to some businesses within this category receiving compensations. NACE group 14.1, in which there have not been any recipients, is included in this description but not the analysis to show the different structures between the industry groups. 23.1, in which there has not been any recipients and includes very few eligible sub-sectors, is not described here, but included in the analysis. See Appendix B for a full list of values used in the analysis. The compensation is stated as compensated processes due to some businesses being compensated for multiple products. This applies to all NACE categories.

07.1 (13.1) Mining of iron ores

This industry code applies to few beneficiaries of the compensation scheme, namely Sydvaranger AS from 2013 to 2016 and Rana Gruber AS from 2017 to 2020. The few producers entails that there are some lacking data, as shown in Table 2. Due to few businesses operating within this category, most of the data to be used in the analysis is not available due to confidentiality issues. This specific category is not on the list for eligible productions in the suggested regulation for Phase IV.

07.1 (13.1) Mining of iron ores	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Production value (m.NOK)	:	:	:	:	:	:	:	:
Energy used (GWh)	233	248	:	97	94	96	:	110
Energy prices (øre/kWh)	43,1	28,5	:	31,2	31,0	47,9	:	22,5
Energy costs (mill. NOK)	101	71	:	30	29	46	:	25
Production value/GWh	:	:	:	:	:	:	:	:
Compensated processes	1	1	1	1	1	1	1	1

Table 2: 07.1 (13.1) Mining of iron ores.

14.1 (17.1) Production of textile, leather and textile and leather products

Within production of textile, leather and textile and leather products, there are only a few sub-products that are covered by the compensation scheme. We can see that the production value has increased from 2013, whereas energy used has been relatively stable at around 12 GWh per year. Within this industry group, there are many businesses operating – between 612 to 924 from 2008 to 2019, and with the energy usage for the industry barely meeting the 10 GWh threshold, no businesses have been compensated throughout the past Phase.

14.1 (17.1) Production of textile, leather etc.	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Production value (m.NOK)	1803	1862	2032	2604	2733,9	2682,8	2677,2	-
Energy used (GWh)	12	12	15	15	9	12	12	10
Energy prices (øre/kWh)	62,1	56,2	52,7	55,3	60,0	72,9	72,0	52,3
Energy costs (mill. NOK)	7	7	9	9	6	8	8	6
Production value/GWh	150,3	155,2	135,5	173,6	303,8	223,6	223,1	-
Compensated processes	0	0	0	0	0	0	0	0

Table 3: 14.1 (17.1) Production of textile, leather and textile and leather products.

17.1 (21.1) Production of pulp, paper and paperboard

In the pulp, paper and paperboard production category, there are 11 different businesses who have received compensation from the 2013 to 2020 period, covered by 8 different companies. As shown in Table 4, production value has increased quite substantially within the period. Energy usage has seen a slight increase, whereas energy prices and energy costs have fluctuated. Production value/GWh have, therefore, also increased a lot – from 2,4 million NOK/GWh in 2013 to 4,1 million NOK/GWh in 2019.

17.1 (21.1) Production of pulp, paper and paperboard	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Production value(m.NOK)	7760	7244	11275	12032	11947,5	13246,8	14339,1	-
Energy used (GWh)	3202	3278	3252	3561	3696	3598	3459	3288
Energy prices (øre/kWh)	31,6	29,8	31,0	28,5	30,7	39,5	33,3	23,6
Energy costs (mill. NOK)	1005	972	1007	1007	1133	1411	1138	769
Production value/GWh	2,4	2,2	3,5	3,4	3,2	3,7	4,1	-
Compensated processes	10	10	10	10	10	10	11	11

Table 4: 17.1 (21.1) Production of pulp, paper and paperboard.

20.1 (24.1) Production of basic chemicals

This industry group includes products such as chlorine, sulfuric acid etc. It, thus, includes many different production processes. In this industry group, there are 19 different businesses who have received compensations, with 8 of them receiving for different production processes within the NACE group, and 13 different companies in total. In this industry group, the production value has fluctuated quite a lot during the period – ranging from 35 969 million NOK to 43 521 million NOK. The decline over the last few years might indicate a reduction in the prices of chemicals, a loss in competitiveness of Norwegian produced chemicals, or a reduction in production caused by other factors. The energy usage within this industry group has also fluctuated accordingly to the production value, whereas energy costs have been quite stable apart from a few years with an increase in energy costs. The production value/GWh has declined slightly, which possibly can be attributed to the slight reduction in production value, coupled with a slight increase in the energy usage. This, in turn, underlines the possibility of a loss in competitiveness of Norwegian producers of chemicals. The reduction can also indicate that there might have been a shift in the products produced towards products requiring more energy-intensive products. The production of fertilizers has been suggested included in the list of eligible productions in the next Phase, and it would be interesting to see how that inclusion might affect these numbers in a few years.

20.1 (24.1) Production of basic chemicals	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**

Production value(m.NOK)	37035	40275	43521	35969	36312,2	36784,3	36039,9	-
Energy used (GWh)	6700	7048	7141	6980	6818	7022	6863	7098
Energy prices (øre/kWh)	35,2	32,7	30,5	32,9	32,9	41,3	40,0	28,7
Energy costs (mill. NOK)	2312	2285	2207	2287	2215	2839	2675	2059
Production value/GWh	5,5	5,7	6,1	5,2	5,3	5,2	5,3	-
Compensated processes	29	30	29	29	29	29	29	28

Table 5: 20.1 (24.1) Production of basic chemicals.

24.1 (27.1) Production of basic iron and steel, and ferro-alloys

This industry group covers activities engaging in production of different metals, such as ferrosilicon, iron and steel. In this category, there are 11 businesses who have received compensation, with 3 of them having multiple eligible production processes, and with 6 companies covering all the productions and businesses. In this industry, the production value has increased from 2013 to 2020, whereas the energy usage has been relatively stable, fluctuating slightly. The energy costs have increased slightly, with fluctuations between the years, and the production value/GWh has increased about 30 % from 2013 to 2019. This could either indicate that there has been a shift towards production of relatively less energy-intensive goods, or that there might have been some energy efficiency improvements within this industry – or that the prices of the good has increased sufficiently to affect the production value/GWh.

24.1 (27.1) Production of basic iron and steel and of ferro-alloys

	2013	2014	2015	2016	2017	2018	2019	2020
Production value(m.NOK)	11133	11120	11512	10860	15291,7	15894,6	15014,7	-
Energy used (GWh)	4895	5167	4961	5069	5286	5216	4923	4821
Energy prices (øre/kWh)	27,6	26,9	28,1	27,8	30,6	34,2	33,6	30,8
Energy costs (mill. NOK)	1353	1388	1394	1410	1620	1782	1654	1486
Production value/GWh	2,3	2,2	2,3	2,1	2,9	3,0	3,0	-
Compensated processes	13	12	13	13	13	12	13	13

Table 6: 24.1 (27.1) Production of basic iron and steel and of ferro-alloys.

24.4 (27.4) Production of basic metals

Goods such as aluminum are included in this industry group. There are 8 different businesses who have received compensation in this category, covered by 7 different companies. In this group, production value has increased quite substantially by about 47 % from 2013 to 2019. We can, however, see that there are some fluctuations between the years within the period. Energy usage has a slight upwards trend, along with energy prices and energy costs – the latter has increased about 34 % from 2013 to 2020. We can see a similar slightly positive trend on production value/GWh within this industry category.

24.4 (27.4) Production of basic metals

	2013	2014	2015	2016	2017	2018	2019	2020
Production value(m.NOK)	39611	46262	50454	42664	53428,5	58303,5	58329,6	-
Energy used (GWh)	19229	19652	20379	20750	20799	21636	21851	21882
Energy prices (øre/kWh)	24,5	24,4	23,3	25,3	26,6	27,8	29,0	28,8
Energy costs (mill. NOK)	4708	4797	4742	5256	5534	6008	6343	6307
Production value/GWh	2,1	2,4	2,5	2,1	2,6	2,7	2,7	-
Compensated processes	6	6	6	10	10	10	10	10

Table 7: 24.4 (27.4) Production of basic metals.

These are the production processes that have received compensations by the Norwegian government during Phase III. In addition to these, 23.1 (26.1) Manufacture of other non-metallic mineral products is included – despite not making the list of compensated businesses in Norway. Mining of iron ores (07.1 (13.1)) are not included in the analysis, as this production process will not be covered in the coming Phase. Textile, leather and textile and leather products (14.1 (17.1)) are only included in this description of data to portray the differences in production value and energy consumption between eligible industries who have received compensation and those who have not. It is not included in the analysis, but the values used in the analysis for all industries in which there is available data can be seen in Appendix B.

4.3 Analysis of the effects of increasing the electricity consumption

NPV calculations would be the ideal method to assess the possible effects of the compensation scheme. This would give us a clear view of all the costs and benefits of the different alternatives. However, due to the lack of data regarding investments and costs for the businesses, this is not possible. A NPV calculation not including all relevant costs, investments and income would not give a realistic view of the situation in the industries covered. Therefore, I have opted for a simplistic approach looking at the degree of which an increase in the electricity consumption, increased production and costs relate to the possible compensation payments. I will do so by looking at the average production value/GWh for the productions at the 3-digit NACE code level, assume a proportional increase of electricity consumption, production value, and costs, and assess how much the compensation make up of those values. This way, I expect to find that the compensations received by reaching the 10 GWh threshold will make up relatively more of the total production value and costs in some industries than others.

There are some possible issues with doing it this way. For instance, NACE group 23.1 non-metallic mineral products contains very few productions who are eligible for compensations. By using data at the 3-digit level, there might be some details that get lost. This should be noted and will be accounted for in the interpretation of the results. By averaging the energy efficiency standards, we should also be cautious when interpreting the findings. For Production of basic metals (24.4 (27.4)), for instance, the standards vary between 13,9 MWh/t and 0,20 MWh/t. The average in this group is 4,6 MWh/tonne. By using the average, the results might be over- or underestimating the true effects for the products. Aluminum, for instance, has the highest standard, and is the product produced by the businesses who receive the most compensation (Alcoa Lista, Alcoa Mosjøen and Sør-Norge Aluminium). I will argue that the effect of using the average standard is representative for the industry group.

4.4 Analysis using chosen method

The analysis is intended to look at a production in any of the 3-digit NACE groups that operates at 8 GWh and assess whether and how the 10 GWh threshold and the following compensation can affect the business' decision to increase its electricity consumption by 2 GWh. As explained, the lack of detailed information leads to a simplified approach to assess the effects of this threshold. Some assumptions are necessary. First, I assume that total costs do not exceed production value. This is a realistic requirement, as production would not be profitable if costs exceeded the production value. The assumption thus becomes

$$(6)\ TC \ \leq prod.val$$

I will also assume that we have a proportional relationship between costs and production value. Therefore, a 25 % increase in electricity usage, will lead to a 25 % increase in total costs – which includes electricity costs – as well as production value. There can be several reasons why this might be an oversimplification of the reality, especially considering economies of scale – the reduction in per unit costs as production increases. Haldi and Whitcomb (1967) found that, for basic industries such as primary metals, economies of scale mostly occur in the initial investment costs, in the operating labor costs and through learning curve effects. Given the highly automated nature of process industries today, I expect that the scale effects of investments will be even larger, emphasizing the possibility of production value increasing more than proportionately in some instances. However, due to the data available and to emphasize the effects of the 10 GWh threshold, the assumption of proportionality is upheld. The assumption thus becomes

$$(7)\ x\% \uparrow EC \rightarrow x\% \uparrow TC\ and\ x\% \uparrow prod.val$$

Where x is the chosen percentage level, which in the base scenario is 25%.

The compensation at 10 GWh for each 3-digit NACE group is necessary to conduct the comparisons. For some of the groups there are energy efficiency standards. In said groups, I have chosen to average the standards, as mentioned earlier in chapter 4. This is used to calculate the production and compensation at 10 GWh for each NACE group in three different scenarios – low-price, medium-price and high-price scenarios. The costs are divided into two options.

$$(8)\ TC = prod.val$$

$$(9)\ TC = \frac{1}{2} prod.val$$

The first option would imply that the production is not profitable, and that revenues = 0, and the second option is where total costs is half of the production value. Since we do not know the true cost structure of the industries at the 3-digit level, I believe these are reasonable scenarios to assess. Production value is reported in million NOK and represents the true production value of the industry groups as reported by Statistics Norway[1].

The production value, cost level and compensation are then compared to the "status quo" level of said variables at 8 GWh. For all industries I calculate the production value/GWh by dividing the production value by the electricity consumption. In the base-scenario, I then multiply this value by 8 – getting the production value/GWh at 8 GWh. The comparison between the base scenario and the 10 GWh scenario is done by dividing the relative increase in the values by the value of the compensation. The marginal effect of moving from 8 GWh to the threshold and thus receiving the compensation is then discovered. For instance, if the compensation divided by $TC = prod.val$ = 0,2, then the compensation would cover 20 % of the cost increase in that specific scenario. The results will be presented in chapter 5.

4.4.1 Description of variables

Production value/GWh

As explained above, the production value/GWh is calculated and used in the analysis. I have estimated the average development of the variable from 2008-2019 and calculate an assumed average production value/GWh in the coming years. I have done so by looking at the slope of the linear trend line, multiplied the slope by 11 and added it to the average from 2008-2019. 11 being the average number of years in each period (2008-2019 and 2021-2030). I assume

[1] https://www.ssb.no/statbank/table/12910 reporting data from 2017 to 2019,
https://www.ssb.no/statbank/table/08596/ reporting data from 2007 to 2017

this value of production value/GWh to be representative for the 2021-2030 period. For the Manufacture of pulp, paper, and paper products (17.1), for instance, the average from 2008-2019 was 3,13 million/GWh. The slope of the trend line was 0,0778, which multiplied by 11 is 0,8558, meaning I have assumed production value/GWh at 3,98 million NOK in that industry group in the analysis.

Average energy efficiency standard

For the NACE groups with efficiency standards, I have averaged the values by adding them and dividing by the total number of standards. The standards are applied to specific products within each industry group. Since I look at the 3-digit level, the application of specific product standards would not be possible to implement in the analysis. Given that I am assessing more of an overall effect for the industry group, the average is assumed to be representative of the effects for the group.

Energy costs as share of production value

I estimate the energy costs as share of production value by dividing energy costs on production value. I then use the development of this share over the 2008-2019 period to estimate an assumed average energy costs/production value share for the coming years using the same method as for production value/GWh. For Production of basic metals (24.4), for instance, energy costs/production value was 0,10 in the 2008-2019 period. The slope of the linear trend line was 0,001, which multiplied by 11 is 0,011. I have thus assumed that this share will be 0,11, or 11 %, in the coming years. This is not used directly in the analysis but presented as characteristics of the industry groups that might help explain the differences in the compensation's share of the cost increase between the industry categories.

5. Results

5.1 Calculation of increased electricity costs

Assume 8 GWh as the base usage, and that the business increases its consumption by 2 GWh, making all electricity used eligible for compensation[2], and an additional cost only linked to the added 2 GWh. For simplicity, we do not include investment costs and other revenues. This would be necessary to get the correct NPV, however, this example is only meant to portray

[2] Based on the Regulation of CO_2-compensation for the industry, there are no limitations as to what fraction of the electricity consumed that are eligible for compensations if it is used in the production of eligible products. I will, therefore, assume that all electricity is covered in the calculation, and not the "excess" above 10 GWh.

the ideal method to assess the 10 GWh threshold. I will base my calculations upon the suggested new regulation and the previous regulation where there are no updated numbers yet, such as the alternative standard, as described in chapter 3.2.3 and 5.1. We assume a carbon intensity factor at 0,53 t/CO_2/MWh, in accordance with the suggested carbon intensity factor, the same alternative standard as in the previous regulation, at 0,8, and the aid intensity at 0,75, which is in accordance with the new suggested regulation. The EUA price is projected to increase sharply throughout the 2021-2030 period. I will use a low-price estimate, a medium price estimate and a high price estimate for the calculations. These values for EUA prices and electricity prices are based upon NVE calculations (NVE, 2021). EUA prices are adjusted for today's (30.03.2022) EU ETS price at 80,81 € (Ember, 2022). The low-price estimate will assume an average EU ETS price of 50 €/tCO_2, the medium price estimate assumes an average EU ETS price of 61 €/tCO_2, and the high price estimate assumes an average EU ETS price of 90 €/tCO_2 for the 2022-2030 period[3]. The electricity price will follow similar patterns, with a low-price estimated average of 41 øre/kWh, a medium price estimated average at 51 øre/kWh and a high price estimated average at 64 øre/kWh.

We will use equation 5. The cash flow will depend on how the compensation is calculated, as explained in chapter 3.2.3. In this example, we assume that there are no other changes than increased electricity consumption, and thus production will not increase accordingly. Recall that there are no initial investments in this example, only increased electricity costs. The different values that are being used in the calculation can be seen in Table 8. I have used the average exchange rate from 16. March 2021 to 16. March 2022 to convert values from Euros to NOK, which according to ECB was at 10,10. This is representative for the development over the past four years (ECB, 2022).

	Estimation of NPV of compensation		
	Low	Medium	High
EU ETS (NOK/tCO_2)	505	616	900
Electricity price (kr/MWh)	410	510	640
Carbon intensity factor (tCO_2/MWh)	0,53	0,53	0,53
Alternative standard	0,8	0,8	0,8
Aid intensity	0,75	0,75	0,75
Additional costs (2 GWh)	-820000	-1020000	-1280000
Additional costs (3 GWh)	-1230000	-1530000	-1920000
Additional costs (4 GWh)	-1640000	-2040000	-2560000

Table 8: Values for NPV calculation

[3] Based upon the calculations of NVEs Langsiktige Kraftmarkedsanalyse 2021-2040 (https://publikasjoner.nve.no/rapport/2021/rapport2021_29.pdf)

To estimate the NPV of this scenario, we would need all costs and revenues, including the investment costs and compensation payments. We would use equation 5, plotting in all costs, revenues, and a discount rate, for all relevant years. This calculation, however, looks at the isolated effect of increasing electricity consumption without increasing the capacity. I have calculated the compensation using the calculation method presented in the amended regulation, as described in equations (3) and (4). I, thus, compare the additional costs of increasing electricity consumption with 2, 3 or 4 GWh compared to the compensation received. The results of the calculations can be seen in Table 9 Profitability calculation of increased electricity consumptionTable 9. As can be seen, the profits of the increased electricity costs when accounting for the eligibility of compensations is positive for all scenarios at a 2 and 3 GWh increased consumption. A rational, profit maximizing firm will, in this example, increase its electricity consumption to become eligible for compensation. For increases in electricity consumption from 4 GWh per year, it is only the high-cost scenario that yields profits when only looking at increased electricity costs and compensations at the 10 GWh threshold.

Profitability calculation			
	Low	Medium	High
EU ETS (NOK/tCO_2)	505	616	900
Electricity price (kr/MWh)	410	510	640
Carbon intensity factor (tCO_2/MWh)	0,53	0,53	0,53
Profits of increased el.consumption (2 GWh)	kr 785 900	kr 938 880	kr 1 582 000
Profits of increased el.consumption (3 GWh)	kr 375 900	kr 428 880	kr 942 000
Profits of increased el.consumption (4 GWh)	-kr 34 100	-kr 81 120	kr 320 000

Table 9 Profitability calculation of increased electricity consumption

If we were to include the investments, which would be necessary for the NPV analysis of the investment decision to be applicable, the results might be different. The lack of investment data is why NPV analysis of the investment decision is not the chosen method for this thesis.

5.2 Results using chosen method

The analyses were conducted for all NACE groups. Of the six, there are only businesses within four of them who have received compensations during Phase III (2013-2020). I have used relevant production value data and made assumptions regarding the cost structure of the productions. They vary according to the production values and have been set at costs = production value and costs = ½ production value. The assumptions are as mentioned in chapter 4,

$$(6)\ TC \ \leq prod.val$$

and

$$(7)\ x\% \uparrow EC \rightarrow x\% \uparrow TC \ and \ x\% \uparrow prod.val$$

The low-, medium-, and high-price scenarios are based upon the same electricity and EUA prices for all sectors. The different compensation calculation methods for productions with energy efficiency standards and those without have been used in all NACE groups. This way, I get to see the differences between the calculation methods, and thus the differences in compensation for productions with and without efficiency standards. I have calculated the average efficiency standard in each NACE category. For the industries without energy efficiency standards, the alternative standard is applied as the efficiency standard. The production level at 10 GWh is calculated based upon the alternative standard, which is then used to calculate the compensation in the "with energy efficiency standard" calculation method. I do this to be able to compare the different calculation methods for all NACE categories. The data needed and used for calculating the compensation is shown in Table 10 below. The x in the average efficiency standard row is replaced with the average efficiency standard for each industry category, or the alternative standard where there are no efficiency standards. An example with an efficiency standard could be an average of 5 tonnes/MWh, in which case the production level would be 2000 tonnes at a 10 GWh consumption level. Without an efficiency standard, where the alternative standard is applied, i.e., 0,8 tonnes/MWh, the production level will be 2500 tonnes at a 10 GWh consumption level.

Compensation calculation							
With energy efficiency standard				**Without energy efficiency standard**			
	Low	Medium	High		Low	Medium	High
EU ETS (NOK/tCO_2)	505	616	900	EU ETS (NOK/tCO_2)	505	616	900
Electricity price (kr/MWh)	410	510	640	Electricity price (kr/MWh)	410	510	640
Carbon intensity factor (tCO_2/MWh)	0,53	0,53	0,53	Carbon intensity factor (tCO_2/MWh)	0,53	0,53	0,53
Average eff.standard	x	x	x	Alternative standard	0,8	0,8	0,8
Aid intensity	0,75	0,75	0,75	Aid intensity	0,75	0,75	0,75

Table 10 Data for calculation of compensations

Total costs are assumed to cover electricity costs but given the structure of EUA prices affecting electricity prices, we can also assume that the electricity costs will differ between the scenarios. I have therefore added the added electricity costs in each scenario. I have assumed an average 2020 price of 230 NOK. The EUA price assumed in each scenario is then used against the baseline of 230 NOK. I will also assume that the carbon intensity factor shows the degree of EUA prices' effect on Norwegian electricity prices. This will be discussed in the discussion. The calculation for the cost increases thus becomes

$$(10) \qquad TC_{10GWh} = TC_{8GWh} * 1{,}25 + ((P^{EUA} - P^{EUA}_{2020}) * 2\ GWh)$$

Since the same EUA prices are used for all industries, the $((P^{EUA} - P^{EUA}_{2020}) * 2\ GWh)$ fraction of the equation becomes as shown in Table 11 for all industries.

Electricity cost increase at 2GWh		
Average EUA price 2020	236	NOK/tCO_2
Carbon intensity factor	0,53	
Added costs low-price scenario	0,29	mill. NOK
Added costs medium-price scenario	0,40	mill. NOK
Added costs high-price scenario	0,70	mill. NOK

Table 11 EUA price effects on electricity costs

The addition of the increased electricity costs on total costs is why production value differs from costs = production value in the results. Production value is included to emphasize that the increased capacity will not only involve increased costs, but also increased production possibilities and potential profits. From Phase III (2013-2020) to the suggested scheme in Phase IV (2021-2030) there has been an increase in the number of productions covered by an efficiency standard. It can be assumed that this trend will continue, possibly making the calculation method using efficiency standards more relevant. I have thus used the alternative standard as a substitute for the energy efficiency standard in this calculation

The results under the different scenarios and assumptions shown above for the categories that are covered by the compensation scheme and in which there are businesses who have received compensation, are presented below.

17.1 (21.1) Manufacture of pulp, paper and paper products

In this category, the scenarios analyzed were in accordance with the description in chapter 4 and above. The original production value at 8 GWh was at 31,85 million NOK and costs = ½ production value was thus 15,92 million NOK. Under the different price scenarios, the results were as shown in Table 12 below. As can be seen, the efficiency standard leads to compensations taking on a larger share of the cost increase compared to productions where the alternative standard is being used, ranging from 24 % to 76 %, compared to 19 % to 61 %. For productions with efficiency standards, the compensation alone could therefore cover almost all of the cost increase related to increased electricity consumption. In this specific category, there are many efficiency standards for different products, such as cardboard, covered tissue etc. The standards range between 0,26 to 0,93 MWh/t produced (EC C(2021) 8413 final). The average efficiency standard at 0,51 MWh/t used in this analysis is likely representative. We can also see that there is a clear positive relationship between the EUA price and the compensation payments, which is as expected given that the compensation seeks to ease the burden of increased EUA prices on the industry's costs. In a high-price scenario, in which costs = production value, i.e., no profits, and with high EUA prices (900 NOK/tCO_2), the compensation would account for 41 % or 33 % of the cost increase of increasing electricity consumption by 2 GWh, when accounting for the increased electricity price. In a low-price scenario, with costs = ½ production value and EUA price at 410 NOK/tCO_2, the compensation would make up 47 % or 38 % of the cost increase respectively. For productions in this category, energy costs as share of production value was 10 % on average from 2008 to 2019. Given the growth within this period, I estimated that the assumed average will remain at 10 % in the coming years.

17.1 (21.1)	**Compensation as share of cost/prod.val. increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,25	0,31	0,45	0,20	0,25	0,36
Costs = prod.value (mill. NOK)	0,24	0,29	0,41	0,19	0,23	0,33
Costs = 1/2 prod.value (mill. NOK)	0,47	0,56	0,76	0,38	0,45	0,61

Table 12 Results for 17.1 (21.1) base scenario

20.1 (23.1) Manufacture of refined petroleum products, chemicals, and chemical products

The original scenario in this category at 8 GWh consumption was a production value = 40,25 million NOK and costs = ½ production value = 20,13 NOK. The results under the different price scenarios can be seen in Table 13 below. In this category, we again see that the efficiency standards lead to more beneficial compensation shares compared to the alternative standard, ranging from 19 % to 62 % compared to 16 % to 50 %. In the high-price scenario with costs = production value, i.e., no profits, and EUA price at 900 NOK/tCO_2, the compensation would account for 33 % or 27 % of the cost increase by increasing electricity consumption from 8 GWh to 10 GWh, when accounting for the increased electricity costs. In the low-price scenario, with costs = ½ production value and EUA prices at 410 NOK/tCO_2, the compensation could make up 38 % or 30 % respectively. The average energy costs/production value was 6 % between 2008 to 2019 and is estimated to be 8 % in the coming years.

20.1 (23.1)	Compensation share of cost/prod.val. increase					
	With efficiency standard			Without efficiency standard		
	Low	Medium	High	Low	Medium	High
Production value	0,20	0,24	0,36	0,16	0,19	0,28
Costs = prod.value (mill. NOK)	0,19	0,23	0,33	0,16	0,19	0,27
Costs = 1/2 prod.value (mill. NOK)	0,38	0,45	0,62	0,30	0,36	0,50

Table 13 Results for 20.1 (23.1) base scenario

23.1 (26.1) Manufacture of other non-metallic mineral products

In this category, there are relatively few products who are covered by the compensation scheme. There have, to date, not been any producers who have received compensation within the group. This makes the comparison of the results presented for this group relative to the other groups where there might be many recipients interesting. The original production value at 8 GWh = 83,63 million NOK and costs = ½ production value = 41,82 million NOK in this category. In the high-price scenario, the compensation would cover 17 % or 13 % of the total cost increase of increased electricity consumption for productions with energy efficiency standards and productions without such standards respectively. The results show that the efficiency standard calculation method would lead to more beneficial conditions for the recipients. In this category there are no energy efficiency standards. The coverage differs between 9 % to 32 % in the efficiency standard grouping, and between 8 % and 26 % in the alternative standard grouping. Energy costs made up 2 % in the productions within this category in the 2008 to 2019 period, with limited growth, and I have estimated that the share will continue to be 2 % in the coming years. We can already see that this industry category differs from the previously covered ones, both in terms of compensation's share of costs, but also the energy cost's share of production value.

23.1 (26.1)	Compensation share of cost/prod.val. increase					
	With efficiency standard			Without efficiency standard		
	Low	Medium	High	Low	Medium	High
Production value	0,10	0,12	0,17	0,08	0,09	0,14
Costs = prod.value (mill. NOK)	0,09	0,11	0,17	0,08	0,09	0,13
Costs = 1/2 prod.value (mill. NOK)	0,19	0,23	0,32	0,15	0,18	0,26

Table 14 Results for 23.1 (26.1) base scenario

24.1 (27.1) Production of basic iron and steel and of ferro-alloys

The 24.1 group have had a stable group of recipients of compensation, with 13 businesses receiving funds most year. In the original scenario at 8 GWh consumption, production value = 21,83 million NOK and costs = ½ production value = 10,92 million NOK. As we can see in Table 15 below, the high-price scenario for this production category with zero profits, total costs = production value and EUA price at 900 NOK/tCO_2, the compensation would make up 58 % of the increase in total cost because of the increase in GWh consumed, accounted for the increased electricity costs. In the low-price scenario, with costs = ½ of production value and low EUA prices, the compensation would make up 67 % of the increased costs. Producers in this category could increase electricity consumption and get 104 % of the cost increase reimbursed in the scenario with the EUA price at 900 NOK/tCO_2 and costs = ½ production value, meaning that the absolute profits would also increase by 4 %. This is not accounting for the increased production value, which also would affect profits. Again, the efficiency standards lead to more beneficial conditions for the recipients, ranging from 35 % to 104 %, whereas for the productions without an efficiency standard the compensation would make up between 28 % to 83 %. This is one of the production groups in which energy costs makes up a significant share of production value. From 2008 to 2019, the energy costs were, on average, 11 %. Given the developments within the period, I have estimated that the average energy costs/production value share will be 14 % in the coming period. This could be part of the explanation of the very positive impacts of the compensation's share of the cost increase.

24.1 (27.1)	**Compensation share of cost/prod.val. increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,37	0,45	0,66	0,29	0,36	0,52
Costs = prod.value (mill. NOK)	0,35	0,42	0,58	0,28	0,33	0,46
Costs = 1/2 prod.value (mill. NOK)	0,67	0,78	1,04	0,53	0,63	0,83

Table 15 Results for 24.1 (27.1) base scenario

24.4 (27.4) Production of basic metals

This is the category in which we find aluminum, among other products, which is a production that receive significant compensation payments. The original scenario at 8 GWh consumption was production value = 21,73 million NOK and costs = ½ production value = 10,87 million NOK. The high-price scenario in this category, where costs = production value and EUA price at 900 NOK/tCO_2, the compensation would make up 58 % for productions with efficiency standards and 47 % for those without. The low-price scenario, with costs = ½ production value and EUA price at 410 NOK/tCO_2, would lead to a coverage of 67 % or 53 % respectively. We can see similar patterns regarding the efficiency and alternative standards here, ranging from 37 % to 105 % and 28 % to 84 %, respectively. The efficiency standard case also leads to a slightly higher "leap" in compensation's share of costs from the medium to high-price scenario compared to the alternative standard case. We can see that this leap is apparent in all scenarios and is increasing as the cost decreases. The average energy cost share on production value in this category was 10 % from 2008 to 2019. Given the growth within the period, I have estimated that the potential share in the coming years will be 11 %. This, same as with NACE category 21.1, can explain the beneficial structure of the compensation scheme for productions within the industry.

24.4 (27.4)	**Compensation share of cost/prod.val. increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,37	0,45	0,66	0,30	0,36	0,53
Costs = prod.value (mill. NOK)	0,35	0,42	0,58	0,28	0,34	0,47
Costs = 1/2 prod.value (mill. NOK)	0,67	0,78	1,05	0,53	0,63	0,84

Table 16 Results for 24.4 (27.4) base scenario

5.3 Sensitivity analysis

To assess the validity of the results, I have conducted a series of analyses for the most "relevant" production processes. That is, the ones in which compensation make up a significant share of the total cost increase of increased electricity consumption. That includes all analyzed NACE-categories.

5.3.1 Scenario 1: 50 % increase in costs and electricity consumption

In the original estimation, I assumed that the percentage increase in electricity consumption, costs and production value was 25 %. This entailed an increase in electricity consumption from 8 GWh to 10 GWh. For this scenario, I have assumed an increase of 50 %, entailing an electricity consumption level at 12 GWh. This can be relevant as it might be difficult to exactly reach the 10 GWh threshold, making further increases in the electricity consumption a possibility. The electricity prices and EUA prices are the same as in the base scenario. The full results for each production process can be found in Appendix C. The patterns are similar to the base scenario, with the shares being somewhat lower. For 17.1 (21.1) paper and pulp, the lowest compensation shares of the cost increase between the two calculation methods (with efficiency standard and without) was 15 % and the highest was 46 %. For 20.1 (23.1) refined petroleum, chemicals etc., the range decreased to between 9 % and 37 %, and for 23.1 (26.1) non-metallic minerals, the range was between 4 % and 19 %. For 24.1 (27.1) iron, steel and ferro-alloys, the variation was between 17 % and 63 %, whereas for 24.4 (27.4) basic metals, the share ranged from 18 % to 63 %. This shows that, for some industries, the compensation can cover a significant share of the cost increases of increased electricity consumption even with larger changes.

5.3.2 Scenario 2: lower EUA prices

In this scenario, I have assumed a 30 % reduction in the EUA prices in each alternative. The low-, medium- and high-price alternatives thus becomes 353,5, 431,2 and 630 NOK/tCO_2, respectively. Other factors remain the same, and the calculation method for the compensation are also kept equal to the base scenario. The values of the compensation will, however, differ from the base scenario, due to the EUA price affecting the magnitude of the compensation. Electricity costs are, as in the base scenario, included in the total costs, and the increases in costs and electricity consumption are the same as the base scenario – from 8 GWh to 10 GWh. The increase in electricity costs due to increased EUA price is accounted for and added to the total costs. For tables including all results, see Appendix D. For productions in NACE-group 17.1 (21.1) paper and pulp, the compensation's share of the cost increase was between 14 % to 57 % between both compensation calculation methods in this scenario. For 20.1 (23.1) chemicals etc., the variation was between 11 % to 46 %, and for 23.1 (26.1) non-metallic minerals the share ranged between 5 % and 23 %. For 24.1 (27.1) iron and steel, the share ranged from 20 % to 80 %, with the same range for 24.4 (27.4) basic metals. Even under this scenario, with the "high" price being well below today's (30.03.2022) EUA price at 80,81 €/tCO_2 (Ember, 2022) the compensation could still cover a significant share of the increased costs of increasing the electricity consumption for some industries.

6. Discussion

The results show that the compensation scheme largely benefits the industries. The fraction of the cost increases of increased electricity consumption that are covered by the compensation are quite high for most production processes, and in some cases, it even exceeds the cost increases. Under the different scenarios analyzed, it is apparent that some industries can maintain a high level of compensation's share of costs under different conditions and might be more robust to changes in EUA prices and production costs. What can this entail for the incentives the industries have to become more energy efficient, and improve their relative climate performances?

As mentioned in this thesis, the effects of the compensation scheme have not been well studied previously. Most empirical and theoretical studies relate to the effects of the EU ETS on different aspects, Martin et al. (2014b) have, for instance, looked at the effects on relocation risk when emission permits are allocated free of charge, and found that the allocation of free permits results in substantial overcompensation given the carbon leakage risk. The isolated effects of the compensation scheme have proven difficult to assess through previous literature. Some relevant studies exist, Ferrara and Giua (2020) looked at the scheme's effect on firms' outcomes and Thema (2020) has investigated industry managers' opinion on the scheme's importance in Norway. Ferrara and Giua (2020) found some evidence that higher levels of subsidies marginally reduce the risk of carbon leakage. Thema (2020) found that industrial managers in EITE industries in Norway expressed an unwillingness of their consumers to pay for more climate friendly options. They concluded that it is likely that the compensation scheme has reduced the carbon leakage among Norwegian recipients. For some production processes other energy goods are important inputs – such as coal in alloy processes. Prosess21 (2020) points out that these energy goods are the ones that need to be reduced for the industry to become climate neutral, indirectly telling that the industries' space for climate action is not primarily within the electricity usage. This could be a reason why the compensation's effect on the businesses' electricity consumption has not been investigated properly.

6.1 The results and the design of the scheme

The results for each NACE industry category were presented in chapter 5 and showed differing results for the different product groups. NACE group Manufacture of other non-metallic mineral products (23.1 (26.1)) was the one with the lowest coverage share, at 18 % to 32 %, which is still a substantial amount. For industries in iron and steel and basic metals, the compensation could make up more than the increased costs even when accounting for increased electricity prices due to increased EUA prices – even though the carbon factor of 0,53 most likely is overestimated. This will be discussed in chapter 6.2.

One important possible shortcoming of this analysis relates to the chosen method. As thoroughly described in chapter 4, there is a huge lack of detailed data for the industries that would be beneficial to have to assess the full picture of the effects of the compensation. This means that I had to "move up" to the 3-digit NACE code level, which in turn reduces the possibilities to assess the more refined characteristics of each product covered by the scheme. The ideal way of analyzing the effect of the compensation scheme would be to conduct a NPV analysis of production processes and businesses at the 4-digit level, at the minimum, with detailed information regarding their cost and revenue structures, as well as the investments needed to increase the capacities. This way, I could have assessed the entire effect of the compensation scheme, and not just the 10 GWh threshold. The chosen method is based upon some assumptions regarding the cost structure of the industries, which I believe are reasonable, but which does not give detailed information as to what the costs are. If, for instance, increased production would require an extra work shift, the costs might not be proportional. These are the details that would be interesting to assess to get the full picture of the possible effect of the compensation scheme, that unfortunately are not available.

By using the production value/GWh, rather than for instance tonnes/GWh, I can make the method translatable between the industries. One tonne aluminum is quite different from one tonne chlorine, for instance. Looking at the increases in costs, production value and compensation by increasing electricity consumption by 25 % does, despite its shortcomings, tell us something about the impacts of the compensation on the different industries. These impacts are highly relevant in the discussion of the effect of the compensation scheme on carbon leakage, but also on how the design of the scheme might affect industries given the possible future developments of the EUA prices.

The 10 GWh threshold does, however, have interesting features making it highly relevant to address. It does require a minimum consumption level, which in turn can facilitate further increases in electricity consumption, which might be problematic. This will form the basis for the further discussion. Without knowing the cost structure of each production, it is not hard to imagine that a producer of glass fiber mattes (23.1) requires less infrastructure, area, work hours, electricity etc., than a producer of aluminum (24.4). The results I have shown are in line with which businesses who have received the most compensation so far. The categories with the highest shares shown in the results are also the industries in which businesses have received the most support so far. Given the data description in chapter 4, we can also see that the industries with the highest shares are also the ones with high levels of electricity consumption. The energy costs also make up a larger share of total costs in these industries. These are all structural characteristics that might help explain how the compensation could make up such a large share of the cost increase.

The design of the scheme will, because of the threshold, favor larger businesses within the EEA. This could have important implications not just for the profitability of businesses affected, but also social implications and environmental effects. By favoring larger businesses, the barriers to entry for smaller businesses might increase, which in turn can lead to a centralization of economic activity within the eligible industries. Ferrara and Giua (2020), for instance, finds that for firms who are a part of a group of multiple businesses or an international company and receive compensation, the value of total assets increases with 13-14 % when compared to stand-alone businesses who do not receive compensation. In the Norwegian context, this might have adverse effects on other policy goals – such as rural policies, which – among other things – aims at maintaining settlements and livelihoods in rural areas. It can also harm the competitiveness of smaller businesses within the EEA. A lack of competition within energy-intensive sectors in the EEA, with foreign emission-intensive and trade-exposed industries not being subject to climate policies, could impact the incentives to become more energy- and climate efficient in the European production processes.

On the other hand, it can be argued that larger businesses will provide more jobs, which will have positive social impacts. Many of the larger industries in Norway are in smaller cities or rural areas, such as Skogn (Norske Skog), Lista (Alcoa) and Husnes (Sør-Norge Aluminium). It could be argued that, by keeping large businesses competitive, the local communities' benefits from the value creation by such firms, which can support rural policy goals. Ferrara and Giua (2020), however, finds that businesses receiving compensation on average reduces their number of employees with 4,4 %, and for recipients in the aluminum sector the number of employees is reduced by 16 %. Their findings suggests that turnover per employee is not affected by the indirect cost compensation. Most of the arguments related to the scheme can be framed to pros and cons. The results in this thesis do, however, show that the compensation does cover a significant amount of the cost increases in most productions and in most scenarios.

6.2 The carbon factor of electricity

The results show that, given the beneficial structure of the design of the compensation scheme, the industries might be incentivized to increase their electricity consumption. In Norway, given the low carbon factor of electricity, the effects on emissions might not be too large today. The carbon factor will be discussed in this chapter. However, with increased transmission capacity to, and the higher carbon factor of electricity in, mainland Europe, the absolute effects on emissions might change in the coming years. There is a lot of uncertainty regarding the energy mix in the EU in the coming years. The goal of reaching climate-neutrality by 2050 will require large investments in renewable energy production on the continent. As seen in Figure 10 below, most EU countries reached their renewable energy targets for 2020, or even exceeding them. This points to a development towards increased renewable energy shares, and thus possibly lower carbon intensity of electricity consumption in Europe in the coming years. However, one of the markets in which the Norwegian price is most affected, is the German market (Pöyry, 2019). The transmission capacity between Norway and other European countries are mainly to Sweden, Denmark, Germany, and the Netherlands. Looking at the renewable energy share in said countries, both Germany and the Netherlands perform worse than the EU average. There could be an increase in the imported carbon intensity of electricity consumed in Norway through the increasing trade with these partners. If the total energy demand in EITE industries increases due to the compensation scheme coupled with possible increased trade in electricity, this could entail negative external effects.

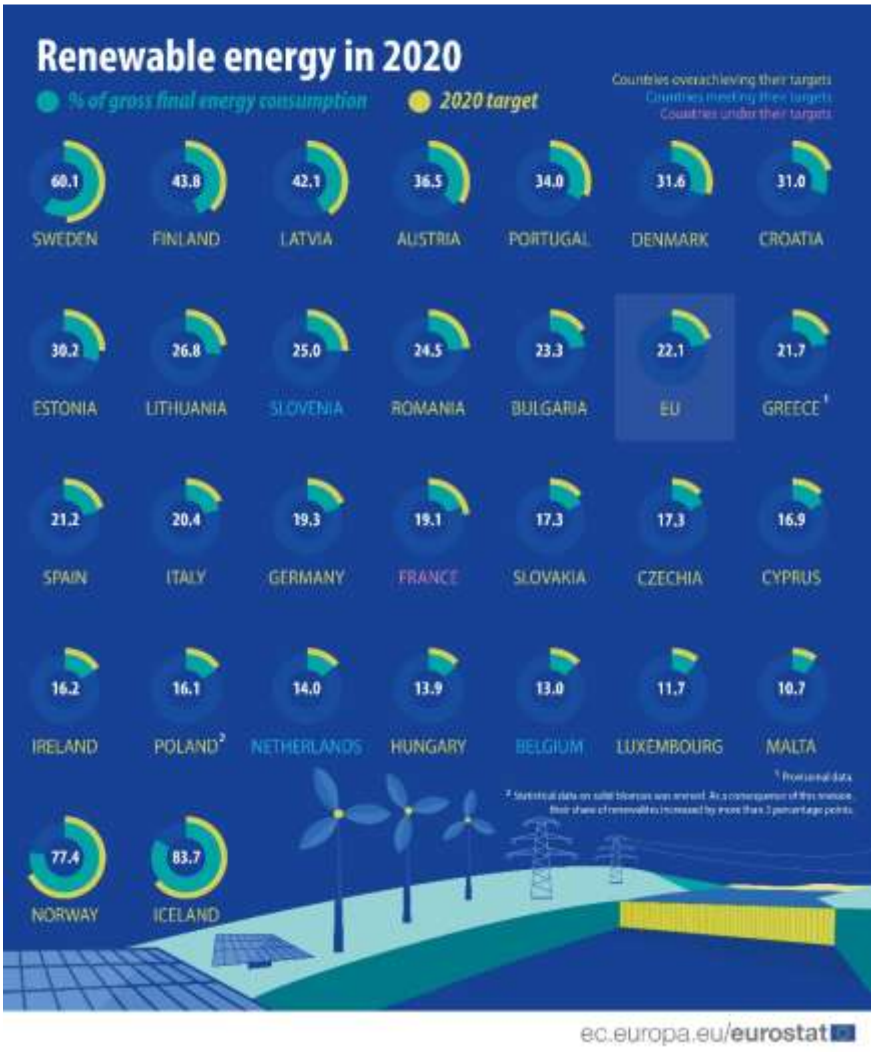

Figure 10 Renewable energy shares in European countries

An overview provided by NVE (2022) shows that the emission intensity of electricity consumed in Norway is very low – 17 gCO_2e/kWh in 2019, 8 gCO_2e/kWh in 2020 and 11 gCO_2e/kWh in 2021. In comparison, the carbon factor of electricity consumed in Germany was 278 gCO_2e/kWh on the 28.04.2022, with trade patterns showing that they were in fact importing greener electricity at that time[4], meaning that the carbon factor can be higher in other periods. NVE's (2022) calculations assume that imported electricity is produced in the country where it is imported from. This might not be the case, and the "real" emission intensity might be higher than reported. In North Norway, the emission intensity on the 10th of May is at 38 g CO_2e/kWh[5], for instance. Despite some possible flaws with this calculation method, it signals the most important characteristics for this discussion – that electricity consumed in Norway is not emission intensive relative to other EEA countries.

The carbon intensity factor used in the calculation for compensation in Norway at 0,53 is, therefore, higher than the actual emission intensity of electricity consumed in Norway. This can lead to an overestimation of the EUA prices' effect on Norwegian electricity prices and, therefore, also the compensation.

6.3 Carbon leakage and competition distortion

The goal of the compensation scheme is to avoid carbon leakage to reach climate goals and reduce global emissions, while keeping European-located industries competitive. There is, however, limited empirical evidence of the real effects of the compensation scheme. Thema (2020) concludes that it is "likely" that the scheme has contributed to reducing the risk of carbon leakage among Norwegian industries. However, criticism (Statistics Norway, 2021) has been pointed at the limited data that is being used in that analysis. Thema's (2020) choice of method was interviewing industrial managers in compensated businesses, who concluded that the scheme was very useful to them. There might, thus, be an inevitable bias in how the respondents would frame and view the scheme. Norsk Industri's (2021) response to the suggested regulation stated that the scheme is "Invaluable for the Norwegian industry (…)" and defines the CO_2 compensation as "established to compensate businesses' actual additional costs because of increased electricity prices because coal- and gas-fired power plants must buy CO_2 permits." The estimated energy costs as share of production value within the processes was presented in chapter 5.1, ranging from 2 % to 14 % between the industry groups. The industries with the highest share were the iron and steel industries at 14 % and basic metals at 11 %. At the same time, their respective compensation coverage of increased costs did not fall below 28 %. Given the assumption that production value is translated into the costs, only 14 % or 11 % of the increased costs accrue to electricity costs. It can be shown, by the results of the analysis, that the compensation makes up a significant share of the

[4] Live electricity map https://app.electricitymap.org/map
[5] Live electricity map https://app.electricitymap.org/map

increase in costs due to increased electricity consumption, also when accounting for increased electricity costs. In NACE group 24.1 iron and steel, for instance, the coverage share does fall below 17 % in any of the scenarios analyzed, and in the base scenario when moving from 8 GWh to 10 GWh, it does not fall below 28 % in any of the price alternatives. The lowest percentage is reached where costs = production value, the compensation is calculated without efficiency standards, and at an EUA price of 50 €. This could be argued to be one of the least realistic alternatives in the base scenario, as the EUA price has not fallen below 58 € yet in 2022 (Ember, 2022). Therefore, it might be that the compensation scheme covers more than the "actual additional costs", at least for businesses moving from below the 10 GWh threshold to above.

The evidence points to the compensation scheme coverage exceeding what it was intended to. State Aid rules within the EU prohibits State aid unless it is exceptionally justified (OJC115/2008/Article 107, p. 0091-0092 (TFEU)). The Treaty also states that aid can be considered granted if it is an "(…) aid to facilitate the development of certain economic activities or of certain economic areas, where such aid does not adversely affect trading conditions to an extent contrary to the common interest." The compensation scheme has been implemented as one of the "justified" measures that enables State aid for the issue regarding indirect emission costs through electricity costs for EITE industries. The Treaty, however, defines that such support should not adversely affect trading conditions. If Norwegian producers are being over-compensated, that is, compensated beyond their actual cost increases due to the EU ETS, their relative competitiveness will be affected. It could then be argued that the relative cost level in Norway compared to other EU countries is higher, Statistics Norway (2021b) estimates that the consumer prices in Norway is 36 % higher than the EU average. I use total costs in my analysis, and given that the industries covered are EITE industries, we can assume that they are faced with market prices. Market prices for EITE goods and important inputs can be assumed to not vary a lot given the characteristics of the industries. The beneficial structure of the compensation scheme is, thus, still apparent.

The subsidy therefore has a trade-distorting effect that might be affecting other member states disproportionately. If so, this could conflict with Article 107 of the TFEU, but since the compensation scheme is implemented by the EU it would indicate that this would be an "exceptionally justified" arrangement. The compensation makes up a deadweight loss that must be weighed against the carbon leakage risk and the following negative effects.

As mentioned, the scheme comes with a set of rules and recommendations. One of them being that the compensation should not make up more than 25 % of total auctioning revenues for the State. In Norway, this share has been almost 10 times higher, at above 200 %. This issue also relates to the State aid rules in the EU, and how they should not be trade distorting. The compensation scheme is voluntary, which will lead to a skewed distribution of which countries might be able – or have a willingness – to implement it. Ferrara and Giua (2020, p. 16) concluded that "the EU ETS indirect cost compensation on average did not have an impact on per worker measures, thus pointing to the absence of market distortions due to the compensation." Norway has a history of supporting or protecting different industries in different ways, such as the extensive protection of the agricultural industry. The compensation scheme seems to be in "true Norwegian spirit" in that sense. Despite Ferrara and Giua (2020) pointing towards the, on average, absence of market distortion, with the total support level highly exceeding the recommended amount, combined with my results and the theoretical effects of a production subsidy, there might be evidence pointing towards the scheme having some effects on the competitiveness of Norwegian producers.

As Martin et al. (2014b) concluded, the structure of free allocation alone led to significant overcompensation given the risk of carbon leakage. Adding the additional compensation to that would indicate that the "significant overcompensation" would be further increased.

The CBAM has been suggested as an alternative to the EU ETS for EITE products. The design is such that it will function as a carbon tariff equivalent. While not all compensation eligible industries are currently covered by the EU ETS, this will impact the industries that are covered by the ETS. The five sectors that are to be covered at first are cement, iron and steel, aluminum, fertilizers, and electricity. Indirect emissions are not to be covered initially, and the compensation scheme will not be discontinued at first. Indirect emissions are to be considered included after the 2023-2025 transition period. If included in the Mechanism, the compensation scheme would need to be phased out. Assous et al. (2021) argues that the effects of including the indirect emissions will be negligible given the increasing share of renewable energy in Europe, and that the compensation scheme will be "naturally" phased out by this. They also argue that the inclusion of indirect emissions would be too troublesome given the relatively low impact on most sectors, apart from aluminum, when looking at the trade situation with China. Figure 11 shows the total CBAM paid for Chinese goods in 2026 and 2035 under different EUA allocation and CBAM covered emissions scenarios. In 2035, the free allocation is reduced to zero, which is why it is increasing (Assous et al., 2021).

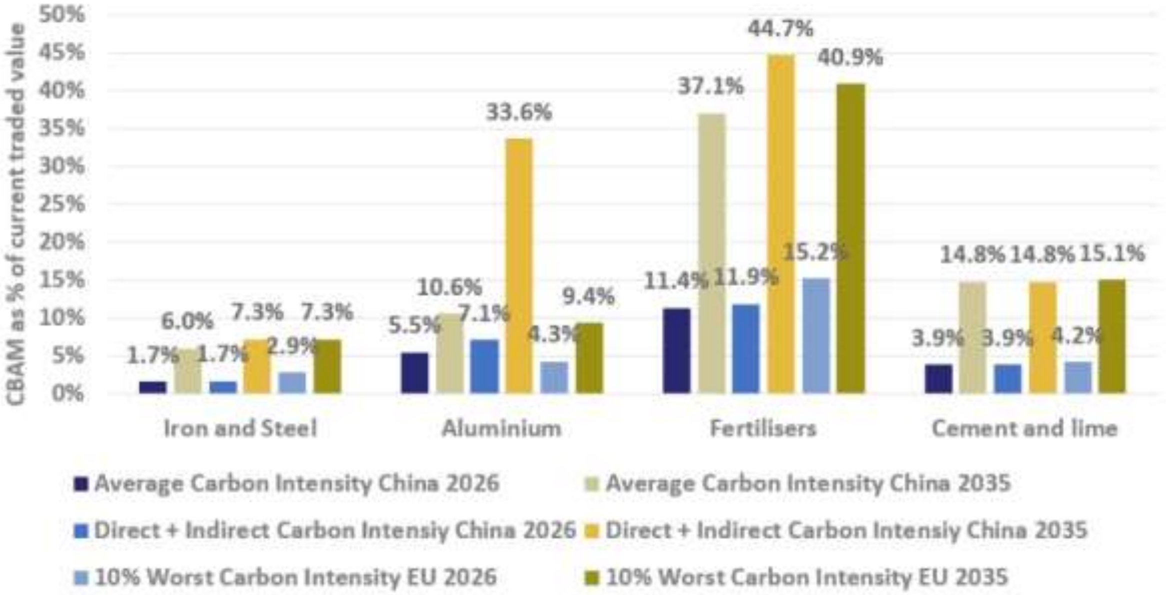

Figure 11: CBAM fees by sector in 2026 and 2035.

Assous et al. (2021) finds that the discontinuation of allocation of free allowances to the industries, amounting to 265 million emission permits, is at an EUA price of 60 € worth 15,9 billion € per year. They also find that it is likely that the costs related to both the CBAM tariffs and the purchase of EUAs will be passed on to the consumers, and that the net effects on imports will be very small. They argue that the free allocation system favors existing high-carbon installations at the expense of lower-carbon competitors, meaning that the incentives to become less carbon intensive is limited. This will also be the case when the CBAM is implemented, the authors argue, and that additional measures for industries to take on low-carbon technologies – such as product requirements and environmental standards – is needed. The effects on the compensation scheme therefore depends upon whether indirect emissions will be included or not. If included, the scheme might be discontinued due to the compensation being deducted from the carbon tariff, which will undermine the intention of the tariff. The effects of the CBAM will not affect EITE industries to a large extent, due to the increased costs being passed on to consumers. So, if the compensation scheme is continued, its effects will remain the same, but it can be expected that the payments will decrease over time as the renewable energy share in Europe increases.

6.4 Potential pitfalls for the coming regulation

The previous regulation was only valid up until 2020, and the new regulation valid from 2021 to 2030 is expected to be amended in 2022. With the new regulation comes a set of changes – most prominently the calculation method in which compensation is no longer based upon historical values, but actual production or electricity consumption levels. In addition to this, there is now a requirement to conduct an energy mapping of the business, as well as meeting one of three requirements. One of which states that the business must ensure that “at least 30 % of their energy consumption stems from renewable energy sources” (Miljødirektoratet, 2021a) (option 2 out of 3). Even if we decide to include oil and coal used as inputs in production processes, given that 98 % of electricity consumed in Norway is produced by renewable energy sources, and electricity constitutes a significant share of the total energy mix, all Norwegian producers will de facto fulfill this requirement. The incentives to implement one of the two others will therefore be obsolete given that they are already eligible for compensation by nature of being located in Norway.

This characteristic also provides interesting other incentives for the European industries. We have already seen that other countries do not have as large a share of renewable energy sources as Norway. For industries located in such countries, the requirements provided in the new regulation can lead to the compensation becoming less profitable, for instance if they decide to choose the option that is to implement the recommendations provided by the energy mapping (1 out of 3 options). This option ensures investments in energy efficiency improvements but reduces the profitability of the scheme for the businesses. This would potentially have a positive effect on the energy efficiency of industrial production in Europe, however, the nature of Norwegian’s energy mix might thus make Norway a more attractive location to potentially move their business. Businesses might decide to relocate to Norway to avoid spending on energy efficiency improvements or using at least 50 % of the compensation on “significant emissions reduction” (option 3 out of 3). Depending on the relative emissions reductions through renewable electricity consumption in Norway vs. Germany, for instance, compared to the potential reductions from the options, the total effect on emissions might be negative. Internal carbon leakage within the EEA might not appear as a problem, due to all EEA countries being covered by the same climate policies. This is not “carbon leakage” per se, but there might be some effects on global emission levels provided by these incentives.

The effects of the high shares shown in chapter 5 might also attract further business to Norway. I have shown that, for some industries and under certain conditions, the compensation might make up more than 100 % of the cost increase related to reaching the compensation threshold of electricity consumption. I have also shown that the emission intensity factor used in the calculation is overestimated given the actual emission intensity of electricity consumption in Norway. The decided level for Norway is at 0,53 tCO_2/MWh. With the 2020 level of 8 gCO_2e/kWh, this points towards the compensation scheme's calculation overestimating the real carbon intensity of electricity consumed in Norwegian industries. The question, then, is to what extent the EUA price affects Norwegian electricity prices, and whether this is equal or similar to the effects on electricity prices in other countries with higher emission intensities. In turn, how that can affect the profitability of the compensation scheme in Norway vs. other countries.

Schumacher et al. (2012) finds that a 1 % increase in the price on carbon will lead to a 0,16 % increase in the electricity prices in Germany, meaning that a 1 € increase in the carbon price will lead to an increase of 0,50 €/MWh. These findings are on the lower end of the estimates provided by other studies, ranging from 0,50 €/MWh to 1 €/MWh. It can be assumed that the German electricity price is affected by the EUA price to a greater extent than Norwegian electricity prices (Aatola et al., 2013). I have assumed that the carbon intensity factor of 0,53 is transferrable to the assumed effect of the EUA price on Norwegian electricity prices – meaning that a 1 € increase in the EUA price will lead to a 0,53 €/MWh, or 5,3 NOK/MWh, increase in the electricity price in Norway. Brenna (2021), however, provides information that Thema have estimated that a 1 € increase in the EUA price will lead to a 0,3 to 0,4 €/MWh – or 3 to 4 NOK/MWh – increase in the electricity price in the Nordics. The results shown in chapter 5 could, therefore, be on the lower spectrum of the compensation's actual share of the additional costs of increasing the electricity consumption – despite, in some cases, covering more than the cost increase.

Electricity prices in Norway are well below the EU average – since 2012, the EU average electricity prices have been 30 % to 200 % higher than the Norwegian prices, meaning that the Norwegian prices are often about half of the average price in the EU (European Commission, 2022c). The low electricity prices is one of the most important competitive advantages for industries in Norway.

If we, thus, assume that the EUA price has a stronger effect on electricity prices on mainland Europe compared to Norway, and that the electricity prices are lower in Norway, the relative profitability of relocating to Norway would be further enhanced by the compensation scheme. This effect's potential impact on emissions within the EEA is beyond the scope of this thesis but given the high estimates for compensation payments in Norway in Phase IV, this should be included in the assessment of the scheme.

6.5 What are the incentives?

Incentives are largely based upon notions from behavioral and applied economics. For example, wages can be seen as an incentive to improve performance and increase effort, which is a positive monetary incentive. “Incentives” can, using common knowledge, be defined as something that motivates you to act in a certain way. One of the effects of the EU ETS is that the increased costs of production due to the internalization of the carbon price yields incentives to improve environmental performance to reduce costs. This is based upon the notions of the Pigouvian tax to discourage activities causing negative externalities, which were further developed into the tradable permit framework characterizing the EU ETS in the 1980s and -90s. However, there is little available research on the environmental incentives of compensation and rebate schemes at the system level.

Ito (2015) argue that, with electricity rebate programs, subsidizing environmental protection programs, such as energy efficiency investments, when environmental goods are not priced, will create asymmetric incentives because the relative increase in negative externalities remain unpriced. This effect will then lead to the negative externalities not being sufficiently accounted for when compared to a Pigouvian tax. The author finds that, when looking at a California electricity rebate program, the asymmetric incentives created by subsidy programs will likely weaken the incentives to reduce negative externalities. The results also show that the price elasticity is crucial when assessing the responsiveness to the incentives.

In the Norwegian context, the consumers of energy-intensive goods are mostly concerned about price, and they do not have any additional willingness to pay for products that are less carbon intensive (Thema, 2020). The incentives for the industries to reduce their carbon footprint appears to be driven by policy decisions rather than internal pressure. Related to Ito’s (2015) findings, the vast support received by such industries in Norway with the following possible weakened incentives to reduce negative externalities, in addition to the lack of internal and external pressure to improve their performance, can serve as a severe barrier to improved environmental performance in the industries.

Since I do not have sufficient data to assess the relative price elasticities for the industries, it is hard to say how responsive the industries might be to the incentives provided. But the energy costs as share of total costs can be seen as a proxy – the assumption being that the higher the share of energy costs, the higher the responsiveness to policies affecting energy costs and -prices. The results showed that the industries with higher energy costs shares benefits more from the compensations in terms of compensation's share of the total cost increases. The compensation can, therefore, possibly incentivize those industries to increase their electricity consumption (or not reduce it) to a greater extent than the other industries. It can also reduce incentives to implement energy efficiency measures in the Norwegian businesses who are above the threshold.

The 10 GWh threshold will possibly, given the findings of this thesis, incentivize increased electricity consumption in certain industries. The compensation's structure of, in practice, being a production or electricity subsidy, could possibly weaken the industries' incentives to reduce their negative externalities overall. Combining these two effects, one that incentivizes increased electricity and the indirect emissions of the covered industries, along with the lacking internal and external pressure to reduce negative externalities, the possible negative impacts need to be assessed against the potential risk and damage effects of carbon leakage. As Martin et al. (2014b) concluded, the exemption criteria in the EU ETS that were designed to protect the competitiveness of leakage exposed industries do little to mitigate the impact of carbon pricing. Their analysis is only including the free allocation of allowances. Given that some of the sectors covered by the compensation scheme are not covered by the EU ETS, the impact of the scheme should be analyzed in its own framework – or in addition to the EU ETS impacts – to see its effect on carbon leakage. This is needed to make any conclusions regarding its actual effects.

7. Conclusion

The EU has been at the forefront of the global emission reductions initiatives, having the world's first, largest and most successful emission trading system. The system does, however, have it caveats. Carbon leakage has been brought up as one of the key issues of climate policies, and the EU ETS is no exception. The extensive support aimed at sectors deemed as carbon leakage exposed has been of key importance in the free allocation of allowances, as well as the design of the compensation scheme. Despite studies not finding sufficient evidence of carbon leakage as a consequence of the EU ETS (Naegle and Zaklan, 2019; Verde 2020), the EU maintains the very beneficial exemptions for such industries. The EU Green Deal will, inevitably, bring about some changes.

Previous analyses have mostly looked at the theoretical and empirical evidence of different aspects of the EU ETS. What has not been thoroughly investigated, is the very specific incentives the system and the compensation scheme can provide. This thesis has investigated and analyzed the 10 GWh threshold of electricity consumption in the indirect cost compensation scheme in Norway. By looking at the compensation's share of total cost increases in different NACE categories, I have been able to analyze the effects of the threshold in a simplified framework. The results show that, for many industries, the structure of the compensation scheme causes the compensation to cover a high share of the cost increase by reaching the threshold. The sensitivity analysis showed that an increase in electricity consumption of up to 4 GWh could be profitable. There is significant uncertainty linked to the development of the EUA price in the coming years. It is widely assumed that it will increase quite significantly. My analysis shows that, even under low EUA prices, the compensation scheme would be very beneficial for most industries. The results from this thesis suggests that the compensation scheme incentivizes increased electricity consumption in eligible businesses operating below the 10 GWh threshold.

The results show most positive impacts for industries operating in basic metals, iron and steel, and ferro-alloys, as well as paper, pulp, and paperboard products. In the Norwegian context, many of the largest installations operate within these industry categories. Given the structure of the compensation scheme, especially considering the carbon factor of electricity consumption, there might be some evidence of overcompensation of Norwegian industries. This is further enhanced when assessing the EUA price's effect on Norwegian electricity prices, which is shown to be overestimated in the calculation of compensations. Caution needs to be made to make conclusions for the industries as a whole, but given the results of this thesis, I believe this should be further investigated to reveal the true effects of the compensation scheme. If the compensations make up more than 100 % of the cost increases, as suggested by the results in some of the scenarios in the analysis, this should be of policy concern. The significant expected compensation payments of 50 to 80 billion NOK in Phase IV can be a source of inefficiency if the businesses may be overly benefitted by the scheme.

Norwegian industries benefit from the use of relatively cheap renewable energy compared to other EU countries. The environmental effects of incentivizing increased electricity consumption are uncertain. Widespread, significant increased demand for electricity will have effects for the electricity supply and can require large infrastructure investments by the State. It can also lead to more trade with mainland Europe. I have shown that the emission intensity of electricity consumption in Norway is very low compared to the EU average. Enabling more trade in electricity can lead to more indirect emissions in Norway in the short to medium run. In the long run, the renewable energy share in mainland Europe is expected to increase, causing the indirect emissions effect to decline. This will reduce the negative environmental effects of increased electricity consumption, as well as the necessity of the compensation scheme. The suggested CBAM will also affect EITE industries, but the inclusion of indirect emissions is not decided, meaning that the compensation scheme can be continued beyond Phase IV.

There are limited studies looking at the compensation scheme’s effects on competitiveness, or the compensation scheme per se. The scheme function as a subsidy, meaning it theoretically could affect the competitiveness of the recipients in the industries where Norwegian exports constitutes significant shares. Studies looking at the EU ETS’ effects on carbon leakage, finds limited evidence supporting the exemptions within the framework countering leakage. Martin et al. (2014a;2014b) suggest that the free allocation of allowances leads to overcompensation of EITE industries given the carbon leakage risk. Given the results of this thesis, I cannot conclude that the compensation scheme helps prevent carbon leakage in Norway. The results do, however, point towards similar evidence of overcompensation from the compensation scheme, which would further enhance the effects identified by Martin et al. (2014a; 2014b). There might be some effects on competition, but the evidence from this thesis combined with previous studies makes it difficult to conclude anything regarding this issue.

Given the results of this thesis, most EITE industries benefit from the compensation scheme financially. The structure of the scheme along with the characteristics of EITE industries in Norway and their consumers could disincentivize abatement efforts. The environmental effects are uncertain, but there is evidence that the scheme can incentivize increased electricity consumption. The possible environmental effects identified, but not quantified, in this thesis are mostly linked to this increase and the relative carbon factor of electricity consumption. The results and discussion of relevant theories and previous studies might suggest a shift within the EEA rather than from the EEA to other, non-regulated areas, which, therefore, is not carbon leakage per definition. This shift could, however, have social welfare implications and competition effects within the EEA.

The results of this thesis are based upon a simplified framework, which need to be accounted for when interpreting the results. The analysis looks at the 10 GWh threshold, which makes any conclusions to the effects of the entirety of the scheme difficult to make. The thesis provide insight into interesting features of the compensation scheme and its incentives in the

Norwegian context, which would be interesting to further investigate for the entirety of the scheme. The vast literature suggesting limited evidence of carbon leakage within the EU ETS also calls for a need to properly investigate the empirical evidence of the effects of the compensation scheme – especially considering the increased payments in the coming years. The effects of the scheme should also be of relevance for the revision of whether, or how, to include indirect emissions in the CBAM.

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Appendix

A – GHGs and Norwegian activities (Miljødirektoratet, 2019)

	Aktiviteter	*Kvotepliktige utslipp*
1	forbrenning av brensler i virksomheter der samlet innfyrt termisk effekt overstiger 20 MW (kvoteplikten gjelder likevel ikke forbrenning av brensler i anlegg for forbrenning av farlig og kommunalt avfall)	Karbondioksid (CO_2)
2	raffinering av mineralolje	Karbondioksid (CO_2)
3	produksjon av koks	Karbondioksid (CO_2)
4	røsting og sintring av metallholdig malm (herunder sulfidholdig malm), inkludert pelletisering	Karbondioksid (CO_2)
5	produksjon av støpejern eller stål (primær- eller sekundærproduksjon), inkludert kontinuerlig støping, med en kapasitet som overstiger 2,5 tonn pr. time	Karbondioksid (CO_2)
6	produksjon eller bearbeiding av jernholdige metaller (inkludert ferrolegeringer) i anlegg med forbrenningsenheter der samlet innfyrt termisk effekt overstiger 20 MW	Karbondioksid (CO_2)
7	produksjon av primæraluminium	Karbondioksid (CO_2) og perfluorkarboner (PFK)
8	produksjon av sekundæraluminium i anlegg med forbrenningsenheter der samlet innfyrt effekt overstiger 20 MW	Karbondioksid (CO_2)
9	produksjon eller bearbeiding av ikke-jernholdige metaller, inkludert produksjon av legeringer, raffinering/foredling og støping i anlegg med forbrenningsenheter der samlet innfyrt termisk effekt (inkludert reduksjonsmidler) overstiger 20 MW	Karbondioksid (CO_2)
10	produksjon av sementklinker i roterovner med en produksjonskapasitet som overstiger 500 tonn pr. døgn eller i andre typer ovner med en produksjonskapasitet som overstiger 50 tonn pr. døgn	Karbondioksid (CO_2)
11	produksjon av kalk eller kalsinering av dolomitt eller magnesitt i roterovner eller i andre ovner med en produksjonskapasitet som overstiger 50 tonn pr. døgn	Karbondioksid (CO_2)
12	produksjon av glass og glassfiber med en smeltekapasitet som overstiger 20 tonn pr. døgn	Karbondioksid (CO_2)
13	produksjon av keramiske produkter ved brenning, herunder takstein, murstein, ildfast stein, fliser, steintøy og porselen, med en produksjonskapasitet som overstiger 75 tonn pr. døgn	Karbondioksid (CO_2)
14	produksjon av mineralull til isolasjonsmateriale ved bruk av glass, stein eller slagg med en smeltekapasitet som overstiger 20 tonn pr. døgn	Karbondioksid (CO_2)
15	tørking eller kalsinering av gips eller produksjon av gipsplater og andre gipsprodukter i anlegg med forbrenningsenheter der samlet innfyrt termisk effekt overstiger 20 MW	Karbondioksid (CO_2)
16	produksjon av masse fra trevirke eller andre fibermaterialer	Karbondioksid (CO_2)

	Aktiviteter	*Kvotepliktige utslipp*
17	produksjon av papir eller kartong med en produksjonskapasitet som overstiger 20 tonn pr. døgn	Karbondioksid (CO_2)
18	produksjon av sot som omfatter karbonisering av organiske stoffer som for eksempel olje, tjære, rester fra krakking og destillasjon i anlegg med forbrenningsenheter der samlet innfyrt termisk effekt overstiger 20 MW	Karbondioksid (CO_2)
19	produksjon av salpetersyre	Karbondioksid (CO_2) og lystgass (N_2O)
20	produksjon av adipinsyre	Karbondioksid (CO_2) og lystgass (N_2O)
21	produksjon av glyoksal og glyoksylsyre	Karbondioksid (CO_2) og lystgass (N_2O)
22	produksjon av ammoniakk	Karbondioksid (CO_2)
23	produksjon av organiske kjemikalier ved krakking, reformering, oksidasjon eller ved lignende prosesser med en produksjonskapasitet som overstiger 100 tonn pr. døgn	Karbondioksid (CO_2)
24	produksjon av hydrogen (H_2) og syntesegass ved reformering eller delvis oksidasjon med en produksjonskapasitet som overstiger 25 tonn pr. døgn	Karbondioksid (CO_2)
25	produksjon av natriumkarbonat (Na_2CO_3) og natriumbikarbonat ($NaHCO_3$)	Karbondioksid (CO_2)
26	fangst av klimagasser fra kvotepliktige virksomheter som skal transporteres og lagres i en geologisk formasjon godkjent av kompetente myndigheter	Karbondioksid (CO_2)
27	transport av klimagasser i rørledninger for lagring i en geologisk formasjon godkjent av kompetente myndigheter	Karbondioksid (CO_2)
28	lagring av klimagasser i en geologisk formasjon godkjent av kompetente myndigheter	Karbondioksid (CO_2)

B - Values used to calculate the results

Data used in the analysis

		With efficiency standard			Without efficiency standard		
	Price scenarios	Low	Medium	High	Low	Medium	High
	Million NOK						
14.1 (17.1)							
8 GWh:	Compensation	0,00	0,00	0,00	0,00	0,00	0,00
	Production value	1861,06	1861,06	1861,06	1861,06	1861,06	1861,06
	Costs = prod.val.	1861,06	1861,06	1861,06	1861,06	1861,06	1861,06
	Costs = 1/2 prod. Val	930,53	930,53	930,53	930,53	930,53	930,53
10 GWh:	Compensation	2,01	2,45	3,58	1,61	1,96	2,86
	Production value	2326,33	2326,33	2326,33	2326,33	2326,33	2326,33
	Costs = prod.val.	2326,61	2326,73	2327,03	2326,61	2326,73	2327,03
	Costs = 1/2 prod. Val	1163,45	1163,57	1163,87	1163,45	1163,57	1163,87
17.1 (21.1)							
8 GWh:	Compensation	0,00	0,00	0,00	0,00	0,00	0,00
	Production value	31,85	31,85	31,85	31,85	31,85	31,85
	Costs = prod.val.	31,85	31,85	31,85	31,85	31,85	31,85
	Costs = 1/2 prod. Val	15,92	15,92	15,92	15,92	15,92	15,92
10 GWh:	Compensation	2,01	2,45	3,58	1,61	1,96	2,86
	Production value	39,81	39,81	39,81	39,81	39,81	39,81
	Costs = prod.val.	40,10	40,21	40,51	40,10	40,21	40,51
	Costs = 1/2 prod. Val	20,19	20,31	20,61	20,19	20,31	20,61
20.1 (23.1)							
8 GWh:	Compensation	0,00	0,00	0,00	0,00	0,00	0,00
	Production value	40,25	40,25	40,25	40,25	40,25	40,25
	Costs = prod.val.	40,25	40,25	40,25	40,25	40,25	40,25
	Costs = 1/2 prod. Val	20,13	20,13	20,13	20,13	20,13	20,13
10 GWh:	Compensation	2,01	2,45	3,58	1,61	1,96	2,86
	Production value	50,32	50,32	50,32	50,32	50,32	50,32
	Costs = prod.val.	50,60	50,72	51,02	50,60	50,72	51,02
	Costs = 1/2 prod. Val	25,44	25,56	25,86	25,44	25,56	25,86
23.1 (26.1)							
8 GWh:	Compensation	0,00	0,00	0,00	0,00	0,00	0,00
	Production value	83,63	83,63	83,63	83,63	83,63	83,63
	Costs = prod.val.	83,63	83,63	83,63	83,63	83,63	83,63
	Costs = 1/2 prod. Val	41,82	41,82	41,82	41,82	41,82	41,82
10 GWh:	Compensation	2,01	2,45	3,58	1,61	1,96	2,86
	Production value	104,54	104,54	104,54	104,54	104,54	104,54
	Costs = prod.val.	104,82	104,94	105,24	104,82	104,94	105,24
	Costs = 1/2 prod. Val	52,56	52,67	52,97	52,56	52,67	52,97
24.1 (27.1)							
8 GWh:	Compensation	0,00	0,00	0,00	0,00	0,00	0,00
	Production value	21,83	21,83	21,83	21,83	21,83	21,83
	Costs = prod.val.	21,83	21,83	21,83	21,83	21,83	21,83
	Costs = 1/2 prod. Val	10,92	10,92	10,92	10,92	10,92	10,92

10 GWh:	Compensation	2,01	2,45	3,58	1,61	1,96	2,86
	Production value	27,29	27,29	27,29	27,29	27,29	27,29
	Costs = prod.val.	27,57	27,69	27,99	27,57	27,69	27,99
	Costs = 1/2 prod. Val	13,93	14,05	14,35	13,93	14,05	14,35
24.4 (27.4)							
8 GWh:	Compensation	0,00	0,00	0,00	0,00	0,00	0,00
	Production value	21,73	21,73	21,73	21,73	21,73	21,73
	Costs = prod.val.	21,73	21,73	21,73	21,73	21,73	21,73
	Costs = 1/2 prod. Val	10,87	10,87	10,87	10,87	10,87	10,87
10 GWh:	Compensation	2,01	2,45	3,58	1,61	1,96	2,86
	Production value	27,17	27,17	27,17	27,17	27,17	27,17
	Costs = prod.val.	27,45	27,57	27,87	27,45	27,57	27,87
	Costs = 1/2 prod. Val	13,87	13,99	14,29	13,87	13,99	14,29

C - Sensitivity analysis – 50 % increase in electricity consumption

For all productions the electricity consumption has been increased with 50 % from 8 GWh to 12 GWh. Given the assumption of proportionality, costs and production value are thus also increased 50 %. The increased electricity costs due to EUA prices is added to total costs, which is why production value is different from costs = production value – as in the results.

17.1 (21.1)	**Compensation share of cost/prod.val. Increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,15	0,18	0,27	0,12	0,15	0,22
Costs = prod.value (mill. NOK)	0,15	0,18	0,25	0,12	0,14	0,20
Costs = 1/2 prod.value (mill. NOK)	0,28	0,34	0,46	0,23	0,27	0,37

20.1 (23.1)	**Compensation share of cost/prod.val. Increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,12	0,15	0,21	0,10	0,12	0,17
Costs = prod.value (mill. NOK)	0,12	0,14	0,20	0,09	0,11	0,16
Costs = 1/2 prod.value (mill. NOK)	0,23	0,27	0,37	0,18	0,22	0,30

23.1 (26.1)	**Compensation share of cost/prod.val. Increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,06	0,07	0,10	0,08	0,09	0,14
Costs = prod.value (mill. NOK)	0,06	0,07	0,10	0,04	0,05	0,07
Costs = 1/2 prod.value (mill. NOK)	0,11	0,12	0,19	0,07	0,09	0,13

24.1 (27.1)	**Compensation share of cost/prod.val. Increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,22	0,27	0,39	0,18	0,22	0,31
Costs = prod.value (mill. NOK)	0,21	0,25	0,35	0,17	0,20	0,28
Costs = 1/2 prod.value (mill. NOK)	0,40	0,47	0,63	0,32	0,38	0,50

24.4 (27.4)	**Compensation share of cost/prod.val. Increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,22	0,27	0,39	0,18	0,22	0,32
Costs = prod.value (mill. NOK)	0,21	0,25	0,35	0,17	0,20	0,28
Costs = 1/2 prod.value (mill. NOK)	0,40	0,47	0,63	0,32	0,38	0,50

D - Sensitivity analysis – 30 % reduction in EUA price

All other factors are kept equal to the base scenario.

17.1 (21.1)	**Compensation share of cost/prod.val. Increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,18	0,22	0,31	0,14	0,17	0,25
Costs = prod.value (mill. NOK)	0,17	0,21	0,30	0,14	0,17	0,24
Costs = 1/2 prod.value (mill. NOK)	0,34	0,41	0,57	0,27	0,33	0,46

20.1 (23.1)	**Compensation share of cost/prod.val. Increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,14	0,17	0,25	0,11	0,14	0,20
Costs = prod.value (mill. NOK)	0,14	0,17	0,24	0,11	0,13	0,19
Costs = 1/2 prod.value (mill. NOK)	0,27	0,33	0,46	0,22	0,26	0,37

23.1 (26.1)	**Compensation share of cost/prod.val. Increase**					
	With efficiency standard			**Without efficiency standard**		
	Low	Medium	High	Low	Medium	High
Production value	0,07	0,08	0,12	0,05	0,07	0,10
Costs = prod.value (mill. NOK)	0,07	0,08	0,12	0,05	0,06	0,09
Costs = 1/2 prod.value (mill. NOK)	0,13	0,16	0,23	0,11	0,13	0,18

24.1 (27.1)	Compensation share of cost/prod.val. Increase					
	With efficiency standard			Without efficiency standard		
	Low	Medium	High	Low	Medium	High
Production value	0,26	0,31	0,46	0,21	0,25	0,37
Costs = prod.value (mill. NOK)	0,25	0,30	0,43	0,20	0,24	0,34
Costs = 1/2 prod.value (mill. NOK)	0,49	0,58	0,80	0,39	0,47	0,64

24.4 (27.4)	Compensation share of cost/prod.val. Increase					
	With efficiency standard			Without efficiency standard		
	Low	Medium	High	Low	Medium	High
Production value	0,26	0,32	0,46	0,21	0,25	0,37
Costs = prod.value (mill. NOK)	0,25	0,30	0,43	0,20	0,24	0,34
Costs = 1/2 prod.value (mill. NOK)	0,49	0,59	0,80	0,40	0,47	0,64

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