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Abstract

The CO_2 emission allowances price level in EU ETS has fluctuated since the implementation of the scheme. The allowance price level influences short-term fuel switch decisions and profitability of investments and due to this, the fluctuation can slow down the implementation of low-carbon solutions. To give the markets a more stable signal of the development of the CO_2 price, carbon price floor (CPF) has been discussed as a potential measure to complement the ETS. The CPF could be implemented in national, regional or EU level.

In this report, the impact of regional CPF implemented either on Nordic or Nordic and Baltic level is analysed concentrating on electricity and heating sector perspectives. In case of electricity markets, the analysis is based on European-wide electricity market simulation with various scenarios. The aim in the analysis is to quantify the potential effects of CPF on electricity generation, electricity flows, CO_2 emissions and wholesale prices. In case of heating sector, the aim is to analyse how CPF could potentially impact on the replacement of fossil fuels both in the short- and long-term .

In the electricity sector, it could be argued that CPF would have only minor cost impacts in the Nordic region due to production mix being to large extent already mostly based on CO_2-free technologies. On the other hand, due to the same fact, the impact of CPF on the electricity generation is likely to be less relevant as in many other regions, for example in Central Europe. Based on the analysis, Nordic CPF could under certain market conditions result in decrease in electricity production with fossil fuels and peat, with only a small impact on average wholesale prices. However, the electricity generation in the Nordics would slightly decrease, being replaced with generation in other market areas.

In the heating sector, the implementation of CPF could also decrease the use of fossil fuels and peat, being replaced by biomass. However, the utilisation of fossil fuels could be expected to decrease with current market conditions and the potential achievable benefits could be further limited by technical constraints in production units.

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Tiivistelmä

Päästöoikeuksien hintataso EU:n päästökaupassa on vaihdellut merkittävästi järjestelmän käyttöönotosta lähtien, mikä vaikuttaa järjestelmän ohjausvaikutukseen niin polttoainevalintojen kuin investointien näkökulmasta. Matala tai epävarma päästöoikeuksien hintataso voi hidastaa päästövähennysten toteutumista päästökaupan piirissä olevilla sektoreilla. Päästöoikeuksien lattiahintaa on ehdotettu keinona varmistaa päästökaupan ohjausvaikutus. Lattiahinta voitaisiin ottaa käyttöön kansallisella, alueellisella tai EU:n tasolla, ja sitä voidaan soveltaa kaikille päästökauppasektoreille tai esimerkiksi ainoastaan energian tuotantoon.

Tässä raportissa tarkastellaan alueellisen, joko vain Pohjoismaissa tai Pohjoismaissa ja Baltiassa sovellettavan lattiahinnan vaikutuksia sähkömarkkinoilla ja kaukolämpösektorilla. Vaikutuksia sähkömarkkinoihin on analysoitu koko Euroopan alueen kattavalla simuloinnilla useissa eri skenaarioissa. Analyysin tavoitteena on arvioida lattiahinnan vaikutuksia sähkön tuotantoon, vientiin sekä markkinahintaan ja päästöihin sähköntuotantosektorilla. Kaukolämpösektorilla tavoitteena on arvioida lattiahinnan mahdollisia vaikutuksia polttoainevaihdoksiin.

Päästöoikeuden lattiahinta vaikuttaisi sähkön markkinahntaan Pohjoismaissa vain vähän, sillä tuotanto perustuu enimmäkseen uusiutuviin tuotantomuotoihin. Tästä johtuen lattiahinnan oletettavat hyödyt ovat todennäköisesti vähemmän merkittäviä kuin monilla muilla alueilla, esimerkiksi Keski-Euroopassa. Analyysin perusteella Pohjoismaissa sovellettu lattiahinta voisi vähentää fossiilisten polttoaineiden ja turpeen käyttöä sähköntuotantoon joissain markkinatilanteissa. Toisaalta pohjoismainen sähköntuotanto vähenisi, ja sitä korvattaisiin tuotannolla muualla Euroopassa, mikä voisi johtaa toimitusvarmuuden heikkenemiseen Pohjoismaissa. Alueellisen päästöoikeuden lattiahinnan vaikutusta EU-alueen kokonaispäästöihin ottaen huomioon markkinavakausvaranto ja päästöoikeuksien veto pois markkinoilta ei oe työssä tarkasti analysoitu.

Kaukolämpösektorilla lattiahinnan avulla voidaan ohjata kaukolämmön tuottajia pois turpeen ja fossiilisten polttoaineiden käytöstä. Toisaalta fossiilisten polttoaineiden käytön voidaan arvioida vähenevän jo nykyisten ohjauskeinojen ja markkinatilanteen myötä, eivätkä polttoainemuutokset aina ole teknisesti tai polttoaineen saatavuuden vuoksi mahdollisia.

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Prisnivån för utsläppsrätter för koldioxid inom ramen för EU ETS har fluktuerat sedan EU ETS genomförande. Utsläppsrätternas prisnivå påverkar kortsiktiga beslut gällande bränslebyten samt investeringarnas lönsamhet. På grund av detta kan fluktuationerna bromsa implementeringen av lösningar med låga koldioxidutsläpp. För att ge marknaden en mer stabil signal gällande utvecklingen av CO_2-priset har ett prisgolv för utsläppsrätter (CPF) diskuterats som en möjlig åtgärd som kunde komplettera EU ETS. Ett golvpris för utsläppsrätter kan implementeras på nationell, regional eller EU-nivå.

I rapporten analyseras effekterna av ett regionalt prisgolv för utsläppsrätter som implementeras antingen på nordisk eller nordisk och baltisk nivå, med fokus på el- och fjärrvärmesektorerna. När det gäller elmarknaden, baseras analysen på simulering av elmarknaden i Europa med olika scenarier. Syftet med analysen är att kvantifiera de potentiella effekterna av ett prisgolv på utsläppsrätter på elproduktion, elflöden, koldioxidutsläpp och grossistmarknadens prisnivå. När det gäller fjärrvärmesektorn är målet att analysera hur ett prisgolv kan påverka utbytet av fossila bränslen mot mer hållbara bränslen, både på kort och lång sikt.

Inom elsektorn i Norden kan man hävda att ett prisgolv endast skulle ha mindre kostnadseffekter på grund av att produktionsmixen i stor utsträckning redan är baserad på koldioxidfria teknologier. Å andra sidan, på grund av samma faktum, kommer effekterna av ett prisgolv på utsläppsrätter på elproduktionen sannolikt att vara mindre betydande än i många andra regioner, som till exempel Centraleuropa. Baserat på analysen kan man komma till slutsatsen att ett nordiskt prisgolv under vissa marknadsförhållanden kan leda till minskad elproduktion från fossila bränslen och torv, med endast en liten påverkan på det genomsnittliga priset på grossistmarknaden. Elproduktionen i Norden skulle dock minska något och ersättas med produktion i andra marknadsområden.

Inom fjärrvärmesektorn kan implementeringen av ett prisgolv på utsläppsrätter också minska användningen av fossila bränslen och torv, som sedan skulle ersättas med förbränning av biomassa. Användning av fossila bränslen kan dock förväntas minska även under nuvarande marknadsförhållanden och de potentiella uppnåbara fördelarna av ett prisgolv kan ytterligare reduceras av tekniska begränsningar i produktionsenheter.

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Contents

1 Introduction

1.1 Background of this study

This study has been prepared as part of a project analysing the impacts of the changes in EU emissions trading schme (EU ETS), and the measures to prevent carbon leakage. The project is part of the implementation of the Government Plan for Analysis, Assessment and Research. Other findings of the project have been published earlier in a separate report.

The aim of the analysis presented in this report is to identify some impacts of a potential Nordic or Nordic and Baltic regional carbon floor price to be applied in electricity and district heating sectors. Carbon price floor could be introduced also to other sectors, and geographically on wider area, but that has not been analysed in this study. The analysis reveals on short-term impacts of a carbon price floor, such as impacts on electricity generation volumes in the Nordics and Baltics and fuel switching in electricity and heat production. The approach selected in this study is especially suitable for identifying potential market distortions caused by regional carbon price floor, but also describe key local impacts on electricity and heating sectors. Due to the selected approach, this study is not able to provide comprehensive analysis of all aspects and impacts of a carbon price floor.

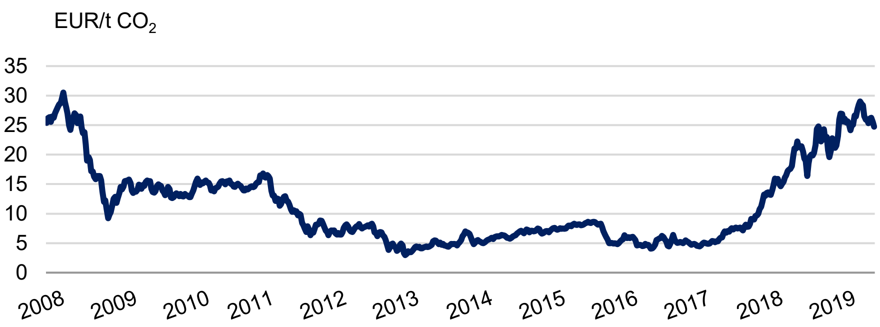
1.2 EU ETS and EUA price developement

In order to combat climate change EU has developed an emissions trading system (EU ETS) in 2005. The core of the scheme is the emission allowances (EUAs), which are either bought from auctions, received free of charge or traded among participating companies. Price of the EUAs is determined by prevailing supply and demand balance. The supply is regulated by a cap, which equals an overall limit on certain greenhouse gases that can be emitted within the system coverage. The system covers power and heat generation, energy-intensive industry and commercial aviation. (European Commission, 2019)

The development of EUA price in the period of 2008–2019 is depicted in Figure 1-1. During that period, there has been notable fluctuation in the EUA price level. The price level has mostly been rather low. In the period of 2009–2018 the EUA prices were below 15 EUR/tCO_2. The demand has been influenced by macro-economic events, such as 2007–2008 financial crisis, and accumulated surplus has resulted in the prices staying low (Fjellheim, 2018).

Currently, CO_2 prices are at high level in comparison to the history. The reason for increased price after autumn 2017 was the agreement on the Market Stability Reserve (MSR) and the doubling of the intake rate of allowances to the MSR. The MSR is a long-term measure, which affects the amount of available EUAs in the market with an aim to reduce the issues of over-supply and long-term price volatility in the carbon price. Since 2017, the concerns that future emission reduction targets could be further tightened have caused additional pressure to EUA price (Refinitiv, 2018).

Figure 1-1 – The development of EUA price in the period of 2008–2019



(EUA Price, 2019)

Potentially low EUA price level in the future and price fluctuation may challenge the long-term emission reduction targets, and also result in higher utilisation of fossil fuels in the short-term. In the short-term, carbon price has an influence on ‘merit order’, which describes an economically optimal operation order of power plants based on marginal costs of power production. From this perspective, potentially low EUA price level does not support the utilisation of low-carbon alternatives and fuel switching. In the long-term, price fluctuation impacts on the profitability and risks of investments, potentially impacting the implementation of new renewable or other low-carbon production units.

1.3 Introduction to carbon price floor

Carbon price floor (CPF) has been discussed as a potential additional policy instrument to complement the EU ETS. CPF could support in ensuring sufficient price level and reducing the fluctuation in CO_2 price level in the short-term as well as presenting a more stable signal of CO_2 price development for long-term investment considerations. In the short-term, the aim of CPF is to ensure sufficient emission price level to support the utilisation of low-carbon alternatives through e.g. fuel switches. In the long-term, the aim is to support the invesments in new production units based on low-carbon options. Also, CPF could provide more clear signal for the regulators of the future development of the CO_2 price level when assessing the required political instruments to achieve emission reduction targets in different sectors.

The carbon price floor can be implemented for example as a minimum price in the auctions of the allowances, or as a top-up tax to the EUA price. Alternatively, carbon price floor could be implemented as a government's commitment to buy allowances below a certain price level or as a subsidy that would be paid to entities possessing more EUAs than the amount they are required to submit. (Hocksell, 2019) The suitable method to set the floor price depends on the coverage of the price floor. For limited geographical area or sectors, the top-up tax or similar method can be applied, whereas minimum auction price would impact the whole EU ETS area.

Carbon price floor can cover either only electricity generation or may be expanded to other sectors as well, for example heating, industrial activities and aviation. CPF is considered to be more flexible than setting fixed allowance price levels as only the minimum allowance price is being controlled (IMF Policy Paper, 2019).

When considering national or regional CPF schemes within EU ETS, it is possible that no decrease in emissions is achieved through CPF due to carbon leakage. For example, the decrease in electricity generation based on fossil fuels in one country could be compensated through electricity imports based on similar generation in another country not participating in the CPF scheme. Also, the implementation CPF could potentially impact on energy production and sourcing cost for energy-intensive industry, which could also lead to carbon leakage, even if the CPF would not directly apply for the industrial emissions.

CPF has been implemented for example in some states in the USA and Canada and in the UK as the only country in Europe. Also, the implementation of CPF is pending upon the parliament's confirmation in the Netherlands. In addition, CPF has been discussed in many other countries like Italy, Spain and France. Also regional CPF schemes have been discussed for example in the Nordic countries. The existing CPF models are discussed further in Section 1.4.

1.4 Carbon price floor assessment methodology

In this report, the impacts of implementing a regional CPF in Nordic and Baltic area are being analysed. The analysis is based on simulation-based approach covering both electricity and heating sector. The aim is to quantify the effects of CPF on the energy production, total emissions, electricity flows and energy prices.

1.4.1 Electricity market assessment

The impact of carbon price floor on Nordic and Baltic power markets has been analysed with a simulation-based approach utilising Pöyry's power market model BID3. The model enables comprehensive simulation in both Nordic and Central Europe electricity markets with aim of quantifying the effects of carbon price floor in the simulated cases. The simulation covers two separate cases, where a carbon price floor is set:

1. Only in the Nordic countries
2. Both in the Nordic and Baltic countries

In this context, the Nordic countries include Finland, Sweden, Norway and Denmark and Baltic countries include Estonia, Latvia and Lithuania. These cases are modelled separately in years 2025 and 2030 based on Pöyry's estimate for the development of electricity markets in terms of e.g. demand, production mix and capacity and interconnections. The capacity assumptions in the model take into account EU's decarbonisation targets stated in Energy Strategy (EU, 2014).

Fuel prices for coal, lignite and gas used in the analysis are based on the New Policies scenario of IEA World Energy Outlook 2018 report (IEA, 2018). Biomass and peat prices in Finland are based on the base scenario in energy and climate strategy of the Finnish government. (Pöyry, 2018). Utilising these assumptions, Base Scenario is formed with no carbon price floor in place (presented in Section 2.2.1). Production capacity assumptions in Base Scenario take the impacts of coal ban in Finland and Denmark into account.

As stated in Section 1.1, EUA prices have been relatively high during the most recent years. As a result, it would be likely that the potential impacts of carbon price floor would be relatively low with the current EUA prices if the CPF target price was not set very high. To analyse the effects of relatively high deviation between the EUA price and carbon price floor price in the Nordics and/or Baltics, the EUA market price in the Base Scenario is assumed to be at a low level of 10 EUR/tCO_2 for simulation purposes. The low price market price assumption for EUAs was selected to be able to identify the impacts of a clearly higher price floor. It was assumed that if a carbon price floor was to be introduced only locally, it would be unlikely that it would be set significantly higher than the current market price, as it would put the actors in different countries to a very different position.

The analysis includes 3 alternative carbon price floor scenarios, defined as follows:

A. CPF is set at 30 EUR/tCO_2 ("CPF 30")
B. CPF is set at 40 EUR/tCO_2 ("CPF 40")
C. CPF is set at 50 EUR/tCO_2 ("CPF 50")

These scenarios have been analysed for both Nordic and Nordic-Baltic carbon price floor cases. The impacts of the scenarios have been analysed in comparison to the Base Scenario.

1.4.2 District heating sector assessment

Due to district heating (DH) being more local in comparison to electricity markets, similar comprehensive market model is not applicable as in the case of electricity markets. The impacts of CPF on district heating sector are analysed through case studies in two separate DH networks. One of the network represents a typical large-scale DH network, while the other represents a medium-scale network. The networks are presented in Section 3.2.

The aim in the analysis is to quantify the effects the CPF could have on marginal production costs and merit order in heat production and the impacts this could potentially have on fuel switches within the analysed networks. Modelling refers to Finnish heating markets and the effects in other Nordic and Baltic countries are analysed on qualitative basis.

Fuel prices in this analysis are in line with the fuel prices utilised in electricity market modelling and fuel taxes are estimated to be at their current level in all scenarios.

Also, the modelling scenarios (CPF 30, CPF 40 and CPF 50) are the same as in the case of electricity market modelling. In case of CHP plants, all the costs and revenues related to electricity production are included in the consideration of marginal heat production cost.

2 Carbon price floor experiences from other market areas

2.1 Carbon price floor in the UK

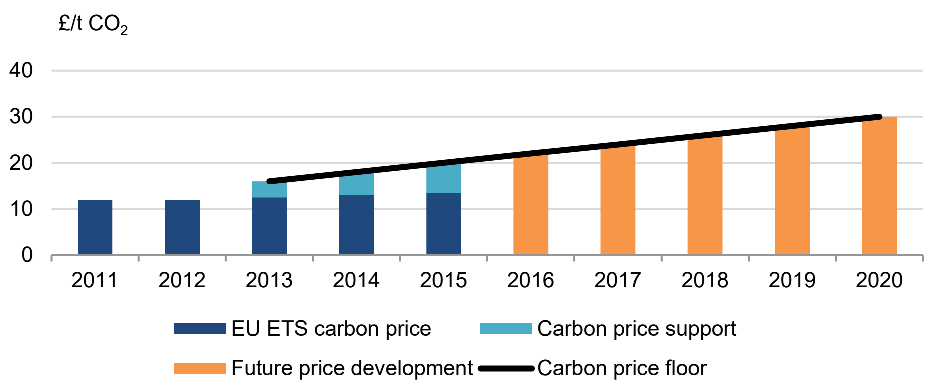
The UK implemented the CPF on April 1, 2013 and their model consists of two components: EUA price and carbon price support (CPS). The EUA price is determined through auctions or carbon market on European level. The CPS, instead, is added stepwise on the top of the EU ETS, so that the target price for emissions for a given year is expected to be met.

The aim in defining the target price is to set the emission price level in such a level that would encourage investments in renewable alternatives but simultaneously not increase production costs in industrial activities considerably. The CPS is calculated utilising Equation (1) (Hirst, 2018):

$$CPS = (target\ carbon\ price - market\ carbon\ price)\ x\ (emission\ factor\ of\ the\ fuel) \quad (1)$$

The CPS is always decided upon for three years in advance, based on ETS price estimates, as illustrated in Figure 1-2. It is merged into an energy price component, called Climate Change Levy (CCL) and it is applied to fossil fuels used for electricity generation. (Hirst, 2018)

Figure 1-1 – Illustration of the carbon price floor in the UK



(HM Treasury, 2011)

The CPS was introduced in 2013 and the target was to increase the emission prices to 30 £/tCO_2 in 2020 and 70 £/tCO_2 in 2030. The target level of 70 £/tCO_2 in 2030 was based the Government's estimate on the price level, which would result in coal phase-out. In contrast to the original plan, a maximum level of 18 £/tCO_2 was set to CPS for the period 2016-2020, as the original target level was considered high influencing the competitive position of the British industry. As one of the main targets of carbon price floor is the increased predictability of the development of CO_2 price level, the recent changes have impacted on the reliability of the system. (Hirst, 2018)

Also, the effect of CPS on emissions has been questioned and its impact on consumer prices has raised concerns. It has been argued that the CPF distorts the global competition and may result in increased carbon leakage from the UK (Hirst, 2018). In addition, coal-based production could still potentially become cost-competitive in comparison to gas-based production under certain market conditions, which cannot be resolved by the existing CPF system. In the case of the UK, this problem is partly mitigated by an emission performance standard, which bans new coal-fired power generation. (Ramaker, 2018)

On the other hand, CPF has received positive feedback as it has been considered to encourage low-carbon investments and the utilisation of coal in the UK has decreased significantly since its introduction in 2013. In the period of 2013–2017, the share of the coal-fired power generation decreased from 41 % to 8 %. The coal-based electricity generation has been mostly replaced with gas-fired power generation and renewable energy sources (RES). However, it is to be noted that due to various energy policies and RES support schemes in the UK, it is challenging to quantify the specific contribution the CPF has made. (Hirst, 2018; Newbery;Reiner;& Ritz, 2018).

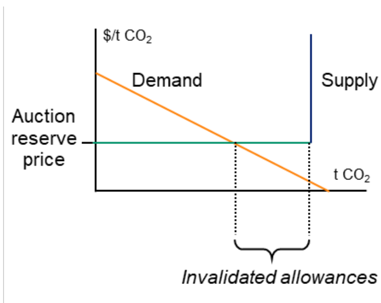
Also, it is to be noted that due to the limited interconnection capacity of the electricity system in the UK, the country is in different position in comparison to other EU countries, where the electricity systems are better interconnected. Due to the limited interconnection capacity, the electricity production in the UK con not easily be replaced by electricity imports, resulting in the replacement of coal with domestic electricity production capacity. (Ramaker, 2018)

2.2 Carbon price floor in the Northeast USA and California

In the USA, there are some state level emission trading schemes, with variety in the implementation of the systems. CPF has been implemented in the emissions trading schemes in California and the Northeast region. California has its own cap-and-trade program, which is linked with the program in Quebec and administered by Western Climate Initiative (WCI) (CARB, 2019). In California, the CPF covers e.g. power plants, manufacturers and refineries (Plumer & Popovich, 2019).

In the Northeast region of the US, nine states have joined Regional Greenhouse Gas Initiative (RGGI), which is a cap-and-trade program targeted to power sector (ICAP USA, 2019). Both in California and in the Northeast region, the CPF model is based on auction reserve price (ARP), which is depicted in Figure 1-3. In this model, a reserve price is set for the emission allowances auction. If allowances are left unsold after the auction, excess allowances are typically invalidated. (Burtraw, ym., 2018)

Figure 1-2 – Auction reserve price methodology



(Burtraw, ym., 2018)

In August 2019, the ARP was on the level of 15,6 USD/tCO_2 and emission allowance price 17,2 USD/tCO_2 in Califronia[1] (Morehouse, 2019). It has been argued that higher emission allowance prices have not been achieved due to high cap in the system. However, California has already executed several climate policies, which have reduced carbon emitting activities. This makes it challenging to analyse the impact of ARP on the emission reductions. (Plumer & Popovich, 2019)

In the states, which belong to RGGI, the ARP equalled to 2,2 USD/tCO_2[2] in 2018, and the average emission allowance price was 4,8 USD/tCO_2 in the same year. The target is to increase ARP by 2.5% annually reflecting on the inflation rate (ICAP USA, 2019). Compared to California, the ETS prices have been low and it is unclear what kind of impact they have had on the emissions (Plumer & Popovich, 2019).

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[1] ARP: appr. 14 EUR/tCO_2, emission allowance price: appr. 15 EUR/tCO_2
[2] appr. 2 EUR/tCO_2

2.3 Carbon price floor in Canada

Canadian carbon pricing scheme is currently one of the most ambitious, as it obliges provinces to reach carbon price of CAN$ 50 per tonne[3] by 2022 (Plumer & Popovich, 2019). Canadian carbon pricing scheme is primarily provincial, and Canadian legislation introduces two pricing options, which must be in line with the federal CPF: provinces can have own cap-and-trade model in place or set a direct carbon price.

If a province fails to introduce their own carbon pricing initiative that meets the targets, the government of Canada creates an ETS model, which applies to power plants and industrial facilities. Alternatively, the government may use a fuel charge similar to carbon tax that covers fossil fuels and combustible waste (Parry & Victor, 2017). As an example, British Columbia has introduced a carbon tax, Ontario and Quebec utilise ETS model and Alberta has a hybrid policy in place, which is a combination of the two (Wood, 2018).

Quebec has linked its ETS program with California through the WCI and thus, also utilises the ARP mechanism (Figure 1-3) in order to set the lower limit for the carbon price. Due to the joint program, the same ARP and emission allowance prices are in place both in Quebec and California. In Quebec, the program covers fossil fuel combustion and emissions in electricity generation, buildings, transport and industry. (ICAP Quebec, 2019) Due to the WCI, Quebec cannot directly impact on its emission prices. Hence, it has been proposed that a carbon price scheme (CPS) similar to the UK system, could be implemented in Quebec as well. (Parry & Victor, 2017)

Ontario was also part of the WCI, but abandoned the ETS in 2018 due to political changes (The Canadian Press, 2018). On top of Ontario leaving the WCI, there is some political uncertainty related to the CPF due to lack of presented concrete actions after the year 2022 (McCarthy, 2019).

2.4 Carbon price floor in the EU ETS region

In principle, it would be possible to implement a CPF scheme covering the whole EU ETS sector and all countries. However, it has been argued to be unlikely, mostly due to difference in current production mix resulting in variance in political interests between the countries (Hocksell, 2019). As a result, regional CPF schemes (for

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[3] 34 EUR/tCO_2

example in Central and Western European area) have been considered more feasible (Graichen & Lenck, 2018).

In summer 2018, it was stated in the Lisbon declaration (European Commission, 2018) that France, Spain and Portugal will support implementation of the CPF. Later in the same year, energy ministry representatives from Denmark, France, Finland, Ireland, Italy, the Netherlands, Portugal, Sweden and the UK held discussions about the CPF (Buli Kamprath, 2018).

Currently CPF has only been implemented in the UK. The Dutch Government has proposed implementing the CPF, but the implementation still depends on the parliament's decision. In the Netherlands, CPF would be implemented as a top-up tax, similarly as in the UK. The scheme would cover electricity producers, setting the CPF at 12.30 EUR/tCO_2 in 2020 and increasing it to 31.90 EUR/tCO_2 in 2030. (Sterling & Potter, 2019)

Considering the assumed impacts of the CPF in the Netherlands, the main difference compared to the UK is electricity network interconnections to other countries. The Netherlands is well-interconnected, which can lead to decrease in domestic electricity production. This would be replaced by increasing electricity imports from the surrounding countries, where emissions would likely increase in this case. (Ramaker, 2018)

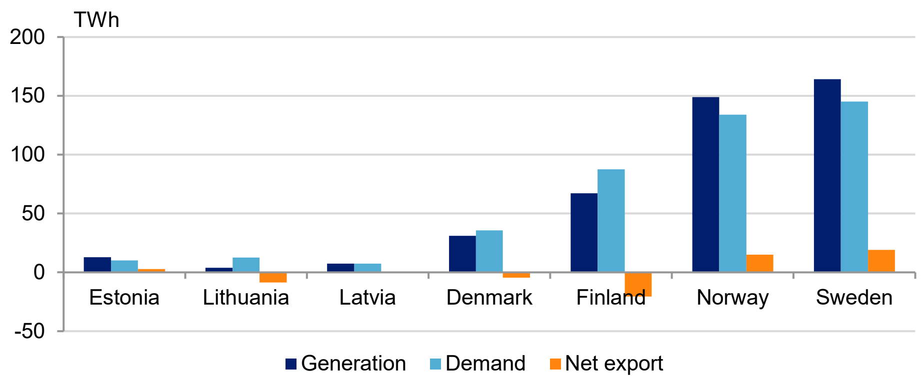
3 Analysis of a carbon price floor impact on electricity markets

This Section includes the overview of the electricity markets in the Nordic and Baltic countries (2.1) as well as simulation-based analysis on the potential impacts of CPF implemented on Nordic countries, or Nordic and Baltic countries. The market overview presents the country-specifc characteristics of these areas in terms of electricity generation, electricity transfer and emissions. The impacts of the CPF based on the market simulation is presented in Section 3.2.

3.1 Electricity market overview in the Nordics and Baltics

In 2016, the total electricity demand in the Nordic countries was 402 TWh and 30 TWh in the Baltic counties. Finland and Lithuania had the highest electricity net imports of approximately 20 TWh/a and 9 TWh/a, respectively. Sweden and Norway are the largest electricity exporters with net exports of 19 TWh/a and 15 TWh/a, respectively. (Eurostat, 2017). Electricity demand, generation and net exports in the Nordic and Baltic countries in 2016 are depicted in Figure 2-1.

Figure 2-1 – Electricity generation, demand and net export in the Nordic and Baltic countries in 2016



(Eurostat, 2017)

As depicted in Figure 2-1, the electricity demand in the Nordic countries is significantly higher in the Nordic countries than the Baltic countries. In the Nordic and Baltic context, these countries are characterised by high population, strong industrial sector with high energy-intensity and cold weather.

Especially in Norway, space heating of buildings is mostly based on electrical heating and due to this, the impact of cold weather on the total annual electricity demand is significant. In comparison to other Nordics countries, electricity demand is relatively low in Denmark, mostly due to less energy-intensive industrial sector and warmer climatic conditions.

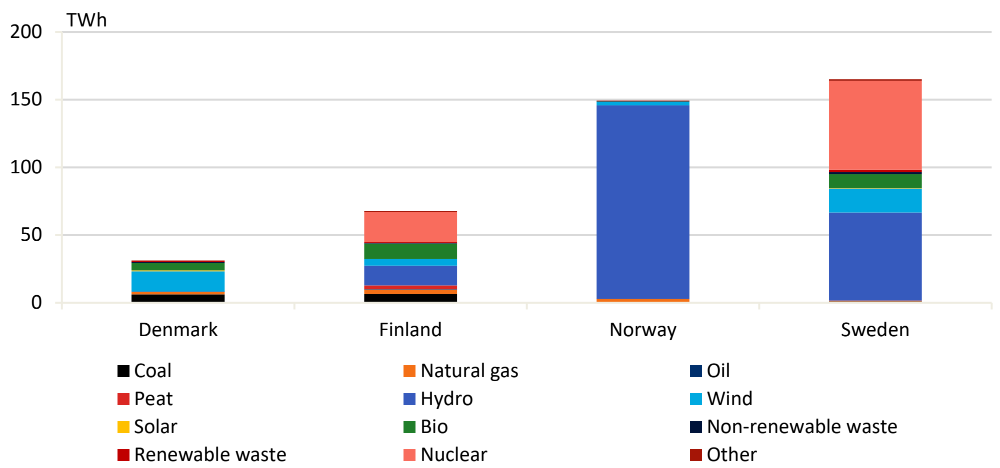
In the Baltic countries, the demand for electricity is significantly lower than in the Nordic countries mostly due to smaller population, warmer weather and lower share of industrial activities.

3.1.1 Electricity market in the Nordic countries

Current electricity generation and capacities in the Nordics

Currently, electricity generation in the Nordic countries is mostly based on renewable production technologies. Due to this, the electricity supply in the Nordics is mostly free from CO_2 emissions already today. Energy generation in the Nordic countries is depicted in Figure 2-2.

Figure 2-2 – Electricity generation in the Nordic countries in 2016



(Eurostat, 2017)

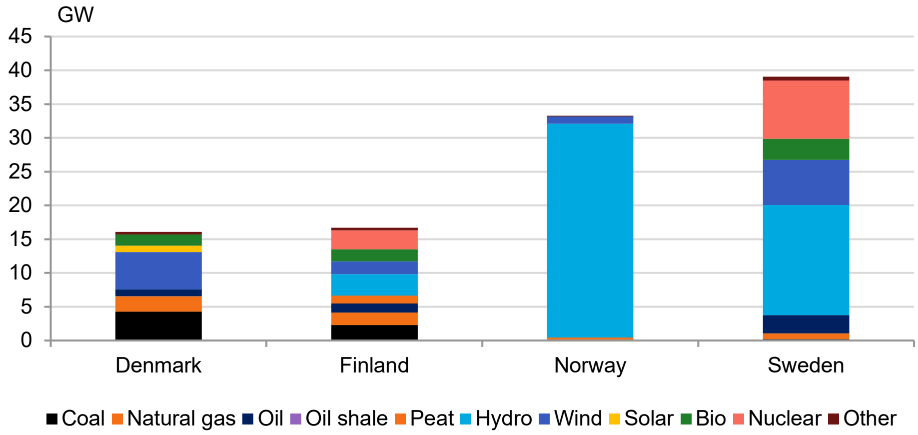
The electricity generation is dominated by hydro power with significant reservoir capacity, followed by nuclear power. In 2016, hydro power accounted for approximately 54 % of the total annual electricity generation and nuclear power for 21 % of the total electricity generation in the Nordics. Nordic countries also have very good wind resources and wind power generation has increased notably during the recent years accounting for 10 % of the total generation in 2016. (Eurostat, 2017)

With the high shares of hydro, nuclear and wind power generation, the share of generation based on fuel combustion is relatively low accounting for 14 % of the total generation, with over half of this generation based on renewable resources (bio fuels and renewable waste). Generation based on non-renewable fuels (coal, natural gas, peat and non-renewable waste) accounted for 7 % of the total annual electricity generation in the Nordics. (Eurostat, 2017)

The Nordic countries differ from each other from energy sources perspective: in Norway the generation is mostly based on hydro power and in Sweden on the combination of nuclear, hydro and wind. The generation in Denmark is characterised by high share of wind generation whereas the generation mix in Finland is more diversified, mostly based on nuclear, hydro and bio fuel-based production. In Denmark and Finland, the share on non-renewable electricity generation is high in comparison to Norway and Sweden accounting for 28 % and 19 % of the total annual generation, respectively.

Electricity generation capacities in the Nordic countries are presented in Figure 2-3. The generation capacities are mostly in line with the annual generation, as depicted in Figure 2-2. The most notable difference in comparison compared to generation results from RES. When energy generation is based on RES, relatively high amount of RES and reserve capacity is needed due to the fluctuating nature of generation. This is highlighted especially in case of Denmark where the share of RES generation (mostly wind) is high. Due to the this, the total capacity in Denmark is almost as high as in Finland even though the total generation is notably lower.

Figure 2-3 – Electricity generation capacities in the Nordic countries in 2016

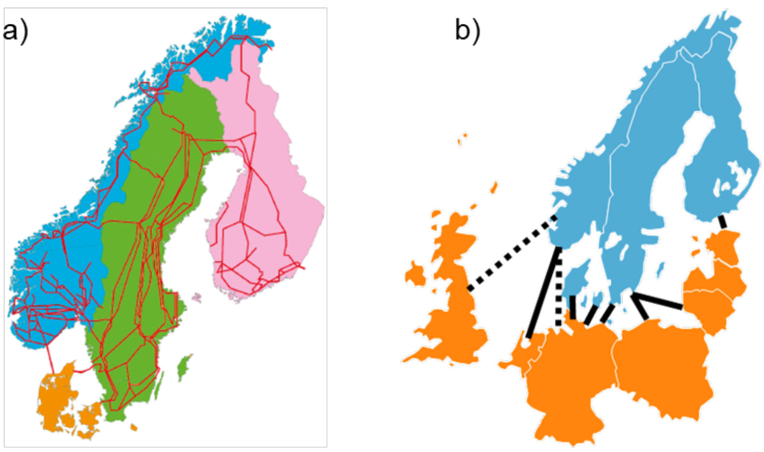


(ENTSO-E, 2019)

Current interconnector capacities in the Nordics

The Nordic countries are well interconnected and also have a common, cross-border market place for power exchange, Nord Pool, in place. Nord Pool provides daily physical electricity trading for the Nordic-Baltic day-ahead market. The existing interconnections within the Nordic countries as well as the interconnections between the Nordic countries and other European countries are illustrated in Figure 2-4.

Figure 2-4 – Existing interconnections in the Nordic countries



(Pöyry); a) interconnections within the Nordic countries, b) interconnections between the Nordics and other European countries

There is also a significant exchange across interconnections out of the Nordic region which are further complemented by new links being constructed to UK, Germany and Netherlands. Due to the high level of interconnections, common market place and high availability of flexible production capacity (Figure 2-3), also transfer volumes within the Nordic markets are high.

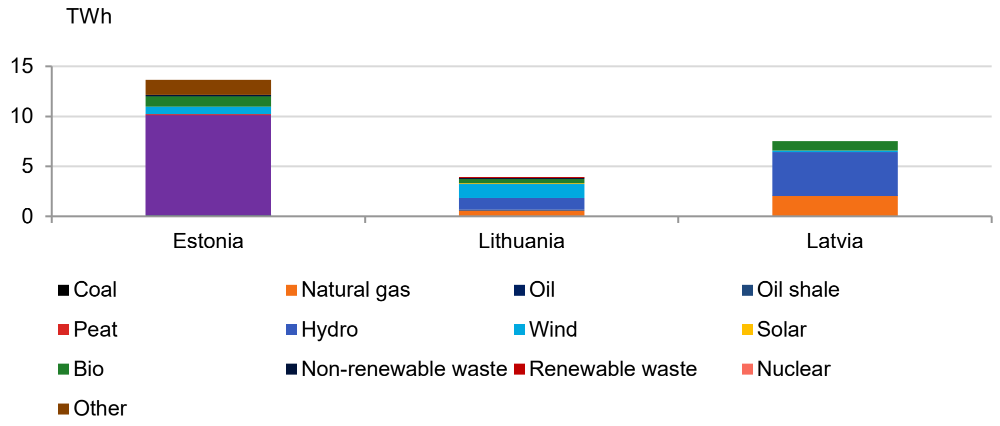
3.1.2 Electricity market in the Baltic countries

Current electricity generation and capacities in the Baltics

Compared to Nordic countries, electricity generation in the Baltics is currently more based on non-renewable energy sources, which accounted for 53 % of the total annual electricity generation in the Baltic countries in 2016. The most significant non-renewable fuels were oil shale and natural gas accounting for 39 % and 11 % of the total generation, respectively. Renewable electricity generation accounted for 41 % with hydro, bio fuels and wind being the most significant renewable energy sources. Hydro accounted for 22 %, bio fuels 10 % and wind 9 % of the total generation in 2016. (Eurostat, 2017).

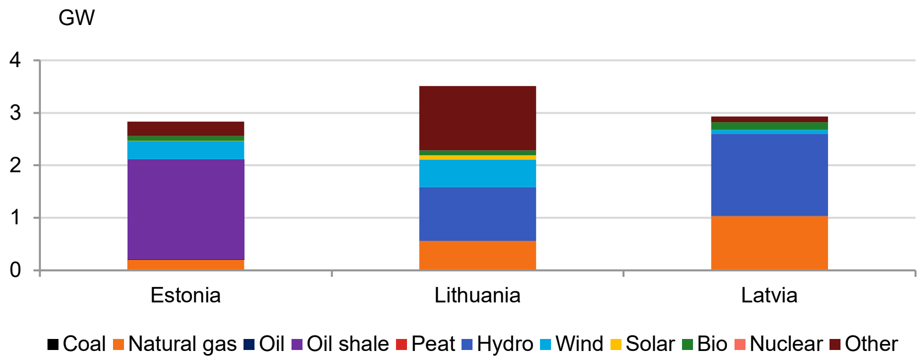
The Baltic countries have some fundamental differences in generation mix and installed capacities. In Estonia, generation is mostly based on oil shale, in Latvia mostly on hydro and natural gas and in Lithuania mostly on wind and hydro. The Baltic countries together consume more electricity than they produce and together create an energy deficit region importing electricity from neighbouring countries. As depicted in Figure 8, Latvia and Lithuania are both net importers while Estonia is a power exporter. Electricity generation and production capacities in the Baltic countries in are depicted in Figure 2-5 and Figure 2-6.

Figure 2-5 – Electricity generation in the Baltic countries in 2016



(Eurostat, 2017)

Figure 2-6 – Electricity generation capacities in the Baltic countries in 2016



(ENTSO-E, 2019)

Current interconnector capacities in the Baltics

Estonian and Lithuanian electricity markets have been fully open for competition since 2013, whereas Latvian electricity market was opened in 2015. On general level, the Baltic electricity market is composed of three well integrated power markets: Estonia, Latvia and Lithuania.

As Figure 2-7 shows, the Baltic market has several interconnections to other markets: to the Nordics in the North and West, to the Russian and Belorussian electricity systems in the East, and to Poland in the South. On top of the interconnection to the

Nordic countries, Baltic countries are also integrated with Nord Pool power market through interconnection between Finland and Estonia. Due to the historical dependence on the Russian system, the Baltic power systems still lack adequate electricity connections, both between themselves and to other parts of the EU for guaranteeing their security of supply and integration into the EU market.

Figure 2-7 – Exsiting interconnections in the Baltic countries

*Dashed red lines illustrate the upcoming interconnections. Existing DC connection, LitPol link I, will be replace by LitPol AC link. (Elering, 2019)

3.2 Carbon price floor impact assessment in the electricity market

3.2.1 Base Scenario

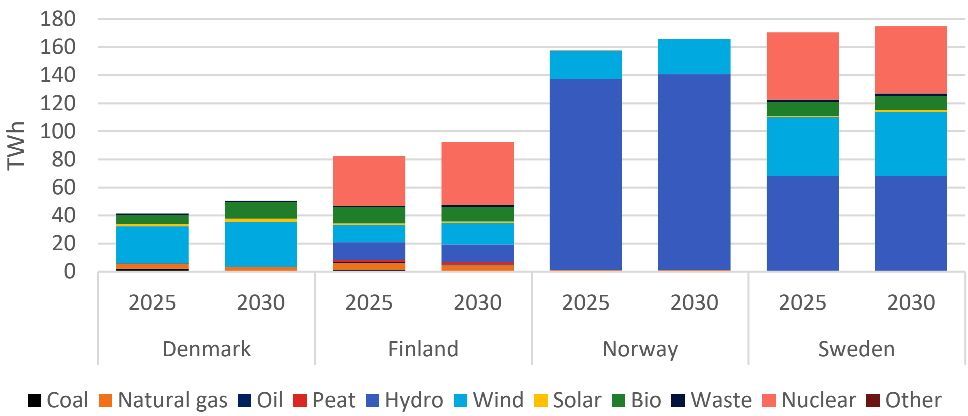
The Base Scenario refers to scenario with no carbon price floor implemented. It is utilised as a reference scenario to quantify the effects of carbon price floor in the other simulation scenarios. The Base Scenario is based on assumed EUA price of 10 EUR/tCO_2 in the simulation year for all countries in the emission trading scheme.

Electricity generation in the Base Scenario

In the Nordic countries, the total electricity generation is projected to increase from 2016 levels (Figure 2-2) in the Base Scenario by 2025 and also between 2025 and 2030. Especially wind power generation would grow in all of the countries in comparison to 2016 in the Base Scenario. In Sweden, generation based on nuclear power is expected to decrease by 2025 due to closing of Oskarshamn 1 (World Nuclear News, 2017) and Ringhals 1 and 2 (World Nuclear News, 2015). In Finland, nuclear generation is expected to increase by 2025 due to start-up of Olkiluoto 3 (Helsinki Times, 2019) and between 2025 and 2030 due to start-up of Hanhikivi 1 (World Nuclear News, 2018).

Another notable change in the electricity market is the decrease in the utilisation of coal due to coal being phased out in Denmark and Finland by 2030. The electricity generation in the Base Scenario in the Nordic countries in 2025 and 2030 is depicted in Figure 2-8.

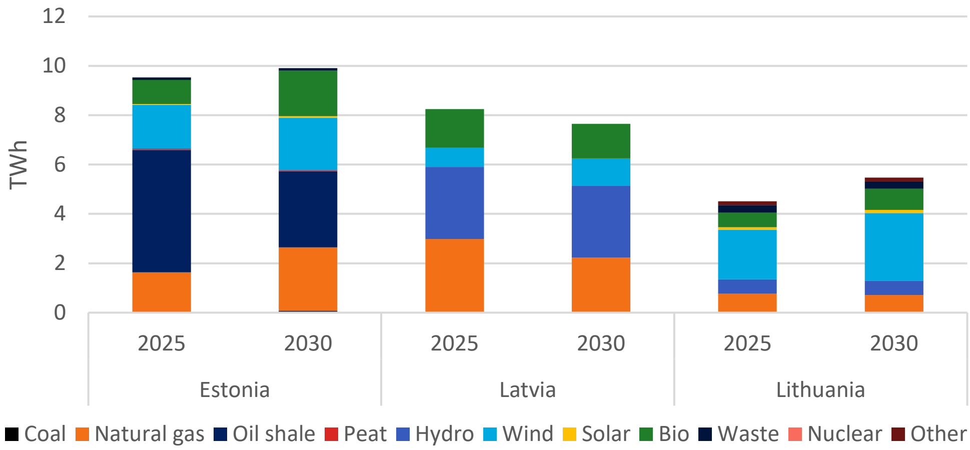
Figure 2-8 – Base Scenario electricity generation by fuel in the Nordic countries



(Pöyry)

Similarly as in the Nordics, notable growth in wind power generation also occurs in the Baltic countries until 2030 in the Base Scenario in comparison to current generation mix (Figure 2-5). Apart from this, the most notable change in the fuel mix in this scenario is the decrease in utilisation of oil shale in Estonia. In Base Scenario, the oil shale would mostly be replaced by wind, natural gas and also bio power generation. Electricity generation in the Base Scenario in the Baltic countries in 2025 and 2030 is depicted in Figure 2-9.

Figure 2-9 – Base Scenario electricity generation by fuel in the Baltic countries



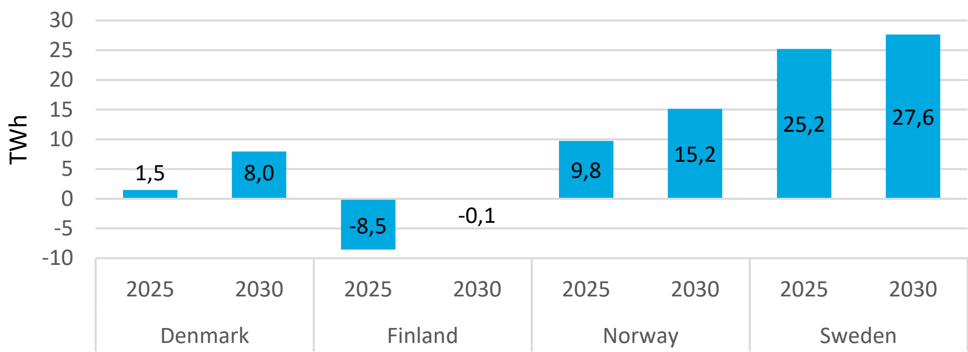
(Pöyry)

Electricity flows in the Base Scenario

Overall, the Nordics would remain an electricity surplus area in the Base Scenario. Based on the simulation, the net exports from the Nordics would increase to approximately 30 TWh/a by 2025 and 50 TWh/a by 2030 in Base Scenario in comparison to current level of approximately 10 TWh/a in 2016 (Figure 2-1).

In contrast to 2016, Denmark would become an electricity net exporter and relatively high increase in exports would occur, especially in Sweden in this scenario. With the new nuclear power plants coming online, Finland's net exports would be around zero in 2030 in Base Scenario. Annual net electricity exports in the Nordic countries in the Base Scenario are presented in Figure 2-10.

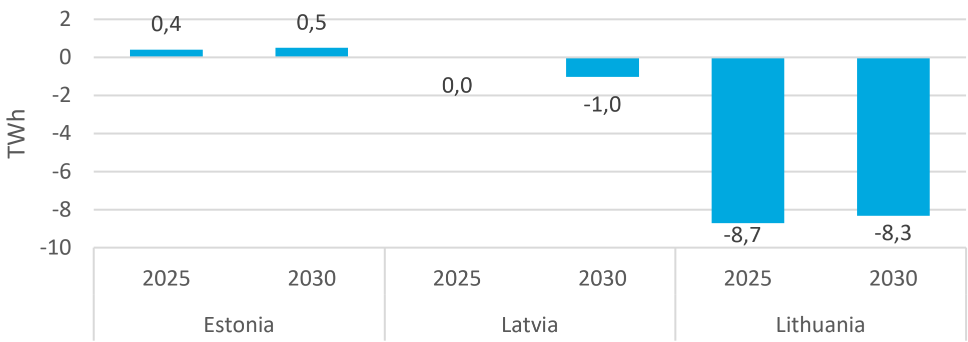
Figure 2-10 – Base Scenario net electricity exports in the Nordic countries



(Pöyry)

Overall, the Baltics would remain an energy deficit area in the Base Scenario, similarly as in 2016 (Figure 2-1). Estonia would remain a net exporter and Latvia and Lithuania both net importers. In this scenario, the most significant net importers to the Baltic area would be Finland, Sweden, Russia and Belarus. Annual electricity net exports in the Baltic countries in the Base Scenario are presented in Figure 2-11.

Figure 2-11 – Base Scenario electricity net exports in the Baltic countries

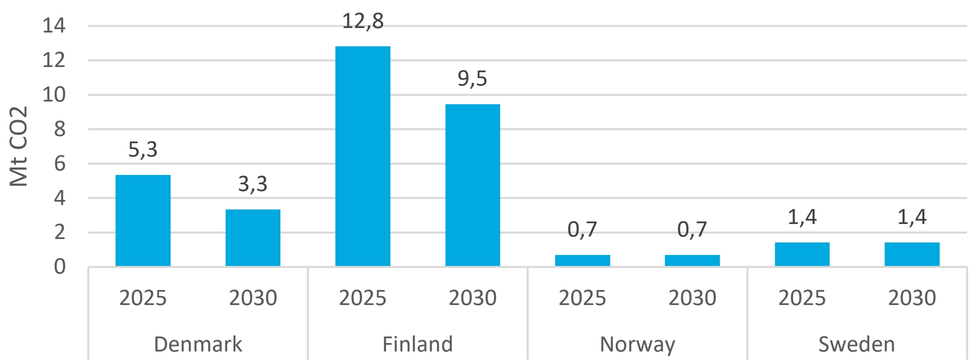


(Pöyry)

CO_2 emissions in the Base Scenario

In Base Scenario, the emissions in the Nordic countries would be relatively low. While the emissions in Denmark and Finland would be low as well, Norway and Sweden would have even lower emissions due to high availability of emission-free energy sources, mostly hydro. The decrease in emissions in Finland and Denmark in the period of 2025–2030 is mostly due to phase-out of coal generation and new nuclear power plant assumed to come online in Finland. The CO_2 emissions in Base Scenario are depicted in Figure 2-12.

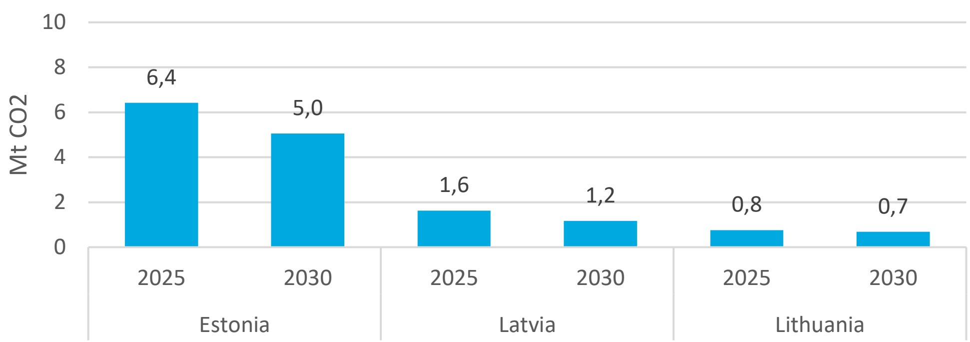
Figure 2-12 – Base Scenario electricity generation CO_2 emissions in the Nordic countries



(Pöyry)

Similarly as already today, most of the emissions in the Baltic countries in Base Scenario would be due to utilisation of oil shale in Estonia. In this scenario, its utilisation would decrease in the period of 2025–2030 resulting in decrease in total emissions in the Baltics. Emissions in Latvia and Lithuania are mostly due to power generation based on natural gas, which is would decrease slightly in this scenario. Total emissions in the Baltics in Base Scenario are shown in Figure 2-13.

Figure 2-13 – Base Scenario electricity generation CO_2 emissions in the Baltic countries



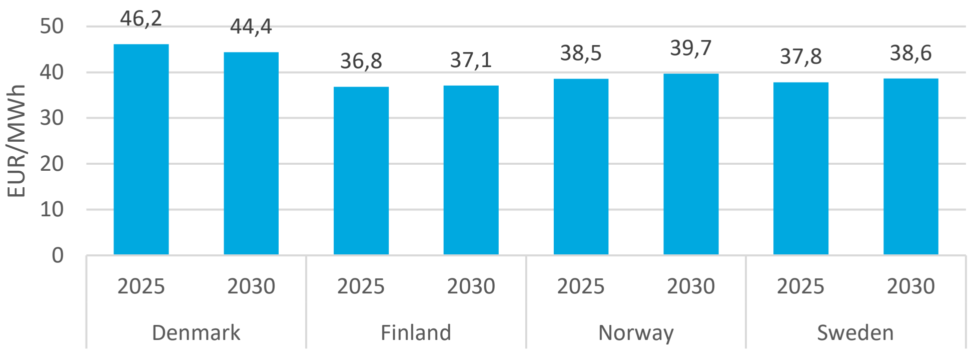
(Pöyry)

Electricity wholesale price in the Base Scenario

In Base Scenario, the average electricity wholesale prices in the Nordics would remain mostly below 40 EUR/MWh. The low price level is explained by the low EUA price assumption of 10 EUR/tCO_2 in Base Scenario. In this scenario, Denmark would be the only major exception to the low electricity price level in other Nordic countries with prices around the level of 45 EUR/MWh.

In Finland, new nuclear generation would stabilise the prices to even lower level than in Norway and Sweden in this scenario. In addition to differences in the production mix, different price levels between the countries are also due to limitations in the inter-country transmission capacities. The wholesale electricity prices in the Nordic countries in the Base Scenario are depicted in Figure 2-14.

Figure 2-14 - Base Scenario electricity wholesale prices in the Nordic countries (EUA price of 10 EUR/tCO_2)

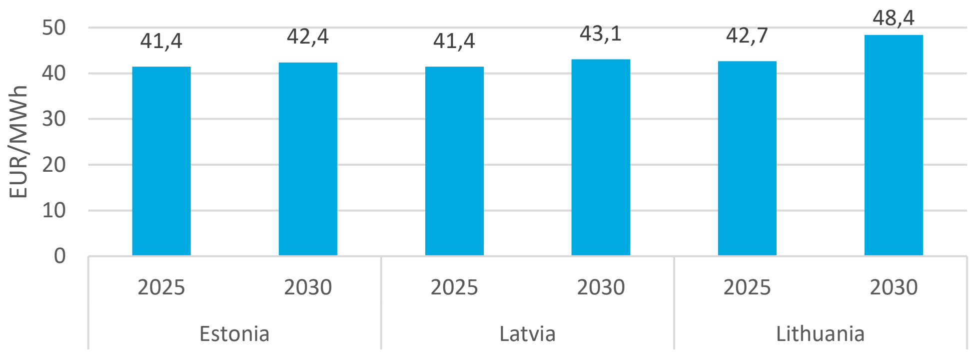


(Pöyry)

In Base Scenario, the average wholesale price level in the Baltics is mostly slightly higher than in the Nordic countries, at around 40-45 EUR/MWh. Exception to this price level is Lithuania in 2030, where the prices would increase to above level of 48 EUR/MWh in this scenario. The high increase in electricity prices in Lithuania is mostly due to decrease in imports from Russia and Belarus resulting from the desynchronisation from Russian electricity system. Due to this, the dependence on imports from Central Europe and Nordic countries increase, which has an especially high impact on Lithuania relying heavily on imports and its own wind power generation.

The wholesale electricity prices in the Baltic countries in the Base Scenario are depicted in Figure 2-15.

Figure 2-15 - Base Scenario electricity wholesale prices in the Baltic countries (EUA price of 10 EUR/tCO_2)



(Pöyry)

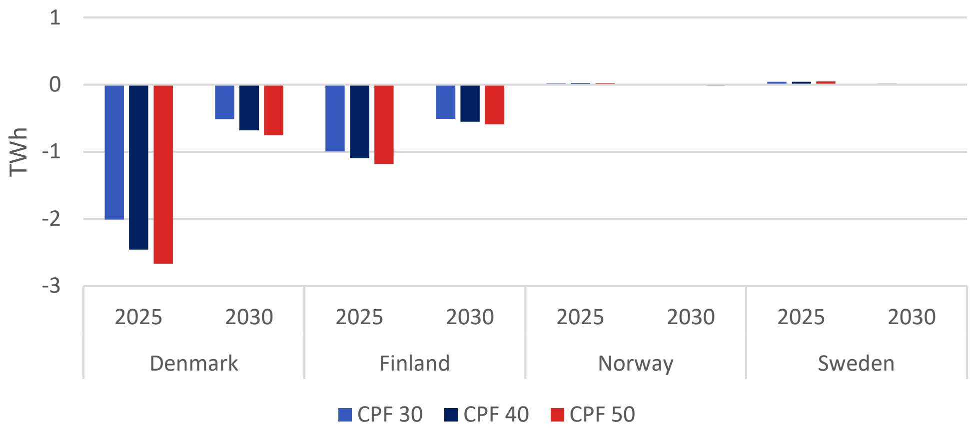
3.2.2 The assessment of Nordic carbon price floor in the electricity market

In this Section, the impact of Nordic carbon price floor is analysed based on the results of the electricity market simulation. The results presented in this section refer to the difference in comparison to the Base Scenario with no CPF price in place and EUA price level assumed at low level of 10 EUR/tCO_2 (presented in Section 2.2.1). The impacts of Nordic-Baltic price floor are analysed separately in Section 2.2.3.

Electricity generation in Nordic carbon price floor scenarios

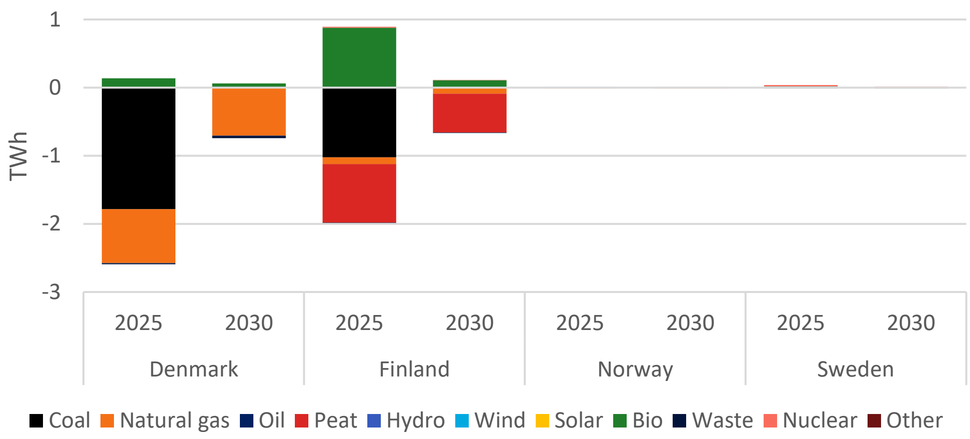
The impact of the analysed CPF scenarios on electricity generation in the Nordic countries is depicted in Figure 2-16, illustrating the difference in comparison to the Base Scenario. The impact on fuel use in electricity generation in the Nordics in CPF 40 Scenario is depicted in Figure 2-17.

Figure 2-16 – The impact of Nordic carbon price floor on electricity generation in comparison to Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

Figure 2-17 – The impact of Nordic carbon price floor on fuels in electricity generation in CPF 40 Scenario in comparison to Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

Based on the simulation, the most significant impact in the CPF scenarios in comparison to Base Scenario would occur in Denmark. In CPF 40 and CPF 50 scenarios, there is up to 6% decrease in 2025 in comparison to total generation in Denmark in Base Scenario. The decrease is mostly due to decrease in generation based on coal and natural gas as the CPF scenarios are seen to incentivise phase-out of coal generation already in 2025. In case of CPF 40, 80 % of coal generation would be phased out until then.

It is to be noted that this scenario assumes a low EUA price of only 10 EUR/tCO_2 in the rest of countries participating in the EU ETS, where Denmark is well interconnected to. This drives imports of electricity from e.g. Germany instead of own generation and there is only a small increase in domestic bio-based production in Denmark. The interconnection flows are discussed further in the next section.

In Finland, the approximate decrease of 2 TWh of electricity production in CPF 30-CPF 50 scenarios in 2025 accounts for 2 % of total power generation in comparison to Base Scenario. In Finland, similar type of impact is seen with coal phase-out as in Denmark. The impact is somewhat smaller in Finland compared to Denmark, mostly due to Finland not being that well interconnected to areas with lower carbon prices in the CPF scenarios.

In addition, the utilisation of peat would decrease while use of biomass would increase in Finland, both by around 1 TWh in CPF 30-CPF 50 scenarios in 2025 compared to the Base scenario. This is mostly due to some plants that utilise biomass in cogeneration with other solid fuels (mostly coal and peat) optimising fuel utilisation. Some plants have some technical constraints for the share of biomass, which has been taken into account in the simulation. The change in the fuel mix in lower in 2030, because there is no longer coal use and peat is also already partly replaced by biomass use in the Base scenario.

In Norway and Sweden, there is practically no impact on generation in comparison to Base Scenario, mostly because the generation is already based on renewables and nuclear with no CO_2 emissions.

Electricity flows in Nordic carbon price floor scenarios

Based on simulation, the impact of Nordic CPF would be the most significant on Denmark, which would become a net importer in 2025 in CPF scenarios in contrast to being net exporter in the Base Scenario (Figure 2-8). Also the net imports in Finland would increase in comparison to Base Scenario. The analysis shows no significant impact on total annual net exports in Norway and Sweden in the CPF scenarios in comparison to Base Scenario. However, the exports would be headed more to Nordic area with exports to Denmark and Finland increasing and the exports to the UK, CWE and Baltics decreasing in comparison to Base Scenario.

In case of Denmark, the decrease in net exports in CPF scenarios in comparison to Base Scenario is mostly due to decrease in electricity exports to the UK and CWE region (mostly Germany and Netherlands) rather than increase in electricity imports. In case of Finland, the decrease in net exports is mainly due to increase in imports from Sweden, but also due to decrease in exports to Estonia in comparison to Base Scenario. The decrease in production by Finland and Denmark in comparison to Base Scenario would be mostly compensated by production based on gas and coal, especially in Germany and Poland in CPF scenarios.

The total annual net flows in Nordic CPF scenarios is depicted in Figure 2-18 and the impact of Nordic CPF on electricity net exports in comparison to Base Scenario is depicted in Figure 2-19.

Figure 2-18 – Total annual net exports in the Nordics in Base and Nordic carbon price floor scenarios

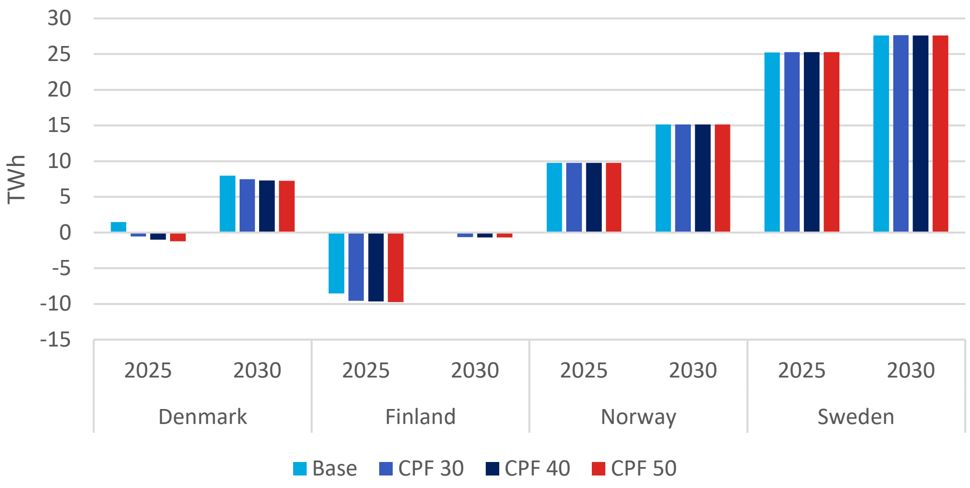
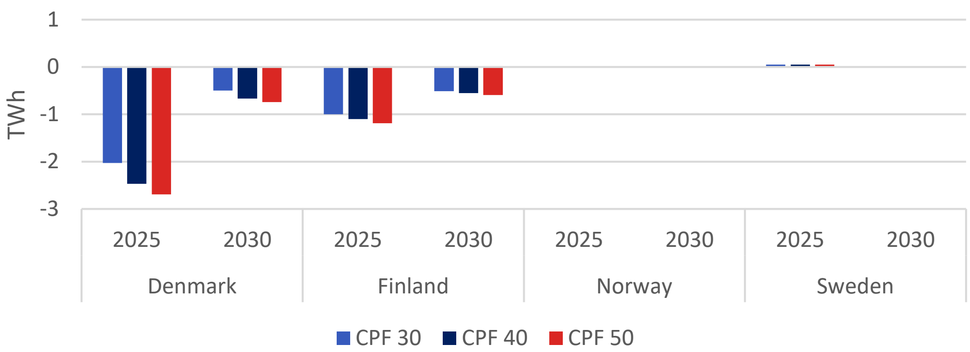


Figure 2-19 – The impact of Nordic carbon price floor on electricity net exports in comparison to Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

CO_2 emissions in Nordic carbon price floor scenarios

Due to decrease in domestic electricity generation based on coal, gas and peat, the CPF scenarios would decrease CO_2 emissions both in Finland and Denmark in comparison to Base Scenario with no material impact in Sweden and Norway (Figure 2-20).

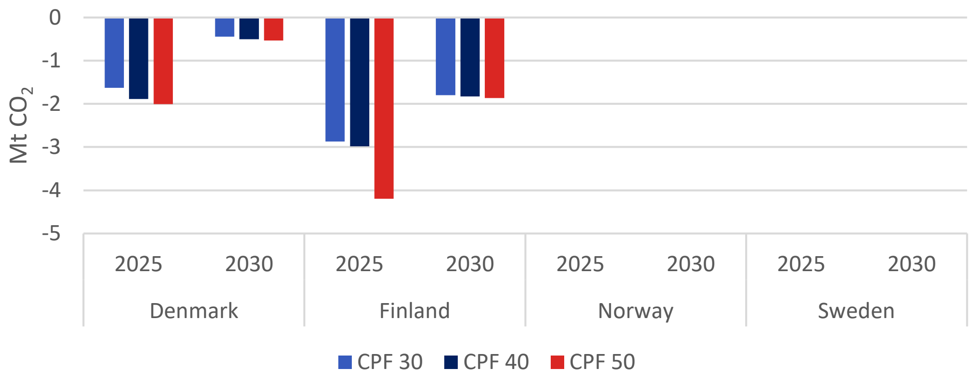
Based on the analysis, the total decrease in emissions in the Nordics in CPF scenarios would account for 22-31 % (4.5-6.2 $MtCO_2$/a depending on CPF scenario) decrease in comparison to total annual emissions in the Nordics in the Base Scenario in 2025 and 15 % (2.2-2.4 $MtCO_2$/a) in 2030. The higher impact in 2025 in comparison to Base Scenario is mostly due to faster phase-out of coal in CPF scenarios. In Finland, the high impact in CPF 50 scenario is mostly due to higher decrease in utilisation of coal in comparison to other analysed scenarios. Based on the analysis, the impact of CPF scenarios in Finland compared Base Scenario in 2030 is lower than in 2025 due to phase-out of coal in Finland and Denmark by 2030.

When considering the impact of Nordic CPF scenarios on European level, CO_2 emissions would increase in other EU ETS countries in comparison to Base Scenario as the decrease in production in the Nordics would be compensated. However, the analysed Nordic CPF scenarios would result in a net decrease of 3-4 $MtCO_2$/a in 2025 and 2 $MtCO_2$/a in 2030 within the power sector of EU ETS countries in comparison to Base Scenario (Figure 2-21). This is due to production based on coal and gas in Denmark and coal and peat in Finland in Base Scenario being mostly replaced by natural gas in CWE region in the CPF scenarios. Electricity production based on natural gas produces lower CO_2 emissions than peat and coal, which would result in net decrease in emissions based on the analysis. Some of the production would also be replaced with production based on coal in Poland, which is considered in the presented net impact.

The previous net decrease of 2-4 $MtCO_2$/a represent only about 0.2% of the total emissions within the ETS. In addition, as the total emissions are set by emission cap, the Nordic carbon price floor should have no actual impact on the total emissions within EU ETS including industry.

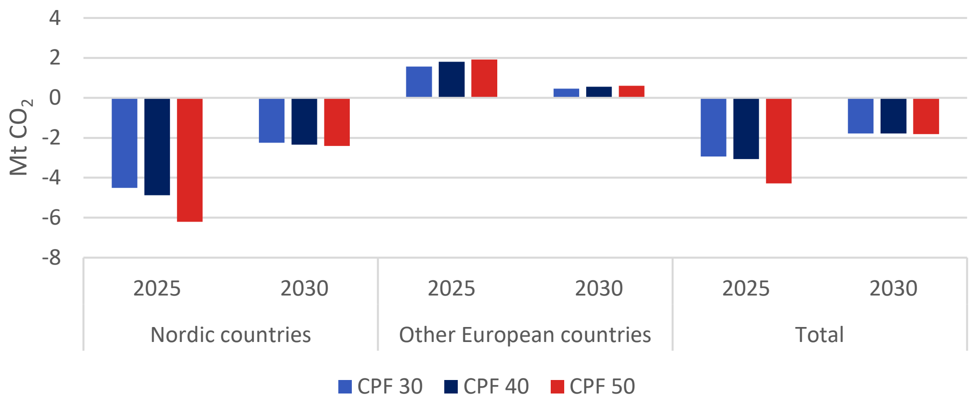
The impact of Nordic price floor on CO_2 emissions in the power sector in Nordic countries is depicted in Figure 2-20 and on European level in Figure 2-21.

Figure 2-20 – The impact of Nordic carbon price floor on CO_2 emissions in comparison to Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

Figure 2-21 – The impact of Nordic carbon price floor on CO_2 emissions in the power sector on European level in comparison to Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

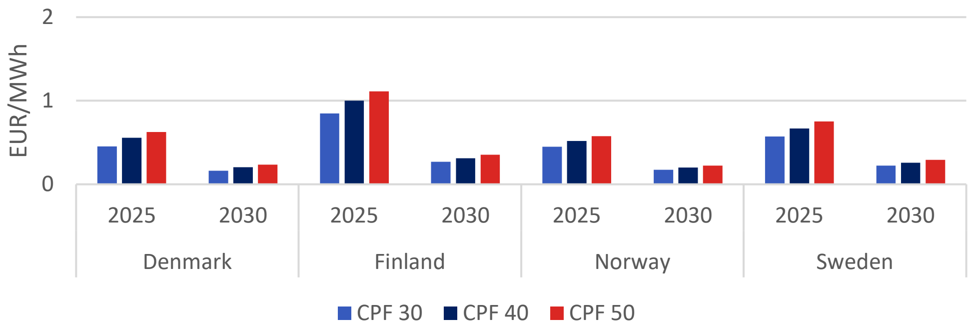
Electricity wholesale price in Nordic price floor scenarios

The wholesale prices in the CPF scenarios are affected by e.g. increase in marginal costs due to higher carbon price and change in net exports. Overall, the impact on electricity wholesale prices in Nordic countries is relatively low in all analysed CPF scenarios, accounting for approximately 1-2 % increase in comparison to Base Scenario. Also, the differences between the analysed CPF scenarios are considered very low, below 0.30 EUR/MWh being the highest variance between the cases.

The reason for the low impact of CPF scenarios to the Nordic wholesale electricity prices is the electricity price formation in the Nordic countries. The price is set by the Norwegian and Swedish hydro production that bid mainly against the thermal plants in the Continental Europe. As in the simualtions the carbon price floor does not affect the costs of continental generation, the opportunity cost of Nordic hydro remains broadly the same as in the Base Scenario.

Based on the simulation, wholesale prices would also increase slightly in comparison to Base in Scenario in other parts of Europe and especially in the Baltics, but by no more than 2-3 %. It is to be noted that in the Base Scenario the electricity prices are low due to assumed EUA price level of 10 EUR/tCO_2 in the scenario. The impact of Nordic CPF on wholesale prices in the Nordics is depicted in Figure 2-22.

Figure 2-22 – The impact of Nordic CPF on average electricity wholesale prices in comparison to Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

3.2.3 The assessment of Nordic-Baltic carbon price floor in the electricity market

In this Section, the impact of Nordic-Baltic carbon price floor is analysed based on the results of the electricity simulation. The results presented in this section refer to the difference in comparison to the Base Scenario with no CPF price in place (presented in Section 2.2.1). In Base Scenario, the EUA price level is assumed to be at 10 EUR/tCO_2.

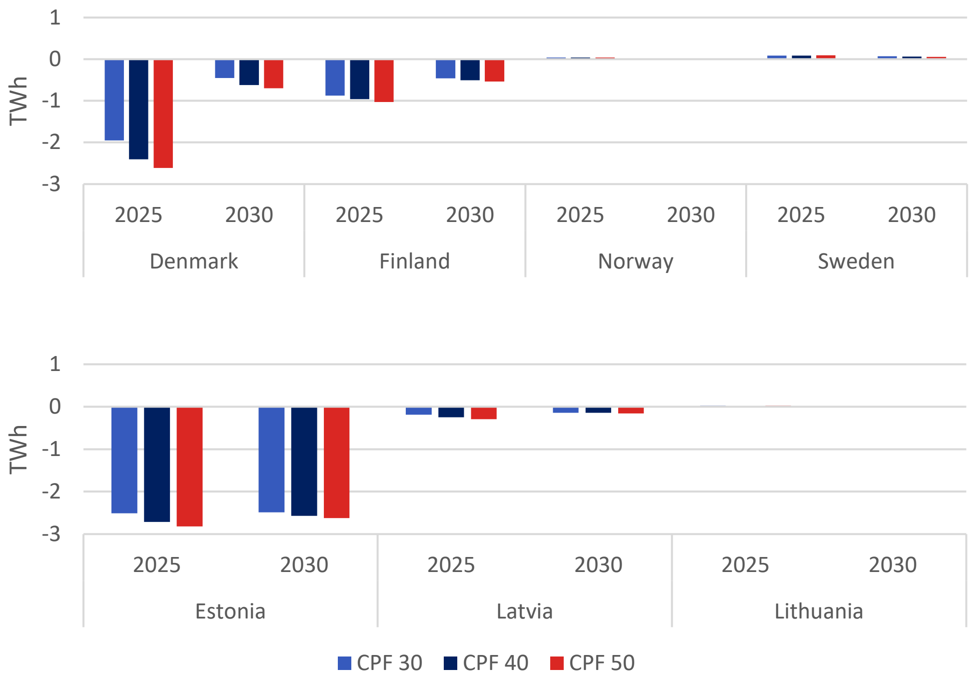
Electricity generation in Nordic-Baltic carbon price floor scenarios

In the Nordic countries, the analysis indicates only a small difference in total electricity generation in Nordic-Baltic CPF scenarios in comparison to Nordic CPF scenarios (Section 2.2.2). Based on the simulation, the electricity generation in the Nordics is circa 0.1-0.2 TWh/a higher in Nordic-Baltic CPF scenarios compared Nordic CPF scenarios with generation based on biomass increasing in the Nordics to compensate for the increased imports to Baltics.

In the Baltic countries, the most significant impact of Nordic-Baltic CPF scenarios in comparison to Base Scenario would occur in Estonia, whereas only small impact on generation would occur in Latvia and Lithuania based on the simulation. The Nordic-Baltic CPF scenarios would account for decrease of 2.5-2.8 TWh/a in Estonia both in 2025 and 2030 in comparison to Base Scenario accounting for decrease of 25-30 % in generation in Estonia. The decrease in production is mainly due to decreased utilisation of oil shale in the CPF scenarios. Also, in Latvia, a small decrease in generation based on natural gas occurs in CPF scenarios.

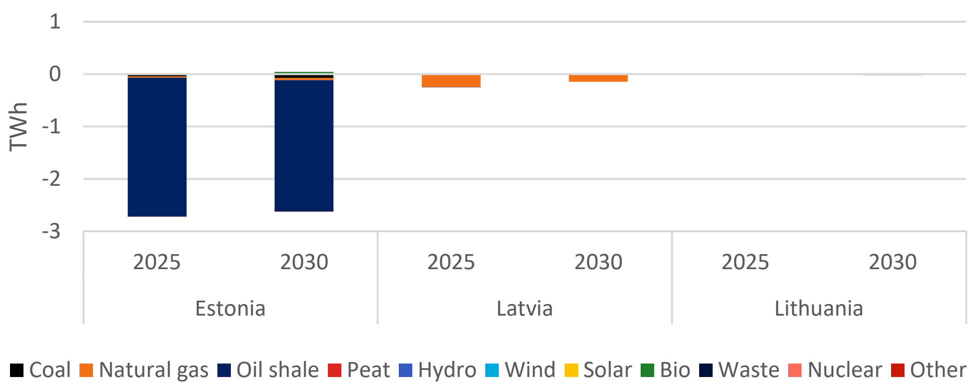
The impact of Nordic-Baltic carbon price floor on total electricity generation is depicted in Figure 2-23. The impact on generation in CPF 40 scenario is analysed fuel-specifically for Baltic countries in Figure 2-24.

Figure 2-23 – The impact of Nordic-Baltic carbon price floor on electricity generation in comparison to Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

Figure 2-24 – The impact of carbon price floor on fuels in electricity generation in the Baltics in CPF 40 scenario in comparison to the Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

Electricity flows in Nordic-Baltic carbon price floor scenarios

Based on the simulation, the electricity flows in the Nordic countries in Nordic-Baltic CPF scenarios are highly similar in comparison to Nordic CPF scenarios (Section 2.2.2) with only small changes of around 0.1-0.2 TWh/a in Finland, for example.

In the Baltics, the most significant impacts of Nordic-Baltic CPF would occur in Estonia, which would become an electricity net importer in CPF scenarios in contrast to being an exporter in the Base Scenario (Figure 2-11). This is partly due to increase in imports from Finland, but mainly due to significant decrease in exports to Latvia in comparison to the Base Scenario based on the simulation. Consequently, this would decrease the exports from Latvia to Lithuania and from Lithuania to Poland in comparison to Base Scenario.

Total annual net flows in the Baltics in Nordic-Baltic CPF scenarios are depicted in Figure 2-25 and the impact of Nordic-Baltic carbon price floor on electricity net exports in comparison to Base Scenario is depicted in

Figure 2-26. The electricity flows in the Nordics are highly similar compared to Nordic CPF scenarios, as depicted in Figure 2-19 and Figure 2-20.

Figure 2-25 – Total annual net flows in the Baltics in Base and Nordic-Baltic carbon price floor scenarios

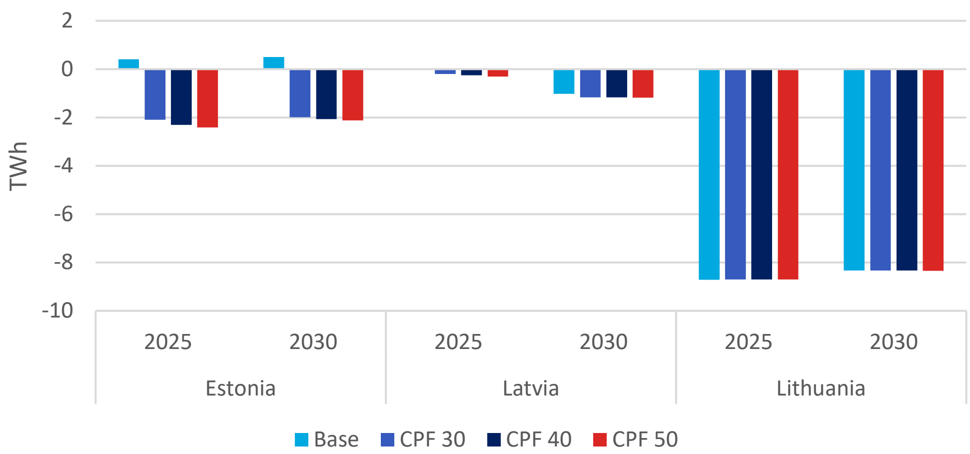
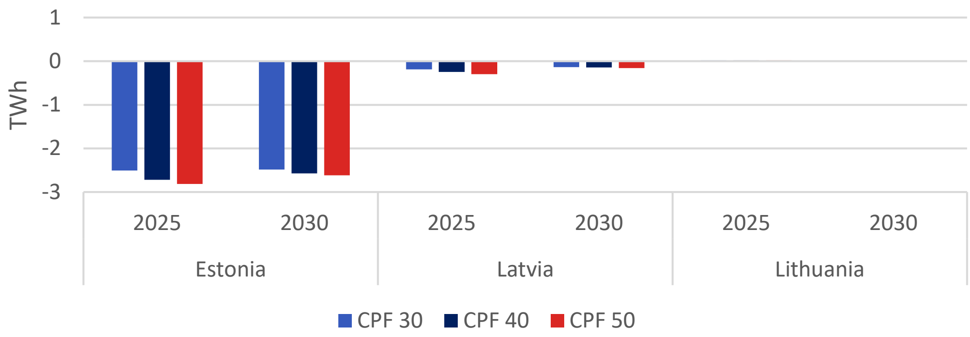


Figure 2-26 –The impact of Nordic-Baltic carbon price floor on electricity net exports in comparison to Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

CO_2 emissions in Nordic-Baltic carbon price floor scenarios

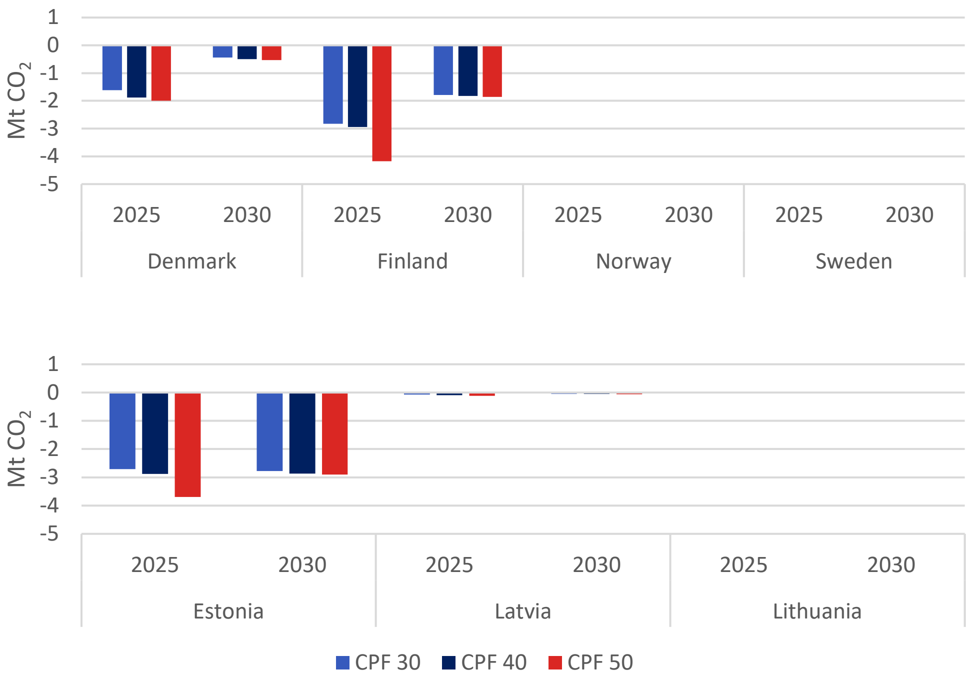
In Nordic-Baltic CPF scenarios, the total emissions in the Nordic countries would remain mostly at the same level in comparison to Nordic CPF scenarios (2.2.2) due to highly similar electricity generation between the cases.

In the Baltic countries, significant decrease in emissions occurs in Nordic-Baltic CPF scenarios in comparison to Base Scenario mostly due to decrease in utilisation of oil shale in Estonia. In other Baltic countries, the impact is mostly low based on the simulation. The emissions decrease in Nordic-Baltic CPF scenarios accounts for up 60 % reduction (4 $MtCO_2$ in CPF 50) in total electricity sector emissions in the Baltics both in 2025 and 2030 in comparison to Base Scenario.

In the Nordic-Baltic CPF scenarios, the electricity generation based on oil shale in Estonia would mostly be replaced with coal-based generation in Poland and gas-based production in CWE region in comparison to Base Scenario. Despite the increase in utilisation of coal in Poland, the Nordic-Baltic CPF would result in 1-2 $MtCO_2$/a higher decrease in emissions in comparison to Nordic CPF scenarios in the EU ETS market. This is mainly due to generation based on gas and coal producing less emissions than production based on oil shale resulting in decrease in emissions as a net effect.

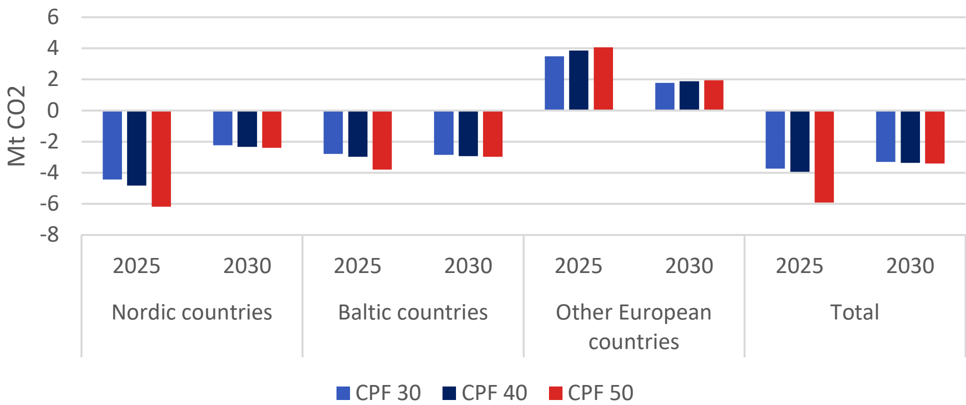
The impact of Nordic-Baltic carbon price floor on CO_2 emissions in the power sector in Nordic and Baltic countries in comparison to the Base Scenario is depicted in Figure 2-27 and on European level in Figure 2-28.

Figure 2-27 – The impact of Nordic-Baltic carbon price floor on CO_2 emissions in Nordic and Baltic countries in comparison to the Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

Figure 2-28 – The impact of Nordic-Baltic carbon price floor on CO2 emissions in the power sector on European level in comparison to the Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

Electricity wholesale price in Nordic-Baltic carbon price floor scenarios

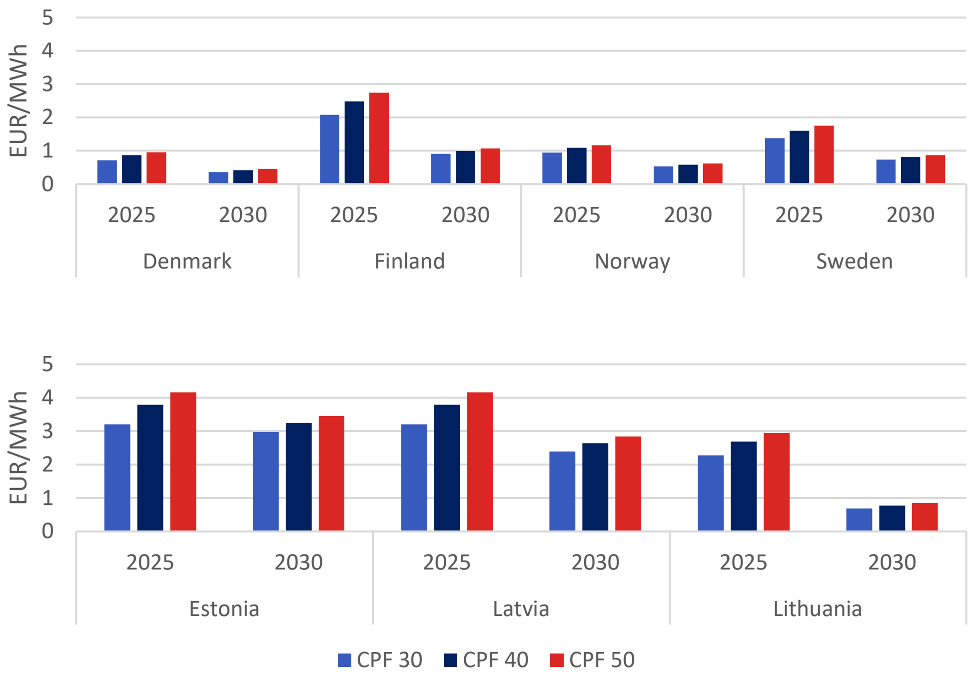
The Nordic-Baltic price scenarios have more significant impact on electricity prices in the Nordic countries than the Nordic CPF scenarios (2.2.2). In Nordic-Baltic CPF scenarios, the increase in prices in the Nordics is on average 3-5 % in 2025 and up to 2 % in 2030. As an example, the impact of Nordic CPF on wholesale electricity price in Finland is around 1 EUR/MWh in 2025, whereas the increase in Nordic-Baltic CPF scenarios is at a level of 2-3 EUR/MWh. Higher price level is mostly due to Nordic-Baltic CPF scenarios resulting in higher demand for the production setting the system prices both in Central Europe and the Nordics in comparison to Nordic CPF scenarios.

In Baltic countries, the impact of Nordic-Baltic CPF on wholesale prices is notably higher than in the Nordic countries. Overall, the weighted average price level in Baltics increase to around 45-46 EUR/MWh in 2025 and up to around 47 EUR/MWh in 2030 in contrast to Base Scenario average prices of 42 EUR/MWh and 45 EUR/MWh in 2025 and 2030, respectively. This is mostly due to increase in marginal costs of production based on oil shale and limitations in interconnection capacities to replace all of this generation cost-efficiently.

In contrast to Latvia and Estonia, relatively small price increases occur in Lithuania in in comparison to Base Scenario with price increases of below 1.0 EUR/MWh in 2030 in all analysed Nordic-CPF scenarios. This is partly due to high electricity price already in the Base Scenario.

The impact of Nordic-Baltic carbon price floor on electricity wholesale prices in comparison to the Base Scenario is depicted in Figure 2-29.

Figure 2-29 – The impact of Nordic-Baltic carbon price floor on electricity wholesale prices in comparison to the Base Scenario



(Pöyry); The figure indicates the difference in the analysed CPF price scenarios in comparison to the Base Scenario

4 Analysis of carbon price floor impacts on heating sector

In this Section, the impact of implementing CPF in the Nordic and Baltic region is analysed from heating sector perspective. The aim of the Section is to analyse the potential impact CPF could have on reducing emissions both in the short-term through fuel switches as well as in the long-term through implementation of low-carbon alternatives.

The analysis covers heating market overview as well as case studies in two DH networks. One of the networks represents a typical large-scale network, whereas the other represents a typical medium-scale network. The CPF scenarios and fuel prices are the same as in the case of electricity market analysis with Finnish fuel taxation applied.

4.1 Heating sector overview in the Nordics and Baltics

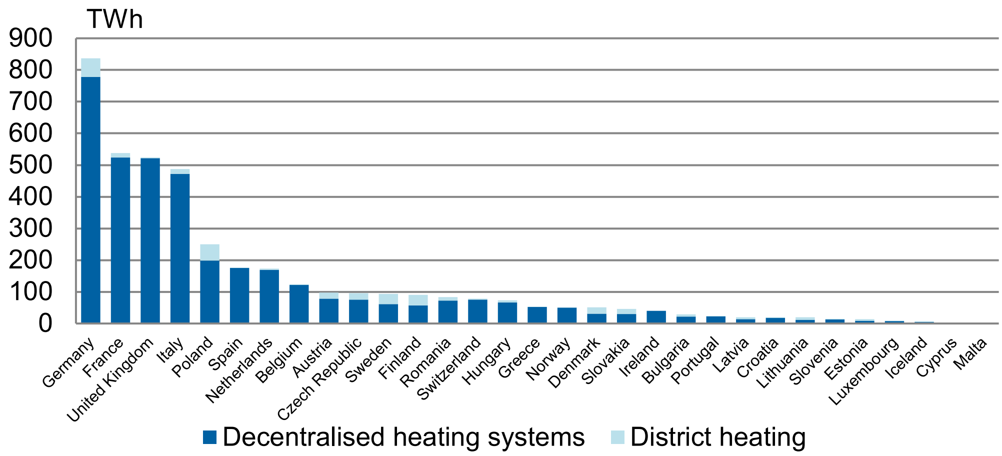
Heating sector consists of space heating and domestic water heating in buildings (e.g. residential, commercial and public sectors) and industrial heating sector. Heat for building sector may be produced either through decentralised heating systems (e.g. building-specific boilers, electrical heating and heat pumps) or centralised heating systems (i.e. district heating).

In centralised heating systems, heat may be produced either through heat-only appliances (e.g. heat-only boilers (HOB) and heat pumps) or combined heat and power (CHP) production. The cost-competitiveness of CHP in comparison to HOB production is affected by e.g. electricity market price, fuel prices and taxation as well as emission allowance prices.

Heating sector is only partially included in the EU ETS. Building-specific heating appliances are not included in EU ETS, whereas industrial heating plants are included in case the capacity of the plant exceeds a limit set in the EU ETS. District heating is typically included in the EU ETS scheme. In case CPF was implemented, industrial heating, as well industrial process emissions, could potentially be excluded from the scheme due to carbon leakage risk. Due to this uncertainty, the main focus in this analysis is on district heating.

Mostly due to cold climatic conditions, the specific heat demand (per capita) in the Nordic and Baltic area is higher than in other parts of Europe. In EU ETS countries, heat generation is largely covered by decentralized heating systems. In contrast to many other European countries, the share of district heating in the Nordic and Baltic countries is high accounting for approximately one-third of the total heat demand in the region. Final heat consumption in EU ETS countries divided in centralised and decentralised heating systems is depicted in Figure 3-1.

Figure 3-1 – Final heat consumption in the EU ETS countries in 2012

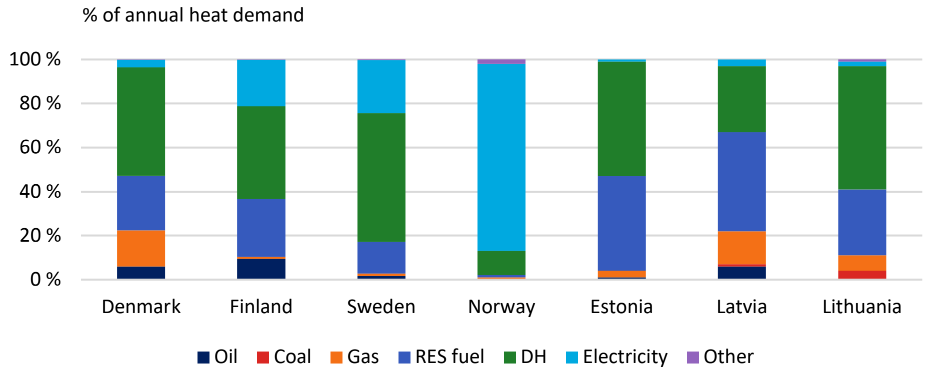


(European Commission, 2016)

In general, the market share of district heating in the Nordics and Baltics is high, especially in the urban areas. A significant exception to this is Norway, where the market share of electric heating is notably higher than in the other countries in this area.

The most significant other energy sources for heating apart from district heating are electricity and building-specific heating appliances based on renewable, mostly wood-based fuels. The energy sources in residential and service sector heating in the Nordics and the Baltics are depicted in Figure 3-2.

Figure 3-2 – Heating energy sources in residential and service sectors in the Nordics and the Baltics in 2018



(Euroheat & Power, 2019; National Statistics)

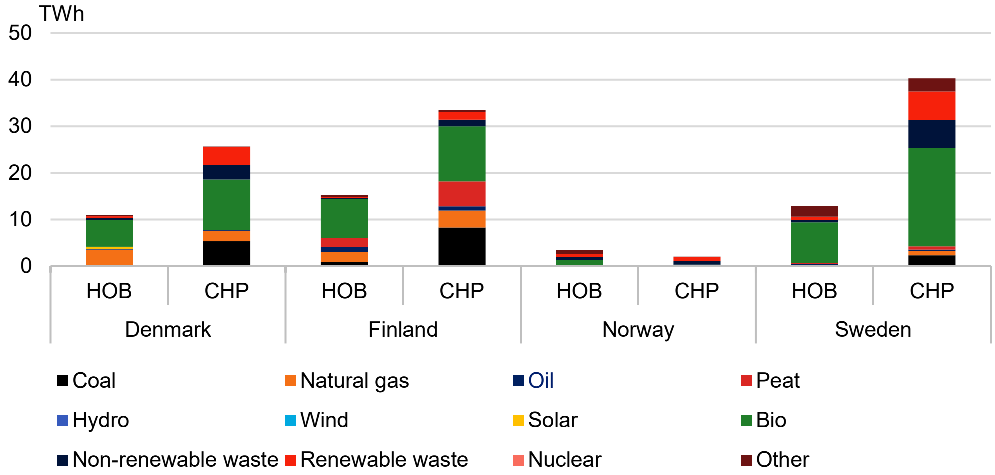
4.1.1 District heating sector in the Nordic countries

In general, district heating production in the Nordics is highly based on CHP accounting for more than 70 % of the total heat production. The share of renewable energy sources[4] in DH production in the Nordics is very high accounting for slightly below 60 % of the total heat production. The high share of renewable fuels limits to some extent the effects of potential carbon price floor in the heating sector.

The most significant non-renewable fuels in the Nordic area are non-renewable waste, coal and natural gas. The relative shares of these fuels is higher in Denmark and Finland (circa 30 % of total annual heat production) than in Sweden and Norway. In addition, a relatively high amount of peat is utilised for heat production in Finland. Energy production in district heating sector in the Nordics in depicted in Figure 3-3.

[4] Including bio fuels, renewable waste and solar

Figure 3-3 – Energy production in district heating sector in the Nordic countries in 2016

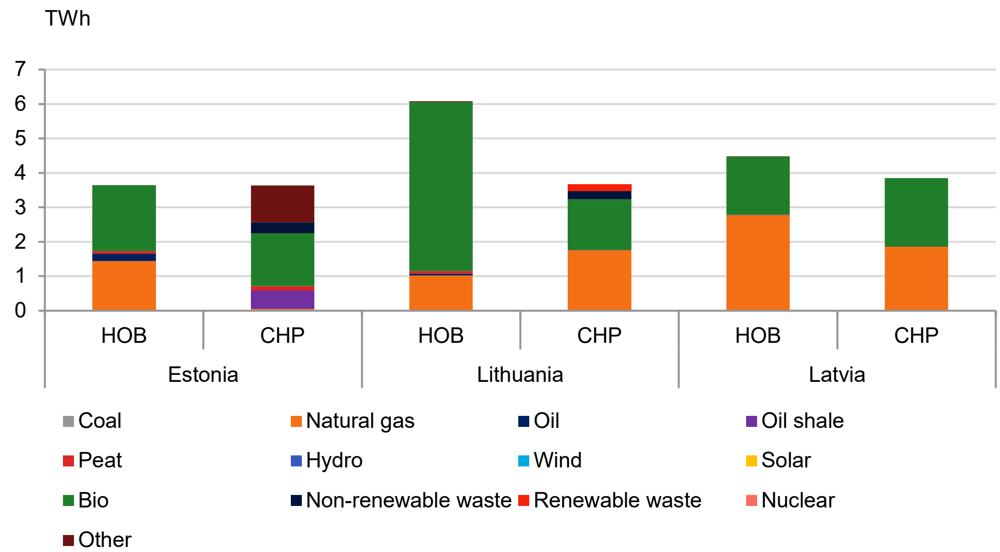


(Eurostat, 2017)

4.1.2 District heating sector in the Baltic countries

In contrast to Nordic countries, the relative share of CHP in the Baltic countries is somewhat lower accounting for circa 44 % of total heat production. In addition, the relative share of natural gas is notably higher than in the Nordic countries accounting for circa 35 % of the total heat production in the Baltics. Also, in Estonia oil shale has a relatively notable role in total heat production. In the Baltic countries, the share of renewable energy sources is circa 54 %[4]. Energy production in the district heating sector in Baltic countries is depicted in Figure 3-4.

Figure 3-4 – Energy production in district heating sector in the Baltic countries in 2016



(Eurostat, 2017)

In the Baltic countries, the utilisation of fossil fuels is expected to decrease in the heating sector and to be replaced by mostly biomass, heat pumps and municipal solid waste. This change has already occurred during the recent years, mostly due to high gas prices and attempts to improve energy security in the Baltic countries, reducing gas imports (Lindroos, ym., 2018). There have been investments in new CHP capacity in Estonia, whereas some of the CHP capacity in Lithuania has been shut down and the remaining capacity is mostly expected to be operated only on irregular basis. (Euroheat & Power, 2019)

4.2 Carbon price floor assessment in heating sector

4.2.1 District heating systems analysed

In this subsection, the impacts of the implementation of CPF on district heating sector are analysed from Finnish district heating sector perspective. The analysis is based on general market assessment in Finland as well as case studies of two example district heat networks described below. While the utilisation of fuels varies network-specifically, the aim of the case studies is to represent typical large and medium networks in Finland. The impacts of CPF on other Nordic and Baltic countries are analysed on qualitative basis.

Finnish district heating sector in general

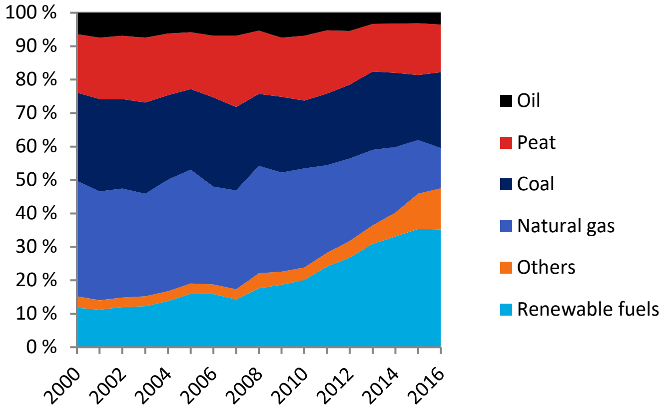
On general level, the implementation of CPF in district heating sector would have an impact on heat production costs based on fossil fuels. In Finland, the CPF would mostly have an impact on the networks with high utilisation of fossil fuels and peat, especially in networks where fuel switching is not feasible from technical or capacity availability perspectives. In this case, the implementation of CPF could potentially result in increase in district heating customer price if the CPF price is clearly higher than the EUA price level.

District heating sector in Finland consists of local, independent district heating systems that are relatively small in size. There are over 150 district heating networks in Finland, typically owned by local energy companies.

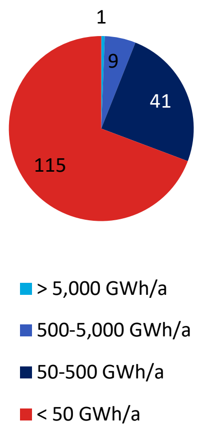
During the recent decades, the share of fossil fuels in the fuel mix of district heat production has decreased, being mostly replaced by renewable fuels, heat pumps and secondary heat sources. Especially the utilisation of natual gas in district heating sector has decreased, which has to large extent been driven by changes in fuel taxation. The development of fuel utilisation in Finnish district heating sector in the period of 2000–2016 as well the number of different size district heating networks in Finland based on annual heat demand are depicted in Figure 3-5.

Figure 3-5 – Fuel consumption and district heating networks in Finland

Fuel consumption in district heating production in Finland in the period of 2000–2016



Number of different size district heating networks in Finland based on annual heat demand in 2017



(Finnish Energy, 2017); 'Others' include mainly secondary heat sources and heat pumps

Apart from fuel market prices and fuel taxation, fuel utilisation per network is dependent on local characteristics, such as availability of low-cost fuels and waste heat streams from local industry, feasibility to import fuels and connection to gas grid. The network-specific production capacity is optimised according to these characteristics and substantial fuel switches often require additional investments. This is because excess cost-efficient capacity is mostly not available and existing production units typically do not support the utilisation of alternative fuels.

Exception to this are multi-fuel boilers utilising solid fuels, which may to some extent enable fuel switching (mostly between biomass and peat). However, some of these production units have a technical constraint for maximum share of biomass. This kind of technical constraint is typical especially in older production units and newer production units may more often utilise biomass as the only fuel.

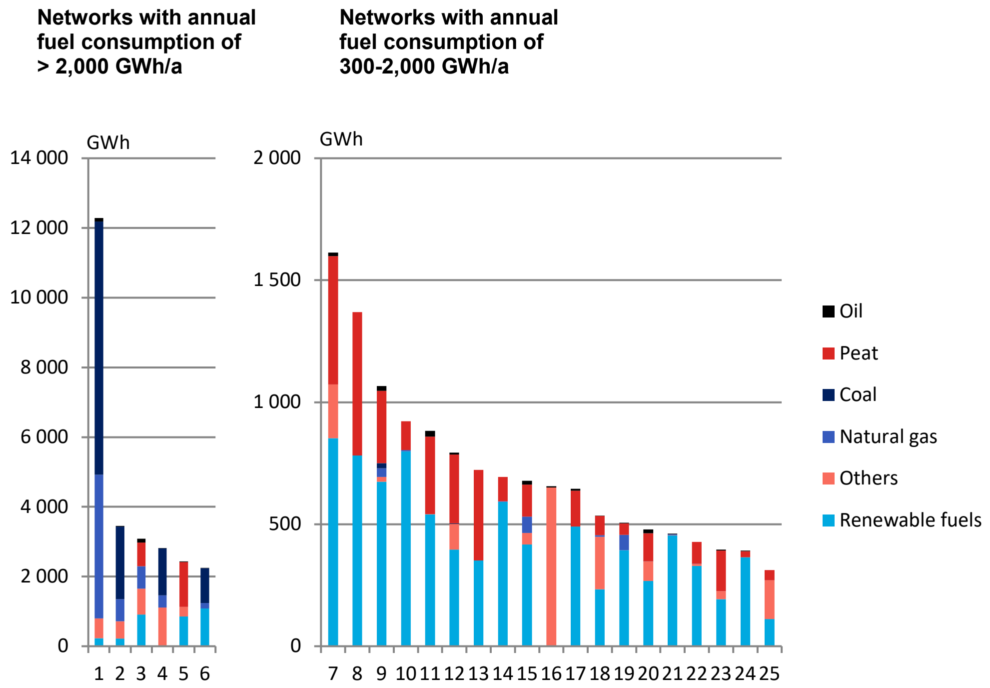
While the utilisation of renewable fuels and secondary heat sources has increased in Finland during the recent history, district heat production in many of the local district heat networks in Finland is still dependent on fossil fuels and peat. In 2017, total fuel consumption in district heating sector in Finland was 52,100 GWh with fossil fuels accounting for 38 % of the consumption, peat 14 % and renewable fuels 35 %.

The importance of peat and fossil fuels varies network-specifically. In 2017, peat or fossil fuels accounted for more than 20 % of total annual network-specific fuel consumption in 83 networks with total consumption in these networks covering almost all of peat consumption in district heating sector in Finland. On the other hand, no peat was utilised in the production mix in 109 networks in 2017. The utilisation of fossil fuels accounted for more than 20 % of total fuel consumption in 26 networks. In most of these networks, no peat was consumed.

Out of the total fuel consumption in Finland in 2017, the largest 25 DH networks accounted for 40,000 GWh. In the large networks, the production is mostly based on CHP production supported by middle and peak load units. In the next chapter, an example of a large district heat network is presented and the impacts of CPF analysed for the example network.

In the largest 25 networks, fossil fuels accounted for 46 % of total fuel consumption, peat 14 % and renewable fuels 29 %. In 16 of these networks, the utilisation of peat or fossil fuels accounted for more than 20 % of total annual fuel consumption in 2017. The utilisation of fossil fuels is especially related to CHP production based on gas and coal as well as peak load production and the share of peat consumption is high in CHP production, as well. Renewable fuels are utilised both in CHP and heat-only production with the relative share being higher in heat-only production. Fuel utilisation in 25 largest district heating networks in Finland in 2017 is depicted in Figure 3-6.

Figure 3-6 – Fuel consumption in 25 largest district heating networks is Finland in 2017



(Finnish Energy, 2017); 'Others' include mainly secondary heat sources and heat pumps

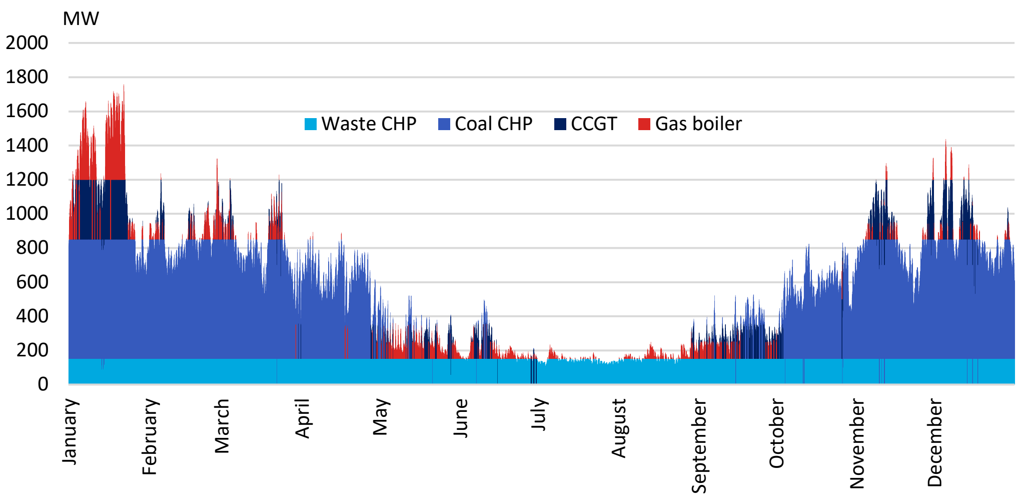
Case study: Heat generation in a typical large network

In a large district heating network, production is typically mostly covered by more than one base load unit supported by several peak load units. The utilisation of the plants is determined by the merit order.

In the network of this case study, base load is mostly covered by waste and coal CHP units with the lowest marginal costs supported by combined cycle gas turbine (CCGT, gas CHP) as well as gas HOBs for peak load purposes.

The heat production in the network is mostly based on CHP accounting for 95 % of the total annual production. The annual total heat demand in 5,000 GWh/a. The annual heat production profile in the network is represented in Figure 3-7.

Figure 3-7 – Heat generation in large network in the Case Study



(Pöyry)

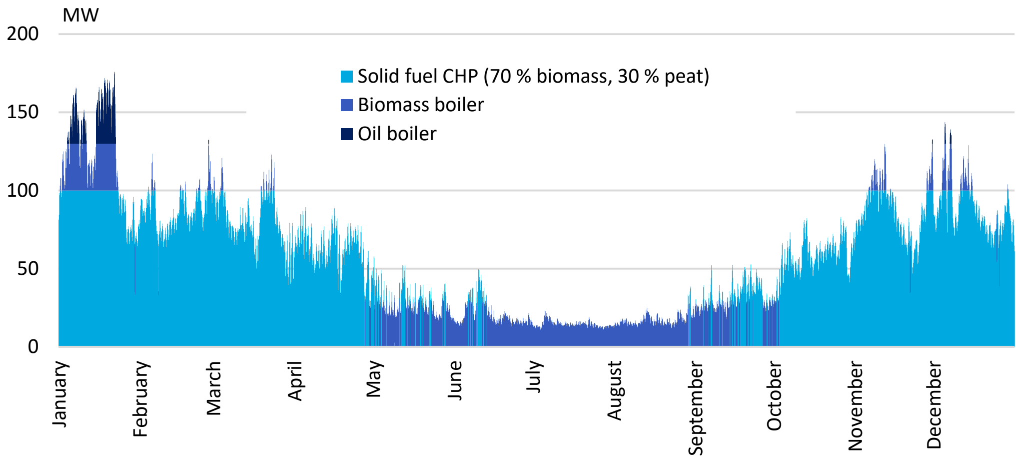
Case study: Heat generation in a typical medium network

In medium and small DH networks, heat production is typically covered by one base load production unit potentially supported by one unit for middle load purposes as well as several peak load production units.

In the DH network in this case study, base load is mostly covered by solid fuel CHP utilising both peat and biomass in the production. In the Base Scenario, cogeneration based on peat and biomass is cost-efficient in comparison to utilising biomass as the only production fuel due to low EUA price level in the scenario. The ratio of peat can typically be to some extent varied to optimise marginal costs.

The base load unit is supported by biomass boiler during heating season as well as during summer months, when heat demand is lower than the minimum production capacity of the CHP unit. Oil-fired boilers are utilised for peak load purposes. The annual total heat demand is 500 GWh/a. The production profile in the medium network is depicted in Figure 3-8.

Figure 3-8 – Heat generation in medium network in the Case Study



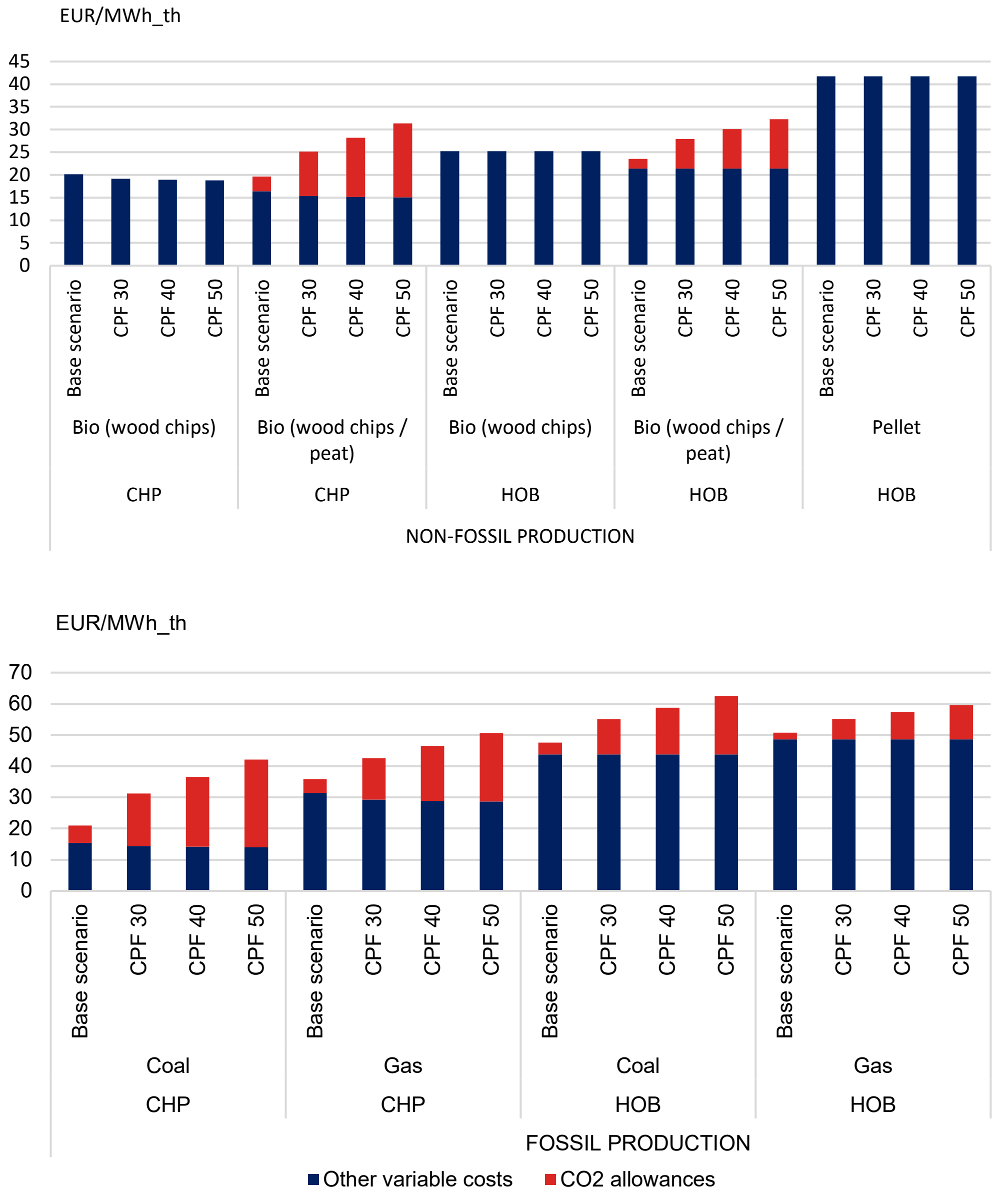
(Pöyry)

4.2.2 Impact of carbon price floor scenarios in heating sector

Impacts of carbon price floor on variable heat generation costs in Finland

The CPF scenarios would significantly increase heat production costs based on fossil fuels and peat in comparison to Base Scenario. The variable costs of heat generation in the different CPF scenarios in 2025 are depicted in Figure 3-9. The impacts in 2030 are highly similar in comparison to 2025 analysis with only minor variance in variable costs due to change in fuel costs.

Figure 3-9 – Variable costs of heat production units in different scenarios in 2025



(Pöyry); In wood chips/ peat cogeneration alternative the share of wood chips is assumed at 70 % and peat at 30 % based on the shares in the Medium network case study

Case study: The impact of CPF scenarios on district heating sector in typical large network

In case of large network, the impacts of CPF on merit order are to some extent limited in the analysed CPF scenarios. This is due to the marginal costs of waste incineration plant being negative as the plant receives gate fees when accepting the waste. Also, the emission allowance price level only influences on the non-renewable share of waste. Due to this, it is very unlikely that changes in emission allowance price level would be sufficient to change the merit order of the waste incineration.

The marginal costs of heat production based on coal are lower than in case of production based on natural gas in all analysed carbon price floor scenarios (Figure 3-9). Even though the analysis indicates that the impact of CPF scenarios is more significant on production based on coal than natural gas, the emission price level in any of the analysed CPF scenarios is not sufficient to change the respective merit order between coal and natural gas heat production. Thus, any of the analysed CPF price scenarios would not be sufficient to support replacement of coal with natural gas on fuel switch basis. This is partly explained by the fact that while price of carbon for Finnish fossil fuel plants increase, the wholesale electricity price does not increase (please see chapter 2.2.2) as it would if the price of carbon increased in the Continental Europe as well. This way the Finnish CCGTs with higher power-to-heat ratio compared to Finnish coal-fired units cannot get the benefit from elevated electricity prices.

However, CPF scenarios would increase the variable costs of generation based on fossil fuels in comparison to Base Scenario potentially supporting the implementation of low-carbon alternatives in more long-term consideration. In other words, it could be beneficial for the Large network to consider replacement of coal- and natural gas-fired units with production units based on renewables in the long-term in the case of CPF scenarios with high price floor.

Case study: The impact of CPF scenarios on district heating sector in typical medium size network

In case of medium size network, the CPF scenarios would increase the marginal costs of the CHP in comparison to Base Scenario as the plant utilises peat as a fuel. In case of Base Scenario, the utilisation of peat could be cost-efficient in comparison to production based on biomass as the only fuel (Figure 3-9). Due to this, the CPF scenarios could potentially support fuel switch from peat to biomass in this case study.

In this case, the fuel switch could be in influenced by a technical constraint of the CHP plant setting the maximum ratio of biomass that can be utilised in the process. If in this case study the CHP plant had a high requirement for peat as a co-firing fuel, HOB based on biomass as a the only fuel would have lower marginal costs than the CHP plant in CPF scenarios with high floor prices (Figure 3-9).

This could result in lower utilisation of the CHP unit in the CPF scenarios with high floor price in comparison to Base Scenario. While this would be beneficial from emissions perspective in this specific network, this would decrease electricity generation by the CHP, which would need to be compensated. In this case, the net effect in emissions within the power sector would be dependent on the energy source of the compensating production.

The impact of CPF scenarios on district heating sector in Nordic and Baltic context

In the Finnish district heating systems, fossil fuels are utilised in almost all networks at least for peak load purposes. Thus, the implementation of CPF would have impacts on district heating sector on national scale depending on the CO_2 price level in EU ETS. The impacts would likely be the most significant in the networks with high utilisation of fossil fuels or peat.

The implementation of CPF would support fuel switching in Finland in comparison to Base Scenario, especially the switching from peat to biomass. However, the impact of this could be to some extent limited due to potential technical constraints related to utilisation of biomass as the only fuel in the existing production units, especially in case of older CHP plants.Also, in case of CPF 40 and CPF 50 scenarios, production based on pellets could become cost-efficient in comparison to heat production based on gas CHP in Finland supporting fuel switch from gas to pellets in this case (Figure 3-9).

In Finland, the utilisation of fossil fuels in district heat production has decreased during the latest decades (Figure 3-6). This is mostly due to increase in fossil fuel taxation making heat production based on renewable fuels more cost-competitive compared to production based on fossil fuels already with low EUA price levels, which is the case in the Base Scenario in this study.

Due to e.g. high fossil fuel taxation in place and expected phase-out of coal in energy production until 2029, the utilisation of fossil fuels may be expected to decrease also in the future in any case. This could to some extent limit the potential effects of CPF in district heating sector in Finland. On the other hand, CPF could decrease the utilisation of peat and fossil fuels in case the EUA price decreases for certain period of time and provide more long-term stability in reducing emissions. In addition, CPF could present a more stable signal of the development of the CO_2 price, which could support the implementation renewable production technologies.

Similarly as in Finland, the utilisation of coal accounts for relatively high share of total heat production in Denmark. However, Denmark also already has plans in place to phase out coal in energy production reducing the significance of CPF.

In Norway and largely in Sweden as well, heat production is highly based on emission-free alternatives already today. In Norway, heating is mostly electrical heating whereas bio- and waste-based production account for high share of total heat production in Sweden. This could limit the potential impacts of CPF in the heating sector in these countries.

On the other hand, the impact of CPF on fuel switch may be more notable in Baltic countries with fossil fuels accounting for relatively high share of total heat production and lower fossil fuel taxation in place. The potential refers especially to natural gas and the utilisation of oil shale in Estonia (Figure 3-4).

When considering the potential for fuel switch in Baltics, it could be considered unlikely that a large number of DH networks would have significant excess production capacity based on renewables in place to support the fuel switch. Due to this, it is considered possible that fuel switch could be achieved in individual networks in case of high carbon floor price but the impacts on national scale could be to some extent limited.

In case the CPF was implemented in heating sector, the production costs of district heating could increase (Figure 3-9) in case the CPF level is high compared to CO_2 price level. This could decrease the competitiveness of district heating compared to decentralised heating solutions e.g. building-specific heat pumps, electric heating and building-specific boilers.

5 Results and conclusions

Results of the analysis

The results of the analysis refer to difference between the simulated Nordic and Nordic-Baltic carbon price floor (CPF) scenarios in comparison to Base Scenario. In Base Scenario, there is no carbon price floor in place and low EUA market price level of 10 EUR/tCO_2 has been assumed. The CPF was assumed to be either 30, 40 or 50 €/t from 2025 to 2030. It should be noted that the results presented are applicable only for the carbon and fuel price levels assumed in this study.

In the **Nordic carbon price floor scenarios**, Sweden and Norway are not highly influenced by the CPF in terms of electricity generation, electricity flows, electricity wholesale prices or emissions in comparison to Base Scenario. In Denmark and Finland, high carbon price floor scenarios would decrease the competitiveness of electricity production based on fossil fuels (mostly natural gas and coal) and peat. Consequently, this would decrease the domestic electricity generation as well as annual net exports in these countries in comparison to Base Scenario.

Based on the simulation, the electricity generation in Denmark and Finland would decrease if CPF was implemented, being mostly compensated by production based on natural gas in Central and Western Europe region. Based on the simulation, compared to total emissions of the EU ETS, relatively insignificant decrease in emissions in electricity generation sector is achieved in all Nordic CPF scenarios in comparison to Base Scenario (3-4 MtCO2/a in 2025 and 2 MtCO2/a in 2030). As the total emissions are still limited by the ETS cap, the net effect on the total emissions of the EU ETS is not this same amount of emissions. However, due to the market stability reserve and allowance cancellation rules, there can also be an impact on the total ETS cap.

Based on the simulation, the impact of Nordic CPF on electricity wholesale prices would be mostly below 1.0 EUR/MWh in 2025 and below 0.50 EUR/MWh in 2030 in the analysed scenarios in comparison to Base Scenario.

In case of the **Nordic-Baltic price floor scenarios**, the overall impact of CPF on the Nordic countries in terms of domestic electricity generation and electricity flows is very similar to the Nordic only CPF.

In Baltic countries, the most significant impacts of the Nordic-Baltic price floor in comparison to Base Scenario concern Estonia, while the changes in Lithuania and Latvia are relatively small. In Estonia, electricity generation based on oil shale decreases, consequently decreasing net electricity exports and also emissions in Estonian electricity production.

Based on the analysis, the decrease in Estonian electricity generation would mostly be replaced by coal-based production in Poland as well as production based on natural gas in Central and Western Europe. As a net effect, higher decrease in total emissions of electricity generation is achieved in comparison to Nordic CPF scenarios.

Based on the simulation, the Nordic-Baltic CPF scenarios have relatively high impact on wholesale electricity prices in the Baltics. In the analysis, the price increases account for up to 3-4 EUR/MWh in comparison to the Base Scenario. This is mostly due to decrease in production based on oil shale in Estonia with no sufficient interconnector capacity in place to compensate for the decrease in production cost-efficiently.

Also, the electricity prices in the Nordics increase slightly more than in case of Nordic price floor, by up to 2-3 EUR/MWh in 2025 and up to 1.0 EUR/MWh in 2030 in Finland, for example. This is mostly due to higher share of the electricity setting the system price level both in Central Europe and the Nordics in comparison to Nordic CPF scenario.

In the **heating sector**, the CPF scenarios would have a significant impact on production costs with fossil fuels in comparison to Base Scenario with low CO_2 price. In the short-term, this could influence fuel switching from fossil fuels (mostly coal and natural gas) and peat to low-carbon alternatives in the cases where this is feasible from technical and fuel availability perspectives.

As a result, the CPF could decrease the utilisation of peat and fossil fuels during the periods with low CO_2 price level and provide more stability and predictability in reducing emissions. In addition, this could speed up the replacement of existing fossil fuel plants with renewable alternatives.

The results of the simulation are presented in Table 1 indicating the difference of the simulated CPF scenarios compared to the Base Scenario in this analysis. In the Base Scenario, there is no carbon price floor in place and EUA price level has been assumed at 10 EUR/tCO_2 for simulation purposes.

Table 1 – The main impacts of Nordic and Nordic-Baltic CPF in comparison to Base Scenario in the simulations

Topic	Impact of Nordic CPF	Impact of Nordic-Baltic CPF
Electricity generation	**Nordics:** Decrease of 3.0-3.8 TWh/a in 2025 and 1.0-1.4 TWh/a in 2030 in domestic electricity generation in the region. The decrease in 2025 is mostly coal generation and split between natural gas and peat generation in 2030.	**Nordics:** Decrease of 2.7-3.5 TWh/a in 2025 and 0.8-1.2 TWh in 2030 in domestic electricity generation in the region **Baltics:** Decrease of 2.6-3.1 TWh/a in 2025 and 2.6-2.8 TWh in 2030 in domestic electricity generation. Over 90% of this is due to decrease in oil shale generation in Estonia
Electricity flows	**Nordics:** Increase in electricity flows within Nordics and decrease in exports to other regions. Denmark would become a net importer in 2025 in contrast of being a net exporter in Base Scenario.	**Nordics:** No significant change in comparison to Nordic CPF **Baltics:** Estonia would become a net importer in contrast of being a net exporter in Base Scenario
CO_2 emissions	**Nordic power sector:** Decrease of 4.5-6.2 MtCO_2/a in 2025 and 2.2-2.4 MtCO_2/a in 2030 in emissions in Nordics **EU ETS market:** Impact to EU-wide emissions is dampened as the total emissions are mostly defined by emission cap of the ETS. Through allowance cancellation after 2023 and possible changes in the design of MSR, the link between the cap and total emissions might be less direct in the future.	**Nordic power sector**: Decrease of 4.4-6.2 MtCO_2/a in 2025 and 2.2-2.4 MtCO_2/a in 2030 in Nordics **Baltic power sector**: Decrease of 2.8-3.8 MtCO_2/a in 2025 and 2.8-3.0 MtCO_2/a in 2030 in Baltics **EU ETS market:** Same as with the Nordic CPF
Electricity wholesale price	**Nordics:** Increase of 0.5-0.8 EUR/MWh (1-2%) in 2025 and 0.2-0.3 EUR/MWh (0.5-1%) in 2030 in average wholesale electricity prices	**Nordics:** Increase of 1.3-1.7 EUR/MWh (3-5%) in 2025 and 0.6-0.8 EUR/MWh (1-2%) in 2030 in average wholesale electricity prices **Baltics:** Increase of 2.8-3.7 EUR/MWh (6-9%) in 2025 and 1.8-2.2 EUR/MWh (4-5%) in 2030 in average wholesale electricity prices

(Pöyry analysis); The Table indicates the results of the simulated CPF scenarios compared to the Base Scenario in this analysis. In Base Scenario, there is no carbon price floor in place and EUA price level has been assumed at low level of 10 EUR/tCO_2 for simulation purposes

Conclusion

The analysis carried out in this study describes the potential impacts of a regional carbon price floor (CPF) compared to a situation where the carbon market price would be 10 €/t (Base Scenario). The very low level for Base Scenario was selected to trigger clear changes in the power market, when the CPF is applied. CPF was assumed to be on the level of 30, 40 or 50 €/t.

The analysis reveals shorter term impacts on electricity market and district heating sector, but is not able to cover the impacts of a carbon price floor on long-term investment decisions. It should be also noted that the potential impacts of Nordic-Baltic CPF on EUA price level or total emissions in the ETS sector covering the various interactions between electricity, fuel and carbon markets have not been analysed in detail.

Based on the analysis, carbon price floor could have some positive impacts on the local CO_2 emissions and fuel switching, but leads to the decrease in total electricity generation in the area. The impacts on the wholesale electricity market price in the Nordic region is limited, because the production mix in the Nordic countries is to a large extent independent of fossil fuels and because electricity price in the Nordics is often indirectly set by continental thermal generation. In addition, the Nordics would likely remain an energy surplus region even if a Nordic CPF was implemented. The local emission reductions would be achieved due to decreased utilisation of coal and peat in the Nordic area both in the electricity and heating sectors.

A regional CPF could have an impact on the generation of certain electricity producers, especially in Finland and Denmark. Consequently, this could impact the profitability of these businesses. Also, this could have an impact on the security of supply in the energy sector, if energy production in the area decreases. Based on the market analysis, the domestic electricity generation would mostly be replaced by generation based on natural gas in Western and Central Europe region.

If CPF would be implemented in Western and Central European region as well, the impacts of Nordic CPF on domestic electricity production are likely to decrease compared to the analysis presented in this study. For example, in the Netherlands the implementation of CPF is currently pending on the parliament’s decision.

According to the analysis, a Nordic-Baltic CPF would result in higher reductions in power sector CO_2 emissions in the region in comparison to Nordic CPF. However, based on the analysis, also the increases in electricity wholesale prices would be somewhat higher than in the case of Nordic CPF. The domestic electricity production in the Baltics would decrease due to CPF, which would make the Baltic area increasingly dependent on electricity imports.

Despite the development towards more renewables in the district heating sector, fossil fuels and peat are still widely utilised in the district heating production mix in Finland both for base and peak load purposes. In 2017, utilisation of peat or fossil fuels accounted for more than 20 % of total annual fuel consumption in 83 networks out of total of circa 150 district heating networks in Finland. Thus, CPF could have a notable impact on district heating sector in Finland on national level.

In district heating sector, the implementation of CPF would have an impact on costs of heat production based on fossil fuels and peat. Due to this, CPF would result in fuel switching, mostly from peat to biomass in Finland.

In Finland, heat production based on fossil fuels is less competitive in comparison to renewable energy sources already with low CO_2 prices, mostly due to relatively high fuel taxes for fossil fuels. Due to the fossil fuel taxation and expected coal phase-out until 2029, the utilisation of fossil fuels is expected to decrease in the future already with the current market conditions. Therefore, the potential impacts of CPF on district heating sector in Finland is limited. However, CPF could decrease the utilisation of peat and fossil fuels in case of low EUA prices for certain period of time, and provide more long-term stability and predictability for emissions reductions.

Similarly to Finland, also in Denmark coal still accounts for relatively high share of total heat production. Also Denmark has coal phase-out plans potentially limiting the impacts of CPF in heating sector in Denmark. In Norway and Sweden, heat production is already largely based on emission-free alternatives, which could limit the impacts of CPF in the heating sector. In Norway, heating is mostly based on electrical heating whereas production based on biofuels and waste account for high share of total production in Sweden.

The impact of CPF on fuel switching in heat production may be more notable in the Baltic countries with fossil fuels accounting for relatively high share of total heat production and lower fossil fuel taxation in place. The fuels, which would be impacted by the CPF include natural gas in all Baltic countries and the utilisation of oil shale in Estonia.

It is also to be noted that the production costs of district heating could increase in case the CPF is high and fuel switch from peat or fossil fuels is not feasible. This could have an impact on district heating customer prices decreasing the competitiveness of district heating in comparison to building-specific heating appliances.

General main conclusions of the CPF are:

- CPF would decrease the volatility of emission allowance prices and provide investors and energy producers with more clear signal of the long-term CO_2 price development

- This could speed up the implementation of renewable and other low-carbon energy production in the long-term both in the heating and in electricity markets. If the CPF is applied for the whole EU, it could lead to faster decrease of emissions on a larger scale and make further tightening of the emission cap politically easier in the future.

- Under country or region specific reduction targets, the CPF would serve as an insurance to politicians and governments that other means for emissions reduction than ETS are not needed.

- Applying a Nordic or Nordic-Baltic CPF would lead to relatively low increase in electricity prices in the Nordic countries. As the costs for fossil fuel and peat fired CHP electricity and district heat production in the Nordic countries would nevertheless increase, the profitability of existing CHP and district heat production would decrease, which might lead to further concerns of the security of supply in The Nordic countries

- After the introduction of the market stability reserve in the ETS and the rules for allowance cancellation after 2023, the link between emissions cap and the actual emissions within the ETS is less direct. Therefore, the application of regional CPF and resulting smaller local emissions can result in decrease of the actual EU-wide carbon emissions as well. This was however, not studied in detail in this report.

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