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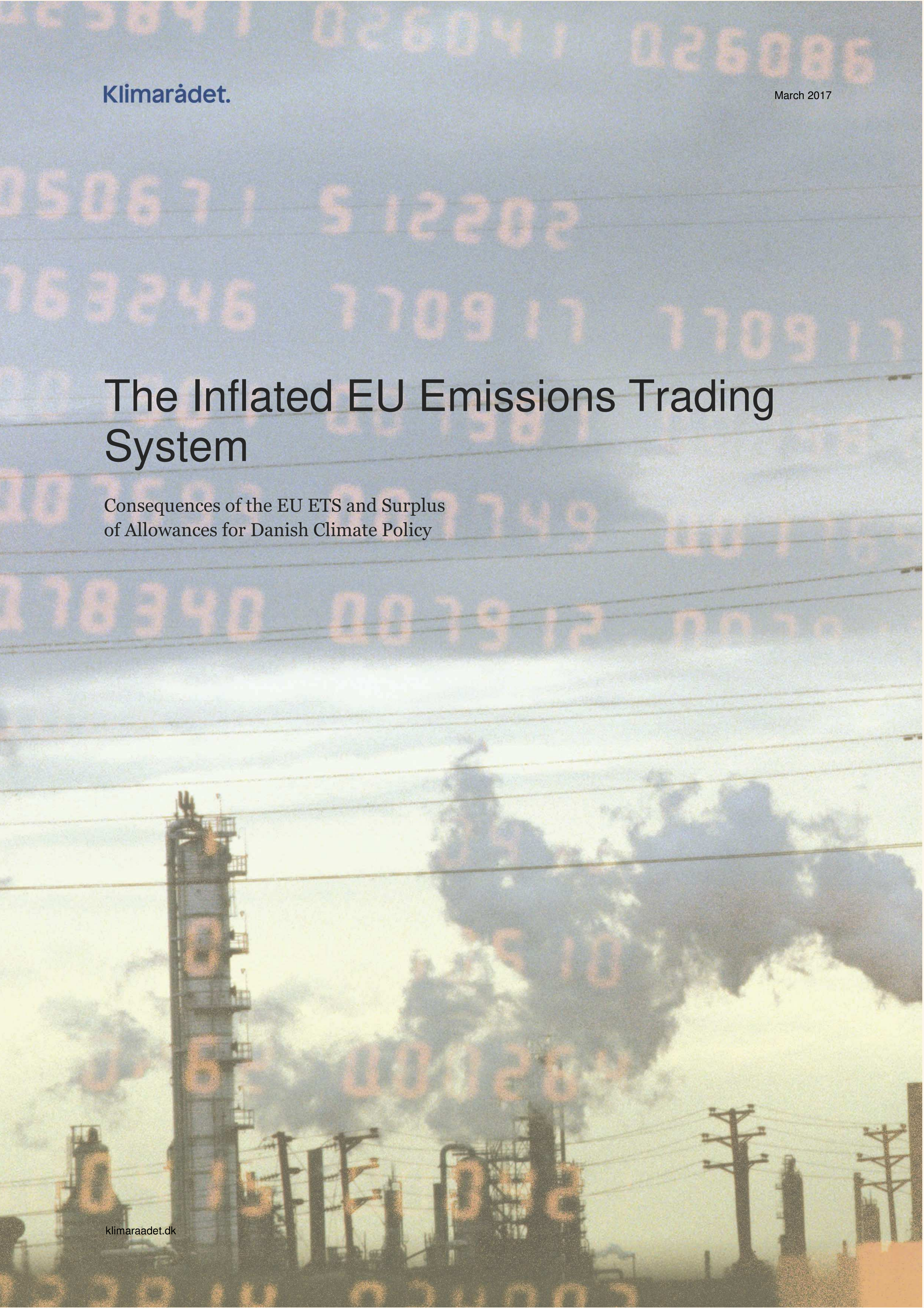
The Inflated EU Emissions Trading System

Consequences of the EU ETS and Surplus of Allowances for Danish Climate Policy



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1 Introduction and Main Points

A main part of EU climate policy is the so-called EU ETS, which caps the emission of greenhouse gases. ETS stands for Emissions Trading System and is a system for trading CO_2 allowances with a view to gradually reducing carbon dioxide emissions in Europe, wherever it is cheapest. The system is one of the international framework conditions for Danish climate policy, and therefore, this analysis by the Danish Council on Climate Change (hereafter the Council) will focus attention on the subject.

Through the emissions trading system companies emitting a lot of CO_2 are each year required to submit allowances equalling their emissions. Operators include power stations, district heating companies and a series of energy-intensive industrial enterprises. Some allowances are distributed among the affected operators, whereas the remaining are auctioned off. It is possible to trade allowances, meaning that an operator holding more allowances than it requires can choose to sell the remaining allowances to an operator short of allowances or to a financial investor buying allowances as an investment entity.

Since its implementation in 2005 the EU ETS has been the subject of some debate. Critics claim that the system does not work, and that there is therefore a need for reducing emissions by other means, e.g. by supporting renewable energy. Others, on the other hand, claim that the system works, and that it renders further attempts to reduce emissions from the affected part of the economy superfluous.

E.g. participants in the Danish climate debate often argue that Denmark's expansion in renewable energy and energy efficiency fails to benefit the climate. The argument is that if Denmark erects wind turbines or increases its energy efficiency it will only free up allowances to be used in other countries – and thus the total emission of CO_2 remains unchanged. This is called the *waterbed effect*, as the carbon emissions, when 'pushed down', will simply 'pop up' elsewhere – like a waterbed. The amount of water in the bed remains unchanged, just like the number of allowances in the EU ETS. Similarly, erecting wind turbines or solar cells will not reduce emissions, only move them elsewhere within the affected sectors. The main question of this analysis is whether this argument holds true, and whether there is a need for a fundamental reorganisation of Danish climate policy.

This analysis of the trading system also makes it possible to answer some topical questions. These years are seeing fierce European debate on a reform of the entire system, which may reduce the supply of allowances. This is caused by the fact that the system is inflated with a large surplus of allowances resulting in allowance prices significantly below the level that can really make renewable energy competitive. It has been proposed that countries should cancel allowances independently, and Sweden has already allocated annual funds to the cancellation of allowances. The analysis examines more closely the effect of a Danish cancellation of allowances compared to the effect of an expansion in renewable energy within the ETS sector.

In addition, towards 2030 Denmark can choose to use cancellation of allowances to meet part of its EU obligation to reduce emissions within the non-ETS sector, that is, the part of the economy that is not covered by the EU ETS.[1] In a previous analysis the Council has advised

[1] The European Commission has proposed that Denmark by 2030 must have reduced the part of its greenhouse gas emissions that come from the non-ETS sector by 39% compared to 2005 levels, though this reduction obligation can be lowered by up to 2 percentage points if the Danish state cancels the issuance of allowances within the ETS sector.

Denmark not to use this opportunity, and the argumentation supporting this recommendation will be further elaborated here.[2]

The main question of the analysis is:

1. Does Denmark's support of renewable energy and energy efficiency within the ETS sector have a beneficial effect on greenhouse gas emissions and damages caused by climate change?

In addition, the Council will consider the following sub-questions:

2. Insofar as supporting renewable energy within the ETS sector benefits the climate, could the money be better spent cancelling allowances instead?
3. Should Denmark use cancellation of allowances rather than other actions to meet its targets for the non-ETS sector?

In order to answer these questions within a coherent frame the Council has developed a stylised economic model for the carbon market able to simulate the effect of various climate change mitigation measures. The model results should not be considered projections of real-world developments, but they offer useful insight into the consequences of potential actions, insofar as the existing and planned rules for the EU ETS are maintained.

Climate policy is based on long-term horizons, and expounding on the full consequences of climate change mitigation measures therefore requires adopting a long-term perspective. Therefore, there is necessarily great uncertainty about the calculated effects, just as the existing climate policy framework conditions will almost certainly be subject to unpredictable future changes. The EU is currently negotiating a reform of the EU ETS, and at the time of writing several proposals have been submitted. This analysis does not attempt to predict how the EU ETS may be revised in the more distant future, but it does offer an idea of the consequences of maintaining the existing ETS rules and the changes that have been proposed so far.

With regard to the main question of the analysis, the Council's simulation model shows that an expansion in renewable energy within the ETS sector has an immediate effect on global emissions, whereas cancellation of allowances will not have an effect until many years from now. The allowances freed up through an expansion in renewable energy will at the earliest result in increased CO_2 emissions many years from now. At the same time, there is reasonable cause to doubt whether such future emissions will in fact take place. If Denmark chooses to focus on cancelling allowances, emissions are likely to be reduced in the long term, but it will take many years for the effect to materialise. These conclusions are based on the existing EU ETS rules. However, implementing the changes proposed by the European Parliament and the Council of the European Union currently being negotiated in the EU will not change these conclusions.

There are good reasons why the international community should prioritise reducing emissions today rather than in the future. Delaying emissions entails delaying damages caused by climate change, and this will buy society time to undertake climate change adaptation. It will also increase its chances of responding to irreversible damages to the climate before it is too late. At the same time, delaying emissions will make it possible to reduce the total amount of emissions with time, as the delayed emissions may never materialise, e.g. due to better technology in the future. This analysis shows that an expansion in renewable energy (or energy efficiency)

[2] See the Danish Council on Climate Change, *Denmark and the EU's 2030 Climate Goals*, 2016.

is very likely to represent a more efficient climate change mitigation measure than cancellation of allowances at national level, as renewable energy leads to greater reductions when there is a surplus of allowances. This conclusion still holds when considering the costs of the various actions compared to their climate effect.

This conclusion is based on the current condition of the EU ETS with a large surplus of allowances. The optimal solution would be to create a shortage on allowances within the EU. An emissions trading system with a shortage on allowances could be a useful tool for supporting the transition to a low carbon society, and therefore Denmark should make an active effort in the EU to instigate a reform of the EU ETS, creating such shortage. However, the reforms that have so far been proposed by the European Parliament, the Council of the European Union and the Commission do not appear to cause such shortage in the short term. If the EU fails to adopt a reform that facilitates a marked reduction in the surplus of allowances before 2020, by which Denmark must decide whether it wishes to use allowances to meet its 2030 non-ETS sector targets, this analysis gives the Council cause to recommend the following in answer to the above questions:

- *Denmark should not use EU ETS as an argument for refraining from supporting renewable energy in the ETS sector if it wants to contribute to the global effort to combat climate change.*
- Denmark should not independently cancel allowances in order to reduce emissions within the ETS sector as an alternative to expansion in renewable energy.
- Denmark should not use the flexibility mechanism which makes it possible to use EU ETS allowances to meet non-ETS sector targets.

The following outlines the analysis' arguments from the above: Section 2 offers a description of the EU ETS, whereas section 3, based on the Council's simulation model, presents two possible scenarios for the future development of the EU ETS. Based on these scenarios, section 4 demonstrates the consequences of an expansion in renewable energy on CO_2 emissions, while section 5 considers the consequences of a comparable cancellation of allowances. Section 6 compares the cost-effectiveness of the two actions, section 7 considers whether national climate change mitigation measures can potentially affect the future issuance of allowances at EU level, while section 8 concludes. Certain reflections of a more technical nature have been placed in the Annexes.

2 The ETS Represents a Main Part of EU Climate Policy

Since its implementation in 2005 the EU ETS has been considered one of the main tools for ensuring that the EU climate targets are met. Today, however, many observers argue that it is failing due to a large surplus of unused allowances. This section offers an introduction to the system and its problems.

How the EU ETS Works

The regulating authority, a so-called regulator, issues a number of allowances which gives the holder permission to emit CO_2 and other greenhouse gases. One allowance represents the right to emit one tonne of CO_2. The regulator thereby ensures that the emission of greenhouse gases does not exceed the desired limit. The regulator has no knowledge of the individual companies' costs of reducing emissions and is therefore prevented from distributing allowances among companies in a way that ensures that the total reduction costs remain as low as possible. Instead the regulator can allow companies to trade allowances, setting a market price of allowances and thus for the right to emit one tonne of CO_2.

In principle, an emissions trading system ensures that society is able to reduce its emissions in the cheapest way possible. The individual company has an incentive to reduce its emissions as long as the cost of lowering its total emissions by one extra tonne of CO_2 is lower than the price of allowances. The company thus saves the expense of buying allowances or gains an income from selling allowances, exceeding its additional reduction costs. All companies will thus have an incentive to reduce emissions to the point where the cost of reducing emissions by one extra tonne of CO_2 corresponds to the price of allowances. The opportunity to trade allowances entails that companies with heavy emission reduction expenses will be interested in buying allowances from companies that are able to reduce emissions at low cost. At the same time, the fixed number of allowances ensures that the total emissions do not exceed the cap.

The EU ETS and Its Development in Phases

In 2005 the EU member states established the CO_2 Emissions Trading System, the EU ETS. The system regulates the emission of the greenhouse gases CO_2, N_2O and PFC from power and heat generation and from various energy-intensive industry sectors, including, among others, steel, aluminium, cement, glass, paper and chemicals.[3] The system covers all EU member states plus Iceland, Norway and Lichtenstein and a total of approx. 11,000 installations and a number of operators within the aviation sector. Around 45% of all EU greenhouse gas emissions are thus regulated by the EU ETS.

The EU ETS was established to ensure that the EU was able to meet the obligations undertaken by the member states in connection with the 1997 Kyoto Protocol.[4] Emissions trading represented a main focus of the Kyoto Protocol, which is one of the reasons why the EU member states decided to introduce an EU emissions trading system. The number of allowances in the period 2008-2012 was set to ensure that the EU would reduce emissions corresponding to its obligations under the Kyoto Protocol.

The ETS was launched in 2005 with a pilot of 'learning by doing', before the Kyoto targets became effective. The greenhouse gas emission reductions envisioned for this first phase, which lasted until the end of 2007, were relatively low. The cap on allowances was set at national level, just as the individual member states were responsible for allocating allowances to specific industries based on estimated needs. Consequently, the number of allowances allocated turned out to be excessive. However, these allowances could not be used in phase 2 of the ETS, the so-called first commitment period of the Kyoto Protocol, from 2008 up to and including 2012.[5]

Phase 2 was meant to ensure that the EU member states would reduce their total greenhouse gas emissions by 8% by 2012 compared to 1990 levels. The rules in phase 2 were stricter than in phase 1. The penalty for emitting greenhouse gases without the required allowances increased from EUR 40 to 100 per tonne of CO_2. At the same time, the proportion of allowances allocated to companies for free fell from 100 to 90%, while the remaining 10% were auctioned off. The total number of allowances was determined by national allocation plans, which meant

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[3] The various activities have been described in Annex 1 of Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EF.

[4] The member states had previously discussed introducing a carbon tax, but the proposal lacked sufficient political backing.

[5] For a description of phases 1 and 2, see *http://ec.europa.eu/clima/policies/ets/pre2013_en*.

that the member states to a large extent could set their own cap on emissions within the ETS sector. Phase 2 also made it possible to use UN credits issued via the Kyoto Protocol's Clean Development Mechanism and Joint Implementation.[6] Surplus allowances from phase 2 could be used in the following phase.

Phase 3, running from 2013 to 2020, includes more gases and sectors than the previous phases. At the same time, the national allocation plans have been discontinued, and the Commission is now responsible for issuing allowances, which are reduced by a certain percentage each year: 1.74% of the average amount of allowances issued each year in the period 2008-2012. The amount of allowances issued is set to ensure that the EU as a whole meets its 21% reduction target for the ETS sector by 2020 compared to 2005 levels. Auction is the standard method for allowance allocation, while clear rules specify that free allowances can only be allocated to industries in risk of carbon leakage.[7]

In July 2015 the Commission presented its proposal for the rules for phase 4 of the EU ETS running from 2021 to 2030. The proposal involves reducing the annual allowance allocation by 2.2% each year compared to 1.74% in phase 3. The 2.2% reduction is meant to ensure that emissions from the ETS sector are reduced by 43% by 2030, compared to 2005 levels, in line with the EU Council conclusions of October 2014. Together with the EU targets for the non-ETS sector, the 43% ensures that the EU is able to achieve a 40% reduction, compared to 1990 levels, for the entire economy, as promised in the Paris Agreement of 2015. In addition, more targeted carbon leakage classification has been introduced, meaning that fewer industries are now eligible to receive free allowances, and the proportion of allowances to be auctioned has been raised to 57%.

Together the European Parliament and the Council of the European Union must set the rules for phase 4 based on the proposal by the Commission. In February 2017 the European Parliament and the Council of the European Union each presented their proposals for a further tightening of the EU ETS compared to the proposal of the Commission, as described in Annex C.

An Inflated Emissions Trading System

Phase 2 from 2008 to 2012 has created a very large surplus of allowances in circulation. An allowance surplus occurs when the amount of allowances issued over a period of time exceeds the amount of allowances used. This accumulated surplus has caused the price of allowances to drop sharply from more than EUR 1,488 per tonne in 2008. In December 2016 the price dropped to around EUR 223 per tonne of CO_2, as shown in Figure 1, and it has only seen a slight increase in the beginning of 2017. At such low price levels, the EU ETS only gives operators limited incentive to reduce emissions, and in 2014 and 2015 the European Parliament and the Council of the European Union therefore passed two reforms of the system. The objective of these reforms was to reduce the surplus of allowances temporarily, facilitating a better balance between the supply and demand for allowances.

[6] Clean Development Mechanism projects can generate allowances by ensuring that companies in industrialised countries (Annex 1: Countries in the Kyoto Protocol) place activities in developing countries that reduce greenhouse gas emissions. Joint Implementation enables industrialised countries to pay for emissions-reducing projects in other industrialised countries and thus to be credited for the reduction.

[7] Carbon leakage refers to the situation that may occur if a sector is subjected to CO_2 regulation and this entails that companies within the sector are outperformed by companies not subject to CO_2 regulation. In cases of full carbon leakage, emissions are transferred from one country to another without reducing the total greenhouse gas emissions, and climate changes thus remain unaffected.

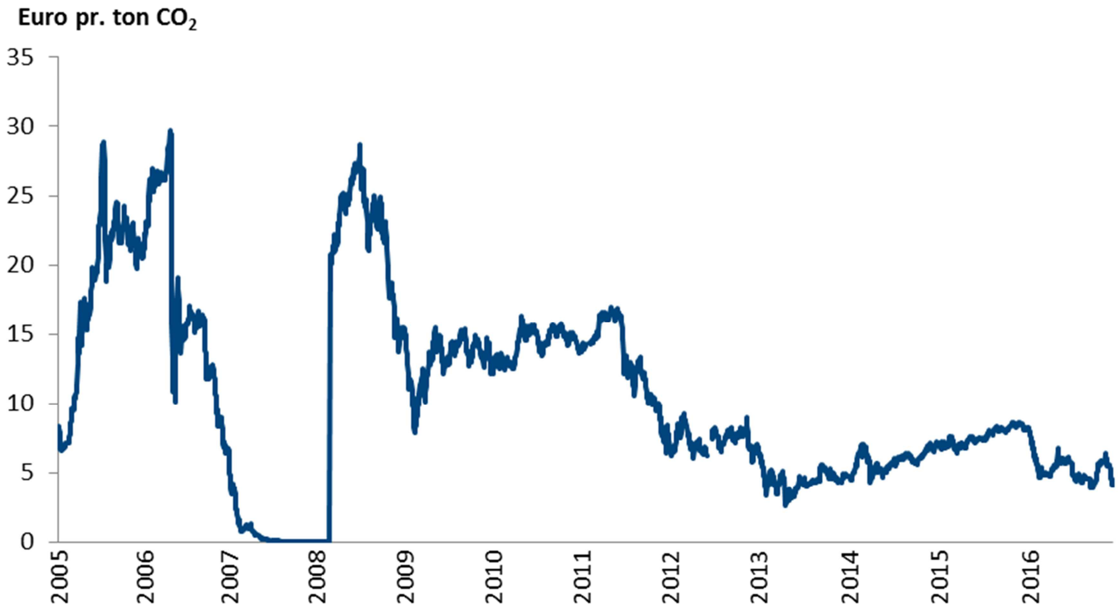

Figure 1 Development of the price of allowances from 2005 up to and including 2016

Note: Allowances could not be transferred from phase 1, which ended in 2007, to phase 2. This explains why the price of allowances fell to zero by the end of phase 1 and rose again with the launch of phase 2 in 2008.

Source: EEX, European Emission Allowance Auction (EUA).

One of the reforms consisted in back-loading of 900 million allowances, corresponding to 15% of the standard amount of allowances issued from 2014 to 2016. This entailed postponing the auctioning of these allowances from 2014-2016 to 2019-2020. The second reform consisted in creating a so-called market stability reserve (MSR) to be introduced in 2019. Each year the reserve will remove 12% of the surplus allowances from the market and place them in the reserve, insofar as there is a surplus of more than 833 million allowances in the market. If, on the other hand, there is a surplus of less than 400 million allowances, each year 100 million allowances from the MSR will be auctioned off.

Figure 2 shows how allowances are transferred to and released from the MSR, respectively. In connection with the passing of the MSR it was also decided to move the back-loaded allowances and certain unused allowances from a separate pool[8] to the reserve when it starts operating in 2019. This means that the MSR from the beginning will contain around 1,500 million allowances. The two reforms have only caused a limited rise in the price of allowances, though, as evident from Figure 1. Thus, the two reforms have not been sufficient to change the EU ETS substantially, which may be a result of the fact that they only remove allowances from the system temporarily.

[8] The EU ETS has a reserve for newly arrived companies and established companies with a marked increase in production. If such a company is entitled to free allowances, they will be allocated from this reserve. Due to the financial crisis, the demand for such allowances has been limited. Originally they were meant to be released into the market, but it has now been decided to transfer them to the MSR.

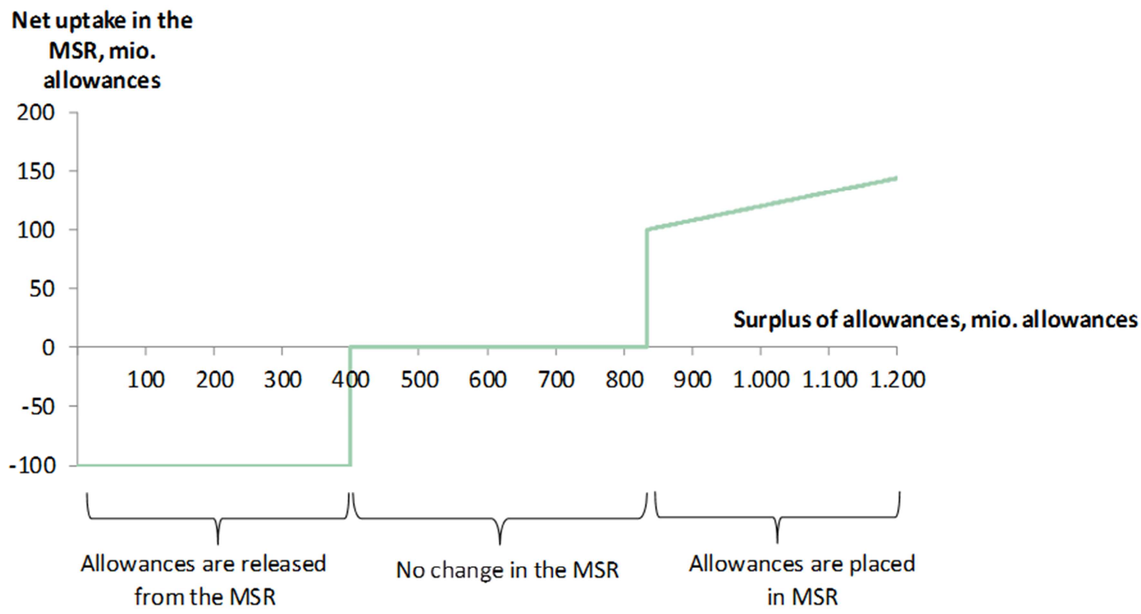

Figure 2 Illustration of the market stability reserve (MSR)

Note: A positive net transfer indicates that allowances are being transferred to the MSR, whereas a negative net transfer indicates that allowances are being released from the MSR.

Source: EU, *Decision 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and amending Directive 2003/87/EC.*

Figure 3 shows that the annual supply of allowances since 2009 exceeds the annual emission levels. This has resulted in a large surplus of allowances, which in 2016 corresponded to around 1,800 million tonnes of CO_2.[9] There are several reasons for the large surplus. Above all, the financial crisis and the European debt crisis caused the demand for allowances to drop sharply. As the industries within the ETS sector are highly cyclical, the crises prompted a large drop in output and therefore also a drop in the demand for allowances within these industries.[10] In addition, access to allowances via the Clean Development Mechanism and Joint Implementation has created an additional surplus in the market. A total of around 1.5 billion certified emission reduction credits have been allocated via these projects.[11] Another main reason for the surplus of allowances is that the price of renewable energy has turned out to be lower than expected, and combined with the member states' national support schemes this has increased the proportion of renewable energy and thus reduced the demand for fossil fuels and allowances. Increased energy efficiency has also caused a reduction in the demand for allowances.[12]

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[9] The surplus figures vary depending on whether or not they include the back-loaded allowances. 400 million allowances were withheld from auction in 2014, 300 million in 2015 and 200 in 2016. See the European Commission, *http://ec.europa.eu/clima/policies/ets/reform_en*.

[10] Jos Delbeke and Peter Vis, *EU Climate Policy Explained*, Routledge, 2015.

[11] European Environment Agency, *ETS data viewer*.

[12] Sandbag, *The ETS in context*, 2015.

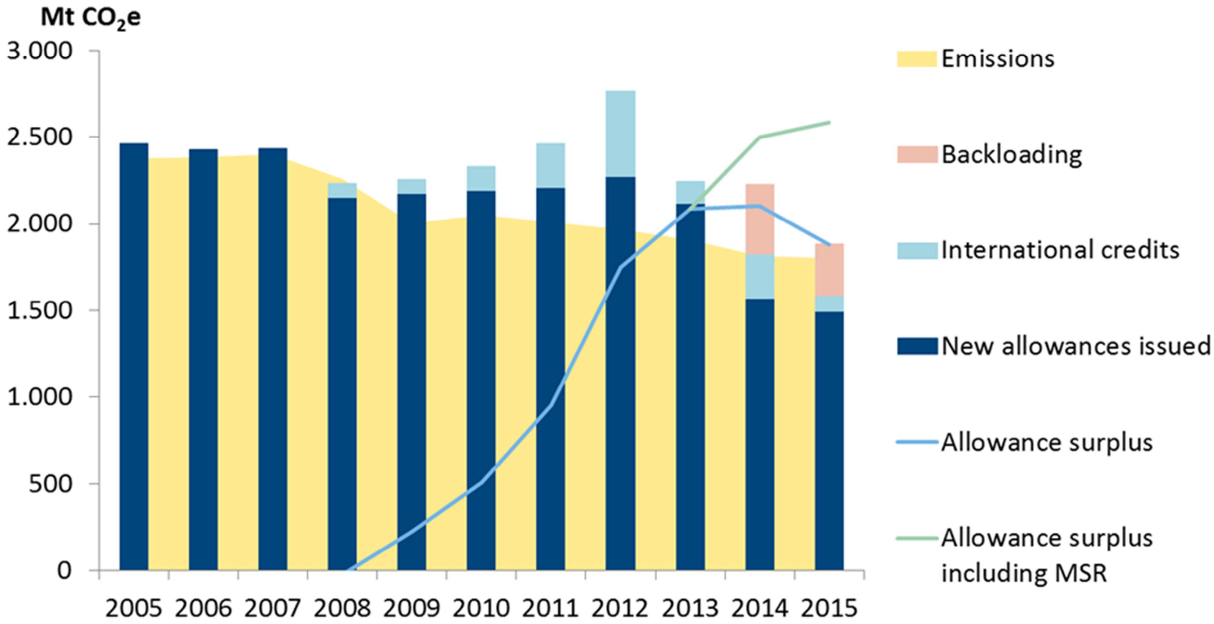

Figure 3 Emission, allowances issued and surplus of allowances from 2005 to 2015

Note: Back-loading began in 2014, and 400 million allowances were withheld from auction in 2014 and 300 million in 2015. These will be transferred to the MSR in 2019 and are therefore not included in the surplus of allowances indicated by the blue line, but have been added to the surplus of allowances shown by the green line.

Source: EEA, *EU Emissions Trading System data from EUTL*, 2015 *http://www.eea.europa.eu/data-and-maps/data/european-union-emissions-trading-scheme-10*.

3 Surplus of Allowances Will Continue Well into the Future

The current surplus of allowances corresponds to the total annual European consumption of allowances. Due to the market stability reserve and the rules proposed for phase 4 of the EU ETS, the surplus will continue well into the future affecting the carbon market's ability to facilitate the transition to a low carbon society. This section will examine the future development of the EU ETS if the rules proposed by the Commission remain unchanged throughout the lifespan of the system. In all probability, the system rules will be adjusted in the future, just as the EU ETS may at some point be replaced by other climate change mitigation measures. Nevertheless, it is useful to examine the consequences of the current framework.

The Council's Simulation Model
The Council has developed a simulation model of the EU ETS in order to analyse the current system and offer recommendations regarding Danish climate policy. The model can be used to estimate the duration of the surplus of allowances as well as the time of the depletion of the MSR and of the last CO_2 emissions from the ETS sector. The model can also be used to analyse the climate impact of political measures affecting the carbon market, e.g. cancellation of allowances or expansion in renewable energy.

Like any other model the Council's simulation model is a stylised version of reality, which can never fully reflect the complexity of the actual market, just as future developments may of course prove the model's assumptions regarding future situations to be incorrect. The model does not take into account political changes of the EU ETS – not because such changes are not expected, but because the nature of such changes can be difficult to predict.

Different reforms have currently been proposed by the various actors of the EU, but it remains uncertain whether the reform to be adopted will be any or neither of these.[13] Therefore, the results of the model are not a projection of the future, but a picture of how the future will look if the existing rules and assumptions of the model apply.[14] The model offers a consistent framework for arguing and an opportunity for assesing the impact of actions and reforms under the conditions given in the model. Models like the Council's simulation model are therefore useful tools for understanding the EU ETS.

The Council's simulation model calculates emission levels, surplus of allowances, number of allowances in the MSR and prices on allowances beginning today and till the day all allowances have been used or there is no longer a demand for allowances. The model ensures that the price of allowances is linked up with the level of CO_2 emissions, that emission levels do not exceed the amount of available allowances, and that investors only save allowances for future years if the price of allowances rises enough to yield a reasonable return.

A main parameter in the model is the development of the amount of allowances issue. The Commission has proposed that the amount of allowances issued after 2020 be reduced by 2.2% each year based on the average amount of allowances issued each year in the period 2008-2012. This rate is likely to be revised at the transition from phase 4 to phase 5 after 2030. However, as mentioned, the model is based on the current rules and proposals by the Commission, maintaining a rate of 2.2% for all future years. This means that the last allowances will be issued in 2057, and that no new allowances will be issued hereafter. However, under the rules in force operators may save allowances to be used after 2057.

The demand for allowances depends on the need for energy and the price of fossil energy in proportion to the price of renewable energy. The price of allowances is a part of the price of fossil energy. Even if the price of allowances remains unchanged, the demand for allowances is expected to fall with time, as the price of renewable energy drops and energy efficiency increases. The Council has not produced projections specifically for this decrease in the demand for allowances, but assumes that the demand will fall at a constant rate if the price of allowances remains unchanged. This rate has been calibrated based on market data, as described in the following subsection.

The price of allowances ensures that there is a connection between supply and demand throughout the lifespan of the EU ETS. Price formation and details of the model have been described in detail in Annex A.

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[13] Annex C outlines the consequences for the EU ETS of the proposals of the European Parliament and the Council of the European Union, respectively. None of the proposals significantly change the qualitative conclusions of this analysis.

[14] The assumptions of the model are outlined in Annex A and the working paper, *Subsidies to renewable energy and the European Emissions Trading System: Is there really a waterbed effect?*, available on the homepage of the Danish Council on Climate Change.

Baseline Scenario for the EU ETS
This analysis examines two scenarios for the EU ETS. Scenario 1 can be considered a baseline scenario. Here the simulation model has been calibrated to meet two conditions:[15]

- The 2017 emission level corresponds to the baseline scenario adopted by the think tank Sandbag. Sandbag is one of the leading observers of the carbon market, and its predictions concerning the carbon market have so far proven to be among the most accurate.[16]
- The model's calculation of the 2017 price of allowances corresponds to the level seen in early January 2017 of around EUR 298 per tonne.

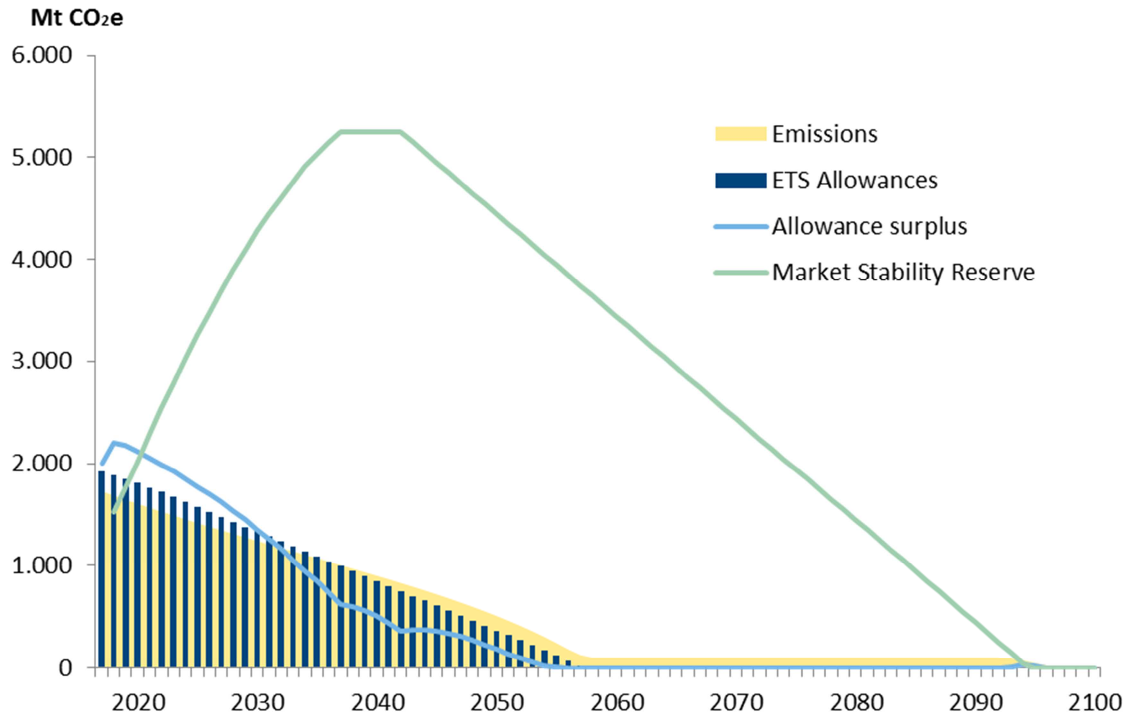

Figure 4 The model's results for emission, surplus of allowances and MSR supply in scenario 1

Note: Surplus of allowances indicates unused allowances still in circulation. Allowances held in the MSR have not been included in the surplus of allowances and are therefore shown separately.

Source: Own calculations.

The results for scenario 1 of the simulation model are shown in Figure 4. Issuance of new allowances follows the proposal by the Commission, as explained above, and is indicated by the dark blue columns. Annual European greenhouse gas emissions within the EU ETS are indicated by the yellow area. When the annual amount of new allowances issued exceeds annual emission levels, it causes an increase in the surplus of allowances, which follows the blue line.

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[15] See Annex A for the details of the calibration.

[16] In January 2017 the news media Carbon Pulse examined various market research companies' projections of emissions within the ETS sector. Among the organisations examined Sandbag was the one that came closest to the actual emissions level. See *http://carbon-pulse.com/14388/* og *http://carbon-pulse.com/2339/* .

When the surplus of allowances exceeds 833 million allowances, a share of the new allowances is transferred to the MSR, as indicated by the green line. Conversely, when there is a surplus of less than 400 million allowances, allowances are released from the reserve, as shown in Figure 2.

The model shows an average 2.5% reduction in emissions each year towards 2030. This is close to the reduction rate experienced since 2005, where emissions have been reduced by 2.7% on average each year. However, the latter figure should be seen in light of the weak economic growth and subsequent low demand for energy following the financial crisis. From 2030 to 2050 the average annual reduction in the model increases to 4.4%. This acceleration is necessary, as the remaining amount of available allowances prevents higher emission levels. The price of allowances is adjusted to facilitate the required reduction in emissions.

Figure 4 also shows that although no new allowances are to be issued after 2057, emissions continue until 2096. This is a result of the large amount of allowances accumulated in and only gradually released from the MSR. According to the model, the MSR will reach its maximum of over 5 billion allowances in 2037. The surplus of allowances, i.e. the amount of allowances in circulation among market operators, will reach its peak at around 2.2 billion in 2018, after which it will see a steady drop. This is caused partly by the reduction in the amount of allowances issued each year and partly by the transfer of allowances to the MSR.

However, the surplus of allowances will continue until 2056. One could say that the cap on allowances does not become *binding* until 2056 and continues to be so until 2092, when there are very few allowances left in the entire system. This entails that emissions in this period correspond precisely to the 100 million allowances released from the MSR each year. In the 2090s there will be very few allowances left in the MSR, and market operators will distribute the last allowances in the reserve across the years 2093-2096.

Scenario 1 is one among many possible scenarios, and it is relevant to compare the scenario to other approximations of the future of the EU ETS. In its baseline scenario, the think tank Sandbag expects to see a surplus of allowances of around 500 million tonnes in 2030 and an MSR supply of around 3,500 million tonnes. In Sandbag's low-emission scenario, the surplus of allowances in 2030 is around 2,200 million tonnes, whereas the MSR supply has increased to around 5,000 million tonnes.[17] By comparison, scenario 1 of the Council has a 2030 surplus of allowances of around 1,200 million tonnes and an MSR supply of around 4,300 million tonnes. In Sandbag's baseline scenario the MSR will not be depleted until the 2060s, while this occurs at a much later point in the low-emission scenario and in scenario 1. Like the Council, Sandbag's scenarios are based on the phase 4 rules proposed by the Commission.

The European Commission has produced a reference scenario projecting emission levels within the ETS sector and the price of allowances. [18] According to this scenario, the surplus of allowances will have disappeared by 2030, and the MSR supply be 1,600 million tonnes. It should be noted, however, that the emission levels in past years shown in the Commission's reference scenario are higher than recorded levels. E.g. according to the reference scenario, the ETS sector emitted around 2,000 million tonnes of CO2 in 2015, which is significantly higher than the verified level of around 1,800 million tonnes. Consequently, emission levels towards 2030 are higher in the reference scenario, causing the surplus of allowances to reach zero sooner.

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[17] Sandbag, *Getting in touch with reality*, 2016.

[18] European Commission, *Reference Scenario – Energy, transport, and GHG emissions – Trends to 2050*, 2016.

In addition, scenarios have been developed by Thomson Reuters Point Carbon,[19] among others, which set emission levels towards 2030 significantly higher than scenario 1. Replicating such a scenario in the Council's model requires altering the calibration to make the demand for allowances high until 2030, after which it drops sharply – e.g. as a result of technological quantum leaps within renewable energy after 2030. Annex C outlines such scenarios and how they affect the conclusions of this analysis. However, the Council finds that such high-emission scenarios require an exorbitant increase in the reduction rates after 2030, if the total emissions are to continue to correspond to the amount of allowances issued throughout the lifespan of the EU ETS, and the Council therefore considers scenario 1 to be the most plausible.

Scenario Where Not All Allowances Are Used

In scenario 1 all issued allowances are eventually translated into emission. However, there is no certainty that this will be the case, and there are two reasons for this. First, it is open to question whether all allowances held in the MSR will eventually be released. It may seem unlikely that MSR allowances are allowed to result in emissions after e.g. 2060. Such emissions would defeat the purpose of the COP21 Paris Agreement, and the EU member states may therefore choose to cancel some of the allowances held in the MSR. At the same time, cancelling allowances once parked in the MSR may appear to be the easiest choice politically.[20] In fact, the Council of the European Union has suggested introducing a cap on the MSR, ensuring that allowances above this cap are cancelled permanently.[21] Similarly, the European Parliament has suggested cancelling a certain amount of allowances held in the MSR. These suggestions are described in more detail in Annex C.

Second, no company may wish to make use of the allowances released from the MSR towards the end of the century, as green technologies may at that point have reached such a high stage of development that fossil production ceases to be attractive, even if the price of allowances is zero. Scenario 2 is an example of this possibility. This scenario is shown in Figure 5 and follows scenario 1, the only difference being that the pace at which the demand for allowances is phased out after 2060 is faster here than in scenario 1. The phase-out reflects a situation where renewable energy becomes competitive sooner.

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[19] Thomson Reuters Point Carbon, *EU ETS review: Don't mention the price, just get it right*, 2016.

[20] For an elaboration of this line of thinking, see Sandbag, *Puncturing the water bed myth*, 2016.

[21] Council of the European Union, *Revision of the emissions trading system: Council agrees its position*, press release of 28 February 2017.

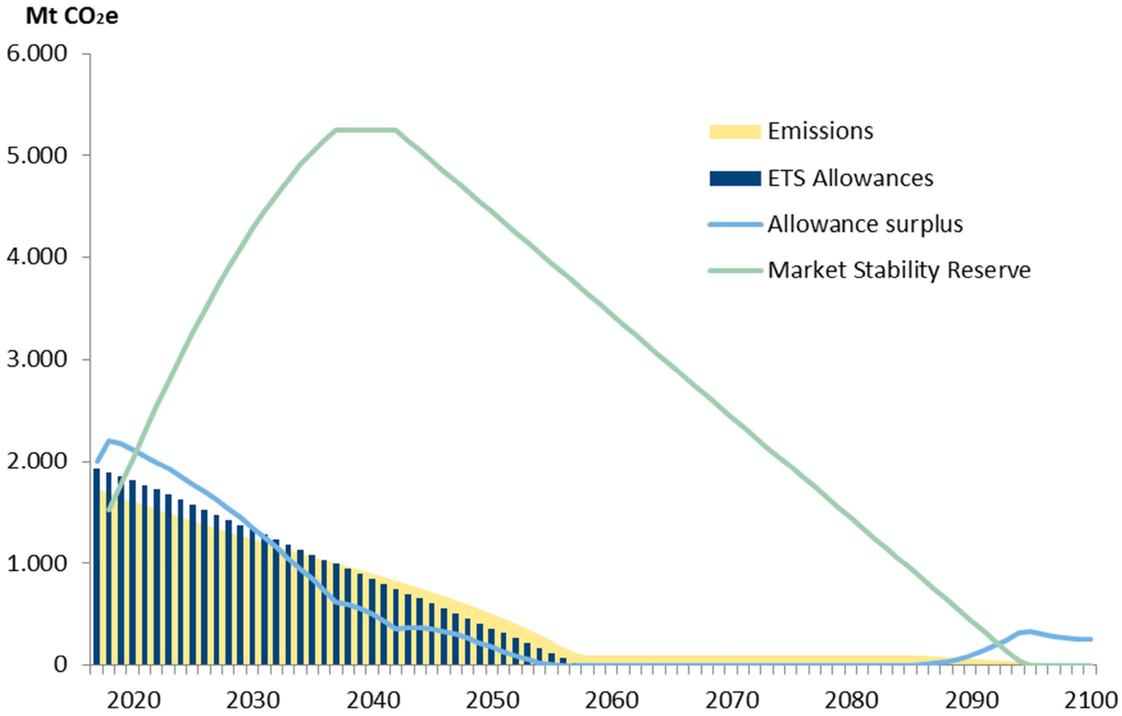

Figure 5 The model's results for emission, surplus of allowances and MSR supply in scenario 2

Note: Compared to scenario 1, renewable energy is more competitive after 2060 in scenario 2.

Source: Own calculations.

By and large, the results of the model for scenario 2 are very similar to scenario 1 – in fact, they are identical up to and including 2085. A main difference is seen after 2086, though, as not all allowances released from the MSR after that point are used in scenario 2, resulting in a permanent surplus of allowances. This permanent surplus of allowances exceeds 400 million allowances; thus, the MSR never reaches zero. The price of allowances will then collapse to zero; however, such a low price of allowances is still not enough to ensure that all allowances are used.

Scenario 2 projects a situation where the total amount of allowances issued is not identical with the total emissions throughout the lifespan of the EU ETS. This may be the case if renewable energy becomes much cheaper in the long term, or following from a solution like the one proposed by the Council of the European Union, cancelling a proportion of the allowances held in the MSR. Sections 4 and 5 show how the various preconditions in scenarios 1 and 2 affect the impact of political actions.

4 Expansion in Renewable Energy Has a Substantial Impact on CO_2 Emissions in the Short Term

Critics often argue that an expansion in renewable energy or energy conservation merely results in increased emissions elsewhere,[22] as the price of allowances drops, stimulating the use of fossil energy now or later. And seeing as the supply of allowances remains unchanged throughout the lifespan of the EU ETS, the same must be true for emission levels. In the international debate, this is often referred to as the *waterbed effect*.[23] When pushed down, a waterbed will simply pop up elsewhere, as the amount of water in the bed remains unchanged. In the public debate, this is often compared to the erection of wind turbines or solar cells, which will not reduce emissions, only move them elsewhere within the EU ETS.

However, comparing the carbon market to a waterbed is somewhat misleading. Because unlike the waterbed, there is no certainty that an expansion in renewable energy will *immediately* lead to increased emissions elsewhere. This is due to the fact that freed-up allowances may be used at a later point (or possibly never). Nevertheless, the concept of the waterbed effect will in this section be used to refer to the phenomenon where a reduction in CO_2 via renewable energy merely results in similar, increased emissions elsewhere now or later.

This section will demonstrate that the waterbed effect may exist, but only at a substantial delay due to the large surplus of allowances. This means that an expansion in renewable energy (or energy conservation) reduces emissions today, while the counter-reaction with increased emission caused by the freed-up allowances is delayed and occurs many years later. In addition, the waterbed effect presupposes that all issued allowances are used eventually, but there is no certainty that this will be the case. The Council's simulation model will be used to illustrate this situation.

Expansion in Renewable Energy Within the ETS sector in Scenario 1

In a hypothetical example Denmark implements an expansion in renewable energy, immediately displacing 8 million tonnes of CO_2 evenly distributed across the period 2021-2030. Figure 6 shows the change in European emissions caused by the action. Naturally, investments in e.g. wind turbines have a lifespan of more than 10 years and will therefore also displace CO_2 for more than 10 years. However, in order to make the expansion in renewable energy comparable to the cancellation of allowances examined in the next section, we will leave this element out of account.

[22] See e.g. the Environmental Economic Council, *Economy and Environment 2014*, 2014.

[23] See e.g. Ecofys, *The waterbed effect and the EU ETS*, 2016.

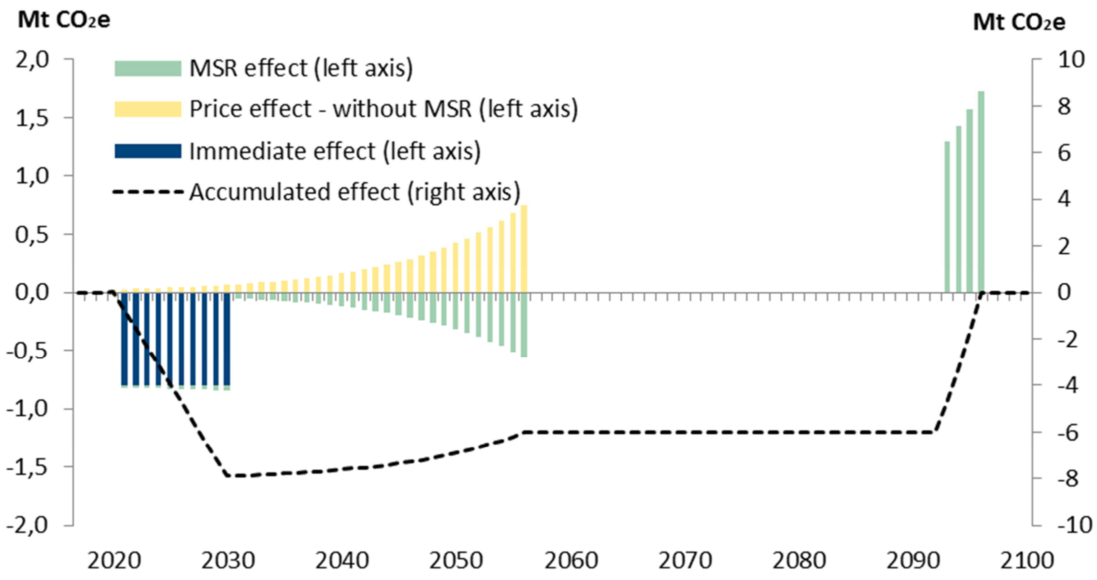

Figure 6 Change in emissions caused by an expansion in renewable energy corresponding to 8 million tonnes of CO_2 in 2021-2030, scenario 1

Note: Scenario 1 is the baseline scenario of the analysis, where all allowances issued are used eventually. The figure shows the change in annual emissions divided into three effects (columns) and the accumulated change in emissions beginning in 2017 (line). A negative change in emissions means a reduction in emissions.

Source: Own calculations.

In Figure 6, the annual change in emissions has been divided into three effects:

- **Immediate effect**: Immediately, 0.8 tonnes of CO_2 are displaced each year in the period 2021-2030. Without the EU ETS, this would be the effect.
- **Price effect without the MSR:** The immediate effect causes prices on allowances to drop towards 2056, when the cap becomes binding, as the demand for allowances is reduced. Seen in isolation, the reduced price of allowances results in increased emissions throughout the period, but especially towards the end of the period.[24]
- **MSR effect:** Finally, the amount of allowances transferred to the MSR is affected by the above effects. Overall, the amount increases due to the increased surplus of allowances. This contributes to keeping the price of allowances up and thus to lowering emission levels towards 2056 compared to a situation where there is no MSR. However, the additional accumulated allowances are released from the reserve in the years 2093-2096 causing increased emissions.

Overall, the three effects aggregates to zero in the long term, as predicted by the waterbed effect. Thus, in the long term – in this case, after 2096 – accumulated emissions are not affected by a Danish expansion in renewable energy in the 2020s. The freed-up allowances are used at

[24] The increase in emissions is largest towards the end of the period 2020-2056, as this is when the price of allowances sees the largest drop. In the model the price of allowances in e.g. 2056 is higher than the 2020 level by a fixed factor, which is determined by the return required by investors for holding allowances. Therefore, a lower 2020 price level will lead to an even bigger price fall in 2056.

a later point, merely postponing emissions. E.g. the emissions accumulated until and including 2030 are around 7.9 million tonnes lower than without the expansion, and in 2050 the figure is around 6.9 million tonnes.

Expansion in Renewable Energy Within the ETS Sector in Scenario 2
An expansion in renewable energy has also been simulated in scenario 2, which presupposes cheaper green technology after 2060 compared to scenario 1. The results are shown in Figure 7.

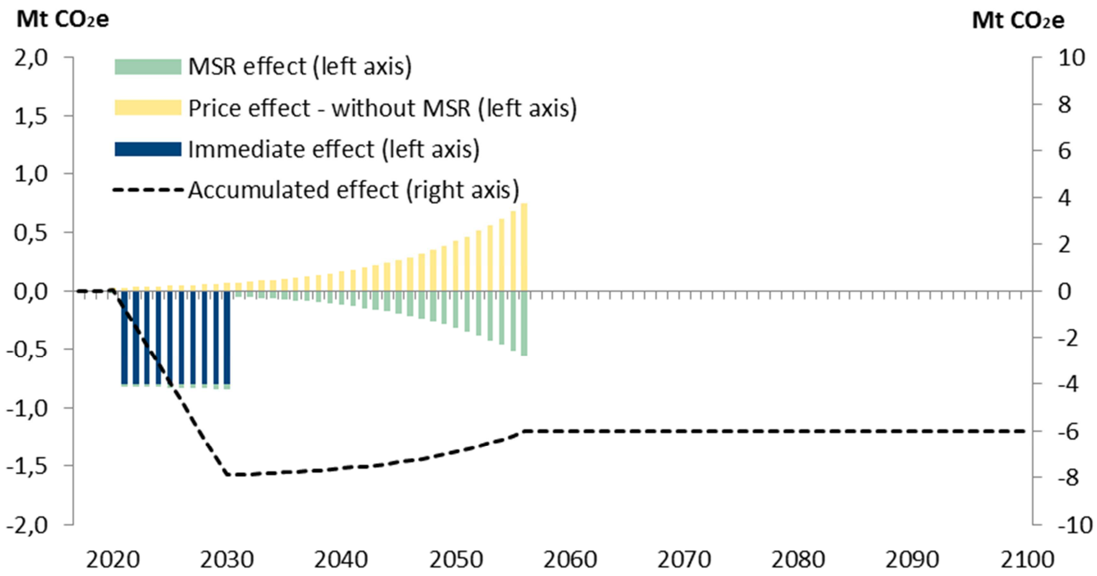

Figure 7 Change in emissions caused by an expansion in renewable energy corresponding to 8 million tonnes of CO_2 in 2021-2030, scenario 2

Note: Renewable energy is more competitive in scenario 2 than in scenario 1, and not all allowances issued are used. The figure shows the change in annual emissions divided into three effects (columns) and the accumulated change in emissions beginning in 2017 (line). A negative change in emissions means a reduction in emissions.

Source: Own calculations.

Figure 7 resembles Figure 6, which shows the results of the same measure for scenario 1. A main difference, however, is that scenario 2 does not see an increase in emissions in the years 2093-2096. The reason for this is that there is no demand for allowances at this point in the scenario; therefore, once released the additional allowances transferred to the MSR due to the expansion are never used. Thus, in this scenario the expansion has a positive effect on the climate, even in the long term, and here the accumulated emissions are reduced by around 6 million tonnes of CO_2. Therefore, the expansion in renewable energy in scenario 2 does not comply with the waterbed effect.

As mentioned in section 3, an alternative interpretation of scenario 2 is that it is decided politically not to release allowances from the MSR after e.g. 2060. If so, the change in emissions caused by an expansion in renewable energy will lead to the same result as in Figure 7, as the additional allowances in the MSR are not translated into emissions.

Advantages of Reductions in the Short Term

An expansion in renewable energy has no effect on the total long-term emissions in scenario 1. Nevertheless, there are several reasons why such a step can be beneficial if one wishes to contribute to the global effort to combat climate change. It is often argued that the effect of one tonne of CO_2 is the same no matter where, when and by whom it is emitted. That is not entirely true, though. With regard to *whom* and *where*, the effect of one tonne of CO_2 is the same, but this is not necessarily the case for *when*.

The question of when emissions will take place has been illustrated in Figure 8, which shows two hypothetical developments for the global CO_2 emissions. Development B postpones emissions to later compared to Development A, but the total emissions from 2017 to 2100 are the same in both developments. The question is whether society would prefer one development over the other – that is, whether the time of emissions matters?

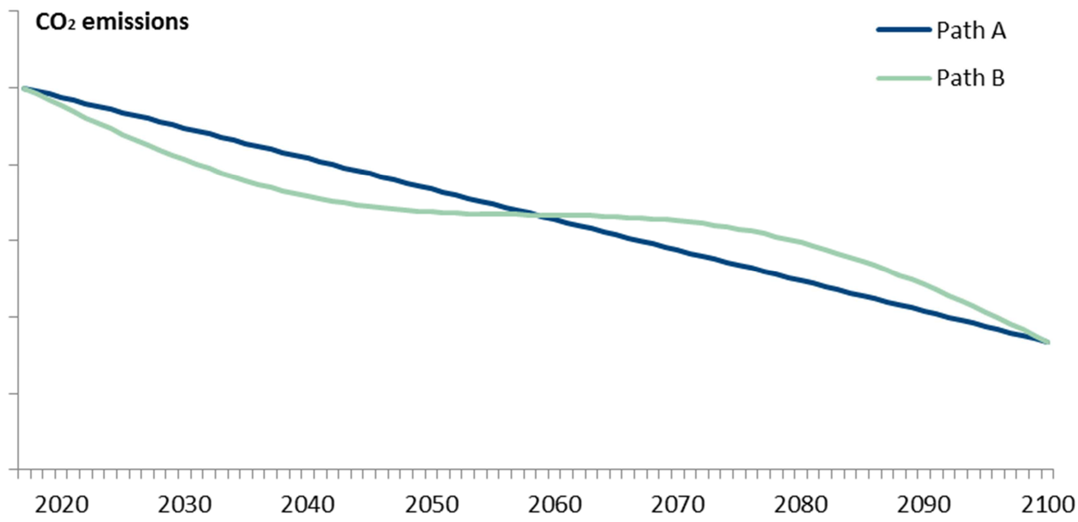

Figure 8 Illustration of two hypothetical developments for the global CO_2 emissions

Note: The total emissions in the period 2017-2100 are the same in both developments.

The Council believes society should prioritise Development B over Development A, as shown in Figure 8, if the price of reductions is the same in the two developments.[25] Accelerating CO_2 reductions, i.e. postponing emissions, will also postpone climate change. These changes result in damage costs, e.g. when rising sea levels increase the frequency of storm surges. It is possible to reduce damages by investing in climate change adaptation, e.g. a dike protecting against rising sea levels, but climate changes also in this case generate costs for society. Postponing climate changes and the costs resulting from damages and/or climate change adaptation are of value to society for at least two reasons:

1. **Adaptation:** Postponing climate changes will give society more time to undertake climate change adaptation, reducing the damages caused by climate changes.

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[25] The economic literature on climate change generally assumes that emission reductions occurring at a later time have less social value. See e.g. Reyer Gerlagh, *Too much oil?*, CESifo Economic Studies 57, 2010 or Frederick van der Ploeg and Cees Withagen, *Is there really a green paradox?*, Journal of Environmental Economics and Management 64(3), 2012.

2. **Financial growth:** If emissions are postponed, the standard of living is likely to be higher when climate changes occur. This will give society a better basis for meeting the expenses of climate change adaptation. At the same time, more advanced technologies will be available, making it easier to implement climate change adaptation.

A third argument for prioritising a short-term reduction in emissions is that it reduces the risk of irreversible climate change:

3. **Irreversible climate change:** Postponing emissions will reduce the risk that global warming reaches a point where climate changes become irreversible, even if emissions are reduced substantially at a later time. If the international community postpones reductions, it may be too late to prevent large, irreversible climate damages, if the climate turns out to be more sensitive to global warming than expected. If, on the other hand, the climate turns out to be less sensitive than assumed, slowing down the pace of CO_2 reductions is easy. Society will therefore maintain a wider range of options by implementing reductions here and now than by postponing them.[26]

On the other hand, it can be argued that the richer we get, the greater the damages caused by climate changes will be, and the damage per tonne of CO_2 emitted therefore increases with time. The richer we are, the more can be ruined by climate changes. This argument speaks in favour of Development A in Figure 8. However, the Council finds that the three arguments outlined above carry more weight, thus supporting Development B.[27]

It is important to emphasise that Development B is preferred over Development A only insofar as the implementation costs are the same for the two developments. If this condition is not met, society should not necessarily prioritise reducing emissions as fast as possible. If the costs of reducing emissions are expected to be much lower in the future than today due to future technological breakthroughs, this may compensate for the additional damage costs of postponing reductions and speak in favour of Development A. It is therefore important to consider the cost-effectiveness of climate change mitigation measures, which affect the time path of emission reductions differently, as seen in section 6 of this analysis.

With regard to a Danish expansion in renewable energy, the preliminary conclusion is that such an expansion represents an effective measure, especially if focus is on short-term reductions. Even if the waterbed effect applies in the long term, as in scenario 1, an acceleration in emission reductions caused by such an expansion can, as a result of the three arguments above, be positive, unless the accelerated pace increases the price of reductions. Add to this that the waterbed effect is uncertain. The additional allowances transferred to the MSR as a result of the Danish expansion may never leave the MSR or, if released, may never be bought. In both cases, an expansion in renewable energy causes a long-term reduction in European emissions. Determining whether renewable energy is the most cost-efficient climate change mitigation measure requires a more thorough economic assessment. This will be explored in more detail in section 6.

Naturally, the shown results depend on the parameters chosen in the simulation model. It seems fairly certain, though, that the surplus of allowances will continue even well after 2030

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[26] The risk of irreversible climate damage has been highlighted by the Intergovernmental Panel on Climate Change, among others. See e.g. IPCC, *Climate Change 2014 – Synthesis Report*, 2014. An argument against reducing emissions now rather than later could be that society thereby for a period of time risks limits itself to using more expensive alternative energy technologies, which may prove inappropriate, if the climate turns out to be less sensitive to CO_2 emissions than previously assumed. However, it must be assumed that the costs hereof would be significantly lower than the great costs of damages caused by dangerous, irreversible climate changes.

[27] The balancing of emissions at different points in the future has been described in more detail in the working paper on the homepage of the Danish Council on Climate Change.

under the existing rules. This in itself is enough to conclude that a large part of the increase in emissions caused by the low price of allowances will not occur until well into the future. Similarly, it seems certain that the last allowances will not be released from the MSR until around or well after 2050. And seeing as an expansion in renewable energy causes an accumulation of allowances in the MSR, a large part of the emissions caused by the freed-up allowances will take place many years from now, if the last allowances are used at all. Therefore, there is solid basis for concluding that an expansion in renewable energy in the short term has a substantial climate effect.

5 Isolated Danish Cancellation of Allowances Will Not Reduce Emissions in the Short Term

Cancellation of allowances is often considered an effective climate change mitigation measure. This is based on the assumption that if the number of available allowances is reduced, so will the chances of emitting CO_2. Anyone can cancel allowances by buying and subsequently destroying them – or by simply choosing not to use or resell the purchased allowances. Instead of spending money on renewable energy, Denmark could choose indirectly to use the money to cancel allowances by abstaining from auctioning a certain amount of the allowances allocated to Denmark. E.g. Sweden has chosen to cancel allowances worth SEK 300 million each year from 2018 to 2040.[28] Should Denmark choose to follow the Swedish example and cancel allowances, at the same time reducing its support for renewable energy in order to cover the loss of revenue caused by the reduced revenue from auctioning off allowances?

Just like cancellation of allowances can be used to reduce emissions within the ETS sector, the EU member states can to a limited extent use it to meet national reduction targets for the non-ETS sectors.[29] Denmark can choose to cancel up to 8 million allowances in the period 2021-2030, which will then be credited to the national reduction targets for the non-ETS sectors. This is one of the so-called flexibility mechanisms. Denmark must announce how many allowances it wishes to cancel in this period no later than by the end of 2019.

Cancellation of Allowances in Scenario 1

The Council has analysed a situation where Denmark cancels 8 million allowances. This may reflect a wish to make use of the full flexibility mechanism which the Commission has proposed assigning to Denmark or, like Sweden, to use cancellation of allowances as a general climate change mitigation measure. It is assumed that 0.8 million allowances will be cancelled each year in the period 2021-2030. The action is therefore fully comparable to the expansion in renewable energy described in section 4.

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[28] At the current price of allowances, the amount corresponds to around 7 million allowances a year. See *http://www.government.se/press-releases/2016/07/real-emission-reductions-and-more-pressure-on-the-eu-due-to-new-swedish-eu-ets-policy/*.

[29] To meet the 2030 national reduction targets for the non-ETS sectors, a few countries have to a limited extent been allowed to use cancellation of allowances. Also see the Danish Council on Climate Change, *Denmark and the EU's 2030 Climate Goals*, 2016.

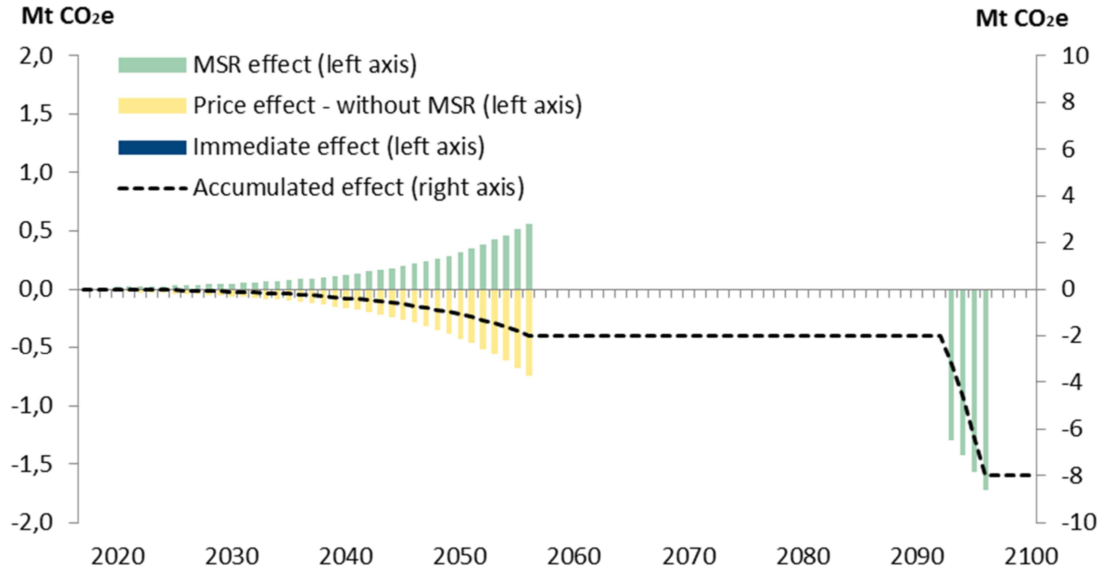

Figure 9 Change in emissions caused by cancellation of 8 million allowances from 2021 to 2030, scenario 1

Note: Scenario 1 is the baseline scenario of the analysis, where all allowances issued are used eventually. The figure shows the change in annual emissions divided into three effects (columns) and the accumulated change in emissions beginning in 2017 (line). A negative change in emissions means a reduction in emissions.

Source: Own calculations.

Figure 9 shows how the total European emissions are affected by the cancellation of allowances – both in individual years and accumulated over the years – in scenario 1 of the simulation model. Cancellation has no immediate climate effect, but instead affects the price of allowances. Cancellation means fewer allowances available for auction, and it raises the price of allowances slightly towards 2056, when the cap becomes binding. The result is reduced emissions in the period – in total a reduction of around 2 million tonnes of CO_2. The cancellation of allowances causes an immediate reduction in the surplus of allowances, which means that fewer allowances are transferred to the MSR. The consequence is reduced emissions in the years 2093-2096, when the reserve is depleted. In total, the reduction in emissions accumulated over the years corresponds to a cancellation of allowances equalling 8 million tonnes of CO_2. This is because all allowances are used eventually in scenario 1, wherefore fewer allowances will *one-to-one* result in reduced emissions in the long term, as predicted by the waterbed effect.

However, Figure 9 shows that for the first many years of the period the pace of emission reductions caused by the cancellation is very slow. By 2030, total emissions have only dropped by around 0.1 million tonnes of CO_2, which merely corresponds to around 1.4% of the total amount of allowances cancelled. 75% of the reduction does not occur until the years 2093-2096. If present-day reductions are assigned more weight than similar reductions in the future, it is unfortunate that such a large part of the reductions are placed far into the future.

Table 1 compares the accumulated emissions in connection with the cancellation of allowances with the comparable expansion in renewable energy from section 4. Emissions have been estimated for the years 2030, 2050 and 2100. In 2100, which here represents the long term, cancellation of allowances has full climate effect, while expansion in renewable energy has no effect. The near opposite is true for 2030, which here represents the short term. Cancellation of allowances has a very limited climate effect, whereas an expansion in renewable energy significantly reduces emissions. In 2050, which represents the short to medium term, renewable energy still results in a significantly higher reduction than cancellation of allowances. Moreover, it should be noted that adding the effects of the two actions always results in the original 8 million-tonne reduction for each time horizon.

MT of CO_2	2030	2050	2100
Cancellation of allowances	-0.11	-1.09	-8.00
Expansion in renewable energy	-7.89	-6.91	0.00

Table 1 Accumulated change in emissions from 2017 up to and including 2030, 2050 and 2100, scenario 1

Note: A negative figure means a reduction in emissions. The table lists the results of a simulation, where 0.8 million allowances are cancelled each year in the period 2021-2030 or where the ETS sector sees an expansion in renewable energy, thereby displacing 0.8 million tonnes of CO_2 each year in the same period.

Source: Own calculations.

Some aspects speak in favour of, others against the two options in Table 1. The advantage of cancelling allowances is that it reduces emissions permanently, while the disadvantage is that this reduction will not occur until many years into the future. As mentioned in section 4, the value of present-day reductions is greater than the value of future reductions. The advantage of an expansion in renewable energy is precisely that emissions are reduced in the short term, while the disadvantage is that these reductions are not permanent.

There are two ways of weighing the advantages and disadvantages of these actions analytically. One way is to focus exclusively on emissions up to and including a given point in time. The shorter the horizon, the more weight is assigned to ensuring that emission reductions occur as soon as possible, that is, the more weight is assigned to the three arguments outlined in section 4. Therefore, if the horizon is 2030 or 2050, expansion in renewable energy has the greatest effect, whereas cancellation of allowances is the most effective option if the chosen time horizon is 2100. This is evident from Table 1.

Another way is to maintain the full time horizon, but to depreciate future emission reductions by a discount rate, thereby assigning less value to future emission reductions. The present value of reductions is then calculated. This method can be considered equivalent of discounting future damage costs following from climate change or discounting future investments in climate adaptation. Adopting this approach and the 4% discount rate of the inter-ministerial *Catalogue of Danish Climate Change Mitigation Measures*[30] would make the present value of emission reductions up to and including 2100 0.93 million tonnes of CO_2 for cancellation of allowances and 4.84 for expansion in renewable energy. Adopting this approach and a 4% discount rate, expansion in renewable energy is clearly preferable, insofar as the costs of the two measures are identical. Choosing a lower rate would push the calculation in favour of cancellation of allowances, and at a rate below 1.3% the effect of cancellation is greater than the effect of expansion in renewable energy based on the present value of emission reductions. Also see Annex B.

[30] Inter-ministerial working group, *Catalogue of Danish Climate Change Mitigation Measures – Reduction Potentials and costs of climate change mitigation measures*, 2013.

It should be emphasised that the conclusions of Table 1 are based on a scenario where emissions continue to drop towards 2030. If the model is adjusted and the historical fall in emissions is curbed up until 2030 and then accelerated, the results in Annex 3 show that the effect of a cancellation of allowances exceeds the effect of an expansion in renewable energy. To arrive at significantly different results would require a significant slowdown, though.

Cancellation of Allowances in Scenario 2

Figure 10 shows the results of same measure as Figure 9, that is, the cancellation of 8 million allowances in Denmark from 2121 to 2030, but now for scenario 2 with cheaper renewable energy in the long term. The difference between the figures is that emissions in Figure 10 are not reduced in the years 2093-2096.

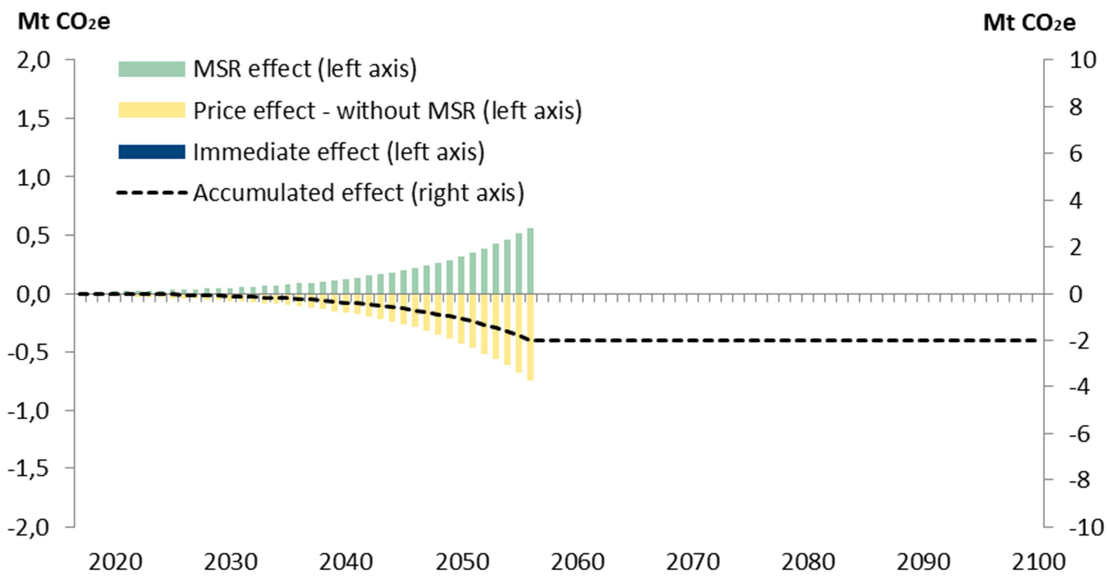

Figure 10 Change in emissions caused by cancellation of 8 million allowances from 2021 to 2030, scenario 2

Note: In scenario 2 renewable energy is more competitive compared to scenario 1, and not all allowances are used. The figure shows the change in annual emissions divided into three effects (columns) and the accumulated change in emissions beginning in 2017 (line). A negative change in emissions means a reduction in emissions.

Source: Own calculations.

Contrary to scenario 1, the last allowances to be released from the MSR in scenario 2 in the years following 2080 are never used. A scenario with competitive renewable energy simply sees no demand for fossil energy at this point in time, even if allowances are available for free.[31] Therefore, a small change in the MSR supply will neither cause more nor less emissions when the MSR is depleted. When the MSR is reduced due to cancellation of allowances, it merely reduces the surplus of allowances towards the end of the century never to be used.

[31] It must be added that a small proportion of the total emissions within the ETS sector does not come from energy consumption, but from so-called process emissions from e.g. cement production. Scenario 2 assumes that competitive solutions will also have been found in the future to avoid such emissions.

Therefore, cancellation of 8 million allowances in scenario 2 entails that the total emissions in the entire period are only reduced by approx. 2 million tonnes of CO_2. This shows that cancellation of allowances will not necessarily result in a similar reduction in European emissions even in the very long term.

MT of CO_2	2030	2050	2100
Cancellation of allowances	-0.11	-1.09	-1.98
Expansion in renewable energy	-7.89	-6.91	-6.02

Table 2 Accumulated change in emissions from 2017 up to and including 2030, 2050 and 2100, scenario 2

Note: A negative figure means a reduction in emissions. The table lists the results of a simulation, where 0.8 million allowances are cancelled each year in the period 2021-2030 or where the ETS sector sees an expansion in renewable energy, thereby displacing 0.8 million tonnes of CO_2 each year in the same period.

Source: Own calculations.

Table 2 compares cancellation of allowances and expansion in renewable energy within the ETS sector in scenario 2. The only difference from scenario 1 is the long term, 2100, where renewable energy now also results in the greatest reduction in total emissions. This means that this measure is the most effective, regardless of how much priority is given to short-term reductions over long-term reductions.

To sum up, this section has shown that the climate effect of expansion in renewable energy within the ETS sector is greater than the effect of cancellation of allowances, especially if focus is on short-term reductions or if future emission reductions are discounted at a sufficiently high rate, which are more or less the same. The best method for postponing emissions is renewable energy, which, as mentioned in section 4, may have a series of advantages. If, on the other hand, reductions are equally valuable regardless of the time of occurrence, cancellation of allowances is the more effective measure in a scenario like scenario 1, where all issued allowances are eventually used. In a scenario where not all allowances are used, like scenario 2, expansion in renewable energy may cause the largest reduction in CO_2 emissions in the very long term.

Cancellation of Allowances to Meet Non-ETS Sector Targets

Cancellation of allowances can be used to meet part of the Danish 2030 targets for the non-ETS sector. The alternative to cancellation is to implement national measures. These may include measures that limit emissions from agriculture or increase the share of renewable energy within transport. Common to these national measures is that they do not affect the price of allowances.[32] Therefore, the immediate displacement of one tonne of CO_2 at national level means that European and global emissions are also reduced by one tonne of CO_2, no matter which time horizon is adopted – at least as long as the measure does not simply transfer emissions to a non-EU country in the form of carbon leakage.[33] If carbon leakage is avoided, such

[32] These include measures that do not merely concern the non-ETS sector. National measures can also entail that emissions are transferred from the non-ETS sector to the ETS sector, e.g. through electrification. Such transfer can be expected to raise the price of allowances.

[33] If emissions are transferred to another EU member state, this country must as a rule reduce its emissions by a similar amount to meet the EU reduction targets for the non-ETS sector. Therefore, carbon leakage cannot in principle occur within the EU. According to the European Commission's proposal for burden-sharing of the total European

measures are therefore better than other measures at producing actual emission reductions by 2030. However, the former may be so expensive that the lowest price per tonne of CO_2 reduced is achieved through cancellation of allowances. This will be elaborated in the next section.

If cancellation of the full 8 million tonnes of CO_2 is used to meet the non-ETS sector targets, the results of the simulation model show that the accumulated European emissions are approx. 7.9 million tonnes higher in 2030 compared to a situation where national measures are implemented instead. If there is a political wish to use cancellation of allowances – possibly to avoid expensive measures within the non-ETS sector – and to avoid increasing emissions before 2030, approx. 73 times as many allowances must be cancelled in total, that is, approx. 582 million allowances. In other words, Denmark, in addition to using the flexible mechanism within the non-ETS section, would have to cancel another 574 million allowances. 582 million allowances correspond to approx. 3.6% of the total number of allowances issued in the EU from 2021 to 2030.

6 What is most Cost-EffectiveneDepends on the Time Horizon

So far the analysis has focussed on the climate effect of various measures. Climate effect denotes the degree to which CO_2 emissions are reduced in the short, short to medium and long term as a result of cancellation of allowances compared to a similar expansion in renewable energy. This section takes the comparison one step further and introduces the financial aspect. What is the cost of one tonne of CO_2 reduction using each of the two measures?

reduction target for 2030, some member states are likely to overcomply with their emissions reduction targets, even without introducing further measures. This also means that carbon leakage may in fact occur if Danish emissions are transferred to another EU member state with a lenient 2030 reduction target. However, if trade in so-called non-ETS sector credits between the member states occurs, the 2030 reduction target will become a binding target for all member states, . The Danish Council on Climate Change has previously touched on this issue (*Danmark og EU's 2030-klimamål, 2016*).

Cost of Measures Within the ETS Sector

In early 2017 the price of one allowance is around EUR 298.[34] However, most projections and prognoses indicate that the price will rise in the future. E.g. the Danish Energy Agency's median estimation is EUR 655 per tonne on average for the period 2021-2030.[35] So if Denmark e.g. chooses to cancel 8 million allowances to meet its non-ETS sector targets, at this price estimate it will cost the Danish state EUR 5,223 million in lost revenue from allowance auctioning. However, in scenario 1 this cancellation only leads to a reduction in accumulated emissions towards 2030 of 0.11 million tonnes of CO_2, as shown in Table 1. The actual price for reducing emissions by one tonne towards 2030 is therefore EUR 5,223 million / 0.11 tonnes of CO_2 = EUR 47,504 per tonne of CO_2.

Calculating the costs of displacing one tonne of CO_2 using renewable energy is far more difficult, as it depends on the technology chosen as a basis for the calculation. One of the cheapest forms of renewable energy is onshore wind energy, and this section will therefore take this technology as its starting point. The inter-ministerial *Catalogue of Danish Climate Change Mitigation Measures* estimates that it will cost society EUR 409 to reduce emissions by one tonne of CO_2 using onshore wind energy rather than energy produced in coal- and gas-fired power plants.[36] The estimate applies to turbines built in 2014, and in all probability, turbines built after 2020 will be somewhat cheaper which suggests that the actual price will be lower. On the other hand, the *Catalogue of Danish Climate Change Mitigation Measures* notes that the estimate does not take into account the costs involved when the land on which the turbines are built can no longer be used for other purposes. This pulls in the opposite direction.

As shown in Table 1, an expansion in renewable energy immediately displacing 8 million tonnes of CO_2 will only reduce total emissions by 7.89 million tonnes towards 2030, because the expansion lowers the price of allowances which, seen in isolation, increases emissions. Therefore, in order to calculate the actual cost per tonne of CO_2 that is displaced as a result of an expansion in renewable energy towards 2030, the figure representing the costs of the immediate displacement of one tonne of CO_2 must therefore be multiplied by 8/7.89. Similarly, the figures in Tables 1 and 2 can be used to calculate the actual social costs of displacing one tonne of CO_2 through cancellation of allowances and expansion in renewable energy, respectively, for different time horizons. Table 3 lists the calculation results for scenario 1 at three different time horizons.[37]

EUR per tonne of CO_2	**2030**	**2050**	**2100**
Cancellation of allowances	47,504	4,791	655
Expansion in renewable energy	417	476	*No CO_2 effect*

Table 2 Social cost per tonne of displaced CO_2 in the ETS sector up to and including 2030, 2050 and 2100, scenario 1

[34] On January 12, 2017 the price of an allowance on the German energy exchange EEX (Primary Market Auction) was EUR 5.3 (app. EUR 293).

[35] Danish Energy Agency, *Samfundsøkonomiske beregningsforudsætninger 2016* (*Assumptions for socioeconomic analyses 2016*).

[36] Inter-ministerial working group, *Catalogue of Danish Climate Change Mitigation Measures – Reduction Potentials and costs of climate change mitigation measures*, 2013.

[37] Table 2 does not take into account that the change in the price of allowances following from Danish measures will affect the social costs differently depending on whether Denmark is a net receiver or donator of allowances. This terms of trade effect is very modest and has therefore not been included in the table. However, it is examined in more detail in the working paper available on the homepage of the Danish Council on Climate Change.

Note: The costs of cancellation of allowances are based on the average price of allowances for 2021-2030 based on the Danish Energy Agency's median estimation. The costs at renewable energy are the *Catalogue of Danish Climate Change Mitigation Measures*' estimate for onshore wind energy, i.e. within the ETS sector. An expansion in renewable energy does not affecttotal emissions when the time horizon is 2100. Mathematically, the cost per tonne of CO2 is infinitely large.

Source: Own calculations.

The calculations in Table 3 suggest that cancellation of allowances is a relatively expensive measure for reducing emissions in the short term towards 2030. The price of each tonne of CO_2 that is displaced is more than EUR 44,640 if the calculation only includes reductions towards 2030. By comparison, the price of expanding renewable energy generation is EUR 417, and even if the frame of reference is significantly more expensive renewable technologies, renewables remain the cheapest option. Adopting a longer time horizon will increase the climate effect of cancellation, causing the price per tonne of CO_2 that is displaced to drop. However, renewable energy is still far cheaper than cancellation of allowances in the short to medium term towards 2050. However, in the long term, 2100, the total emission reduction following from an expansion in renewable energy drops to zero in scenario 1, in theory causing the price per tonne of CO_2 to rise to an infinitely high level. Therefore, the conclusion is that cancellation of allowances as a climate change mitigation measure is most cost-effective only at a sufficiently long time horizon.

As mentioned in section 5, the choice between short- and long-term emissions, respectively, can be presented using a discount rate. A calculation of the price per tonne of CO_2that is displaced in the period 2017-2100 based on the present value will show that the price of cancellation of allowances is EUR 5,632 per tonne at a 4% discount rate. By comparison, the price of expanding renewable energy is EUR 677 per tonne . Only at a discount rate below 1% makes cancellation of allowances the most cost-effective instrument.

Scenario 2 differs from scenario 1 in the long term. As outlined in sections 4 and 5, the difference in scenario 2 is that cancellation of allowances does not result in an equal amount of emission reductions, while renewable energy actually has a long-term climate effect. Converted into social costs, as in Table 3, the price per tonne of CO_2 is EUR 2,731 at cancellation of allowances and EUR 543 at expansion in renewable energy when the time horizon is 2100 and discounting is not used. This shows that in scenario 2 renewable energy is also most cost-effective in the very long term. In other words, an expansion of renewable energy is the most cost-effective measure regardless of the choice of discount rate.

Cost of measures within the non-ets sector

If the question is whether Denmark should choose to cancel allowances to meet its non-ETS sector obligations, a comparison of this measure to the price of wind turbines is irrelevant. Instead, cancellation of allowances must be compared to the costs of displacing one tonne of CO_2 through national measures within the non-ETS sector. These may e.g. include the use of biofuel for transport purposes and thus not wind turbines, which belong in the ETS sector.

The price of reducing emissions within the non-ETS sector is likely to vary considerably between measures within agriculture, transport, individual heating and other areas, respectively. This is suggested in the *Catalogue of Danish Climate Change Mitigation Measures*. A possible estimate is approx. EUR 7,440 per tonne, which according to Ea Energianalyse's analysis *Green Roadmap 2030* is the average price per tonne of CO_2 in the transport sector, if the entire sector must reduce its emissions significantly.[38] A significant reduction in precisely transport seems reasonable if Denmark shall meet its 2030 targets for the non-ETS sector.

The price of EUR 7,440 per tonne can be compared directly to the price of cancellation of allowances in Table 3. As the price of cancellation is more than EUR 44,640 per tonne until 2030, national measures within the non-ETS sector are most cost-effective in the short term, even though such measures are significantly more expensive than in the ETS-section. However, a sufficient expansion of the time horizon will make cancellation of allowances the cheapest option. If the time perspective is presented by applying a 4% discount rate, the present cost of displacing one tonne of CO_2 through cancelling alloances is EUR 5,632 in scenario 1, as mentioned above. This makes cancellation of allowances the most cost-effective option. In scenario 2 the price of displacing one tonne of CO_2 via cancellation is EUR 8,147 based on the present value and at a 4% discount rate. This option is slightly more expensive than the price of EUR 7,440 for national reduction measures; however, the chosen rate does not have to be lowered much to change this. Therefore, it cannot be determined unambiguously whether cancellation of allowances or national measures constitutes the most cost-effective action.

Finally, it is worth mentioning that the costs of CO_2 reductions presented here apply to a situation where the reduction efforts of Denmark or other EU member states do not simply transfer emissions to a non-EU country. If this happens, the price per tonne will rise, if calculated as the cost per tonne of CO_2 reduced at global level. However, the risk of carbon leakage is present both in connection with Danish climate measures and when European emissions are reduced by raising the price of allowances. Thus, carbon leakage is a potential factor, both when e.g. the non-ETS sector is subjected to national mitigation measures and when emissions in the ETS sector must meet given emission reduction targets.

7 Danish measures can affect the quantity of allowances issued in the future

So far the analysis has taken the future issuance of allowances for granted. In other words, the analysis assumes that the quantity of allowances issued each year follows present rules and those proposed by the Commission, hence no further allowances is issued after 2057. This assumption, however, do not take into account the actions Denmark and other countries un-

[38] This is the price at a 35% reduction in transport emissions in 2030 compared to 2005 levels. See Ea Energy Analyses, *Green Roadmap* 2030, 2015.

dertake in the meantime. As outlined in this section of the analysis, the actions of Denmark and other countries affect the quantity of allowances issued in the future.

The Commission has presented a proposal for the issuance of allowances from 2020 and onwards. The proposal, which awaits final adoption, entails a linear reduction of allowances issued each year by a factor of 2.2% of the base year. Unless it is decided otherwise, the 2.2% will continue after 2030,, although the 2.2% is likely to change as the level of ambitions in the climate area changes. The European Council will most likely establish a 2040 reduction target for the ETS sector, after which the Commission will propose a revision of the reduction of allowances issued to meet this target. Subsequently, this proposal is likely to be adjusted during negotiations between the member states and the European Parliament before it can be adopted.

Effect of National Measures on the Quantity of Allowances Issued in the Future

The negotiations in the European Council and, subsequently, in the European Parliament and the Council of the European Union can be seen to balance two goals. On the one hand, the EU and its member states wish to reduce the quantity of allowances issued as much as possible in order to contribute to the global effort to combat climate change. On the other hand, they also wish to lower the price of allowances as much as possible to safeguard the European industry and to avoid burdening citizens with high electricity and heating costs. The EU member states will weigh the two considerations differently, and the result of the negotiations is expected to reflect the desired balance at EU level between the two considerations. The current negotiations of a reform of the EU ETS can be said to reflect an imbalance between these two considerations and a wish to give greater priority to Europe's contribution to the global effort to combat climate change.

However, national measures can affect the balance between the two goals. If e.g. a country or a coalition of countries chose to cancel allowances independently, the surplus of allowances will be lower when negotiations on phase 5 (beginning in 2030) commence. This means that less CO_2 will be emitted in the remaining lifespan of the EU ETS for a given quantity of allowances issued in phase 5 and subsequent phases. The consequence for the negotiations will be an opportunity to lower the climate ambitions and instead give more priority to financial considerations, insofar as there is a wish to restore the balance between the price of allowances and the effort to combat climate change. This means that the quantity of new allowances will be greater than without the national cancellation of allowances. Put differently, cancellation of allowances will raise the price of allowances and thus the costs for businesses and citizens. In order to alleviate this problem, focus will be on issuing more allowances than otherwise planned in order to lower the price of allowances to a level which the member states in general consider reasonable. Figure 11 illustrates this point.

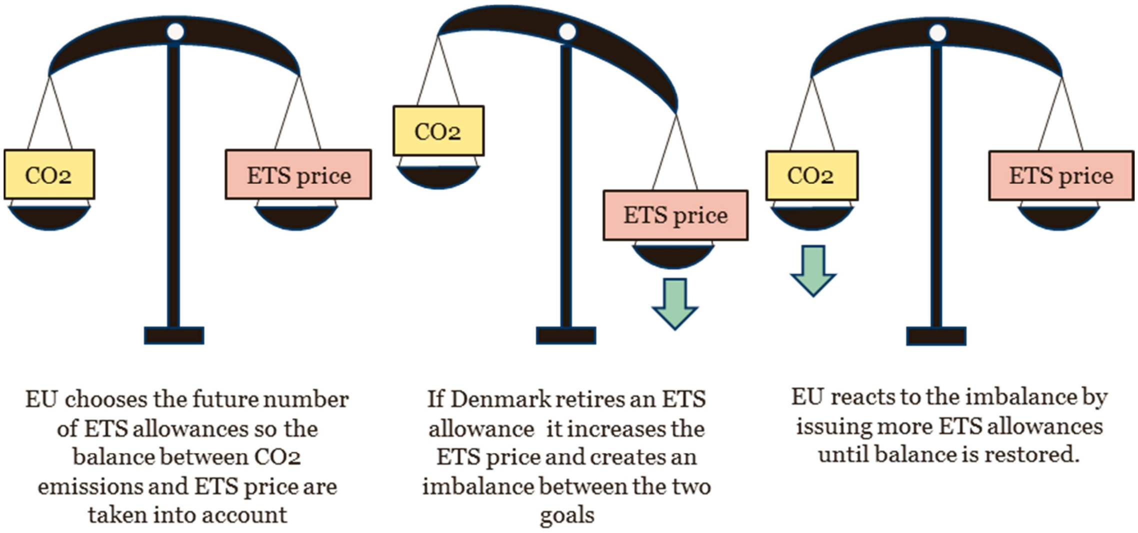

Figure 11 Illustration of the consequences of Danish cancellation of allowances on the EU's issuance of allowances

The working paper available on the Council's homepage demonstrates this argument within the framework of a formal model. Among other things, the paper shows that if Denmark cancels allowances, it is likely to cause the EU to issue a similar amount of allowances at subsequent negotiations, causing the action to have had no climate effect whatsoever. It is probably uncertain whether the reaction of the EU will cause the effect of the cancellation of allowances to disappear altogether. However, it seems highly likely that the effect of a Danish cancellation of allowances will be diluted to some extent by a future increase in theissued number of allowances.

Expansion in renewable energy has the opposite effect. If e.g. Denmark displaces emissions by building renewable energy capacity, it will cause adrop in the price of allowances. This creates an opportunity to choose a slightly more climate-friendly path by issuing a slightly reduced amount of allowances, even though it causes the price of allowances to rise slightly. Thereby, expansion in renewable energy has a second climate effect in addition to the one previously described in this analysis, as the expansion pushes the future EU climate policy in a greener direction. The present proposal for a reform of the EU ETS that reduces the supply of allowances can be seen as an example of this effect. That is because part of the surplus of allowances is caused by national-level support for renewable energy, which creates a push for a reduction in the quantity of allowances issued at EU level.

In conclusion, the arguments presented in this section suggest that renewable energy has a political advantage over cancellation of allowances. Whereas cancellation of allowances at national level raises the price of allowances, a national-level expansion in renewable energy would lower it. And a lower price of allowances makes it more likely that the EU will reduce the amount of allowances issued in the future.

8 Conclussionand recommendations

This analysis has examined the impact of the EU ETS on Danish climate measures. The analysis, which is based on the Council's simulation model for the carbon market, has focussed on two measures, namely expansion in renewable energy within the ETS sector and cancellation of ETS allowances.

Expansion in renewable energy within the ETS sector causes a significant reduction in total European emissions in the short term, that is, until 2030, due to the system's large existing surplus of allowances. However, expansion also causes the price of allowances to drop, resulting in increasing emissions especially after 2040. For the very long term towards 2100, it is possible that the accumulated emissions reduction is to zero. However, expansion may also make allowances available that are never used, causing expansion to have a long-term climate effect. This is the case if renewable energy becomes so competitive that it the demand for allowances in the long term is eliminated. Another possibility is that political decision is made to cancel the allowances that were made available by the renewable energy expansion and then transferred to to the so-called market stability reserve. This is one of the suggestions made by the Council of the European Union and thus expansion in renewable energy in the ETS sector will also have a long-term climate effect.

Cancellation of allowances does not result in significant short-term emission reductions. This is again a result of the large surplus of allowances. The majority of reductions do not occur until many years into the future, specifically after 2090 in scenario 1, although the precise year is of course uncertain. It is also uncertain whether cancellation of one allowance in fact results in the reduction of one tonne of CO_2 when taking the total lifespan of the EU ETS into account. This will for example not be the case in situations where not all allowances are used, as exemplified in scenario 2.

In the non-ETS sector emissions can be reduced by implementing national measures, which may involve renewable energy, energy conservation or change in production methods within agriculture. Here displacement of one tonne of CO_2 causes an immediate reduction in Danish emissions of one tonne of CO_2. And if national measures do not result in carbon leakage, global emissions are also reduced by one tonne.

The EU ETS is currently inflated and suffering from a large surplus of allowances. The consequence hereof is an allowances price thatprevents the system from truly driving the transition towards a low-carbon-society. Some argue that the EU ETS works well in the sense that emissions stay below the politically set cap. However, the low price of allowances indicates that the costs of reducing CO_2 emissions are far below the generally estimated global social costs of emissions.[39] Consequently, the low price of allowances indicates that society will profit from a tightening of the EU ETS, which would further reduce emissions and bring the price of allowances closer to the cost of emitting an extra tonne of CO_2.

If the surplus is reduced significantly, the EU ETS will be able to play a vital role in the EU's future climate policy. In February 2017 the European Parliament adopted a proposal for tightening the system, among other things by increasing the number of allowances transferred to the market stability reserve when the system faces a large surplus of allowances; however, the simulation results in Annex C show that a possible adoption of the proposal will not change the conclusions drawn above significantly. Likewise, the Council of the European Union has presented its proposal for a reform that will cancel some of the allowances held in the reserve, but

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[39] For the price of allowances to correspond to the estimated marginal damage costs of CO_2 emission, it would have to be much higher. For estimates of required CO_2 prices of CO_2, see e.g. Nicholas Stern and Simon Dietz, *Endogenous growth, convexity of damages and climate risk: how Nordhaus' framework supports deep cuts in carbon emissions*, 2014, Centre for Climate Change Economics and Policy Working Paper No. 180 Grantham Research Institute on Climate Change and the Environment Working Paper No. 159.

this initiative will neither ensure scarcity in the carbon market in the short term. Denmark should therefore make an active effort in the EU to further reform the EU ETS.

The above analysis has taken as its starting point the current large surplus of allowances. Therefore, the following recommendations apply to a situation where there is not implmented a reform that reduces the surplus of allowances before the beginning of phase 4 of the EU ETS in 2020. Also these recommendations provide answers to the three questions described in the introduction to this analysis.

1) The first and main question of the analysis is whether Danish support of renewable energy within the ETS sector has any effect on the effort to combat climate change? Three things speak in favour of a yes to this question.

   a. Expansion accelerates emission reductions, which contributes to reducing the risk that global warming may lead to irreversible, dangerous climate changes, just as it postpones the costs of damages caused by climate changes, which financially is an advantage.

   b. With the current planned policy it is possible that the surplus of allowances becomes permanent, hence expansion in renewable energy will also reduce emissions in the very long term.

   c. A Danish expansion in renewable energy will increase the EU's incentive to further reduce the amount of allowances issued in connection with the next revision.

   On this basis, the Council recommends:

   - *Denmark should not use EU ETS as an argument for refraining from supporting renewable energy in the ETS sector if it wants to contribute to the global effort to combat climate change.*

2) The second question of the analysis is whether the money would be better spent cancelling allowances rather than expanding in renewable energy within the ETS sector? Four things speak against this:

   a. Cancellation of allowances postpones reductions to a later date, which contributes to the risk of irreversible, dangerous climate changes and moves forward the costs of damages caused by climate damages.

   b. There is uncertainty as to whether these reductions would in fact take place. Partly, the simulations of the Danish Council of Climate Change show that in some scenarios the reductions will never materialise, and partly the rules of the EU ETS may be very different many years from now.

   c. Expansion in renewable energy is by far the most cost-effective option, if focus is on reducing emissions in the short and the medium term.

   d. Independent Danish cancellation of allowances will increase the EU's incentive to issue more allowances in connection with the next revision than would otherwise have been the case.

   On this basis, the Council recommends:

   Denmark should not independently cancel allowances in order to reduce emissions within the ETS sector as an alternative to expanding renewable energy.

3) The third question of the analysis is whether Denmarkshould make use of the flexible mechanism within the non-ETS sector target that allows it to use up to 8 million allowanc-

es to meet the 2030 target, instead of taking national measures,. Two things speak against using this flexible mechanism:

a. Denmark has to implement measures for the non-ETS sector at some point to meet the target of becoming a low-emission society by 2050. The Council's analysis of the target for the non-ETS sector elaborates on this argument.[40]

b. Cancellation of allowances will postpone reductions to well beyond 2030, thus creating uncertainty as to whether they will ever materialise.

On the other hand, cancellation of allowances may turn out to be more cost-effective than national measures, although the opposite may also be the case. All in all, the Council considers the two above-mentioned arguments to carry the most weight.

On this basis, the Council recommends:

Denmark should not make use of the flexibility mechanism that allows it to use allowances from the EU ETS to meet the target for the non-ETS sector.

[40] See the Danish Council on Climate Change, *Denmark and the EU's 2030 Climate Goals-*, 2016.

Annex A The Council's Simulation Model for the EU ETS

This annex describes the Council's simulation model for the EU ETS. For more detail, see the working paper available on the Council's homepage.

The model simulates the EU ETS on an annual basis from 2017 to 2100. The main elements of the model are:

- **Issuance of new allowances:** Issuance of allowances is subject to the current rules towards 2020 and the Commission's proposal for a 2.2% reduction from 2020 and up to and including 2057.

- **MSR:** The model follows the current rules for the MSR. This means that 12% of the surplus of allowances is transferred to the MSR when it exceeds 833 million allowances, whereas 100 million allowances are released when there is a surplus of less than 400 million allowances.

- **Demand for allowances:** It is assumed that the demand for allowances to cover emissions in a given year t follows this linear function:

  $$U_t = a_t - b \cdot q_t,$$

  where U represents emissions in million tonnes, q represents the price of allowances in EUR per tonne, while a and b are parameters. b is assumed to be constant over time and equal to 0.3, which is in accordance with the assumptions of Sandbag.[41] a is assumed to fall with time, which reflects the assumption that the demand for allowances will fall independent of the price of allowances. a has been calibrated; thus, annual emission levels in 2017 correspond more or less to Sandbag's baseline scenario. Beginning in 2017 a is assumed to fall at a fixed percentage rate each year, and this rate has been calibrated so that the model's 2017 price of allowances corresponds to the current level at approx. EUR 298 per tonne.[42] The rate has been calibrated to approx. 2.2%. In scenario 2 it is increased to 5% after 2060.

- **Required return on investment:** The model assumes that investors buying allowances for the purpose of resale will expect a return on investment of 10% pa. This is relatively high compared to other types of investments, e.g. stocks, but the high return reflects that investing in the carbon market is considered particularly risky, as political decisions may suddenly cause the price of allowances to fall, just as there is no knowing how long EU decision-makers will continue to support the carbon market. The assumptions of the Council correspond to Sandbag, which also uses 10% in its modelling. Furthermore, a German study has shown that investors buying allowances as investment objects require an expected return on investment above 10%.[43] Annex C examines the consequences of a required return on investment below 10%.

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[41] 0.3 more or less corresponds to an allowance price elasticity of 0.01 in 2017. The full price elasticity, which also includes the price of fossil fuels, is around 4-5 times higher.

[42] The current market price probably reflects the fact that the market takes into account a range of future EU ETS scenarios for. This does not apply to the model, where the future scenario is known.

[43] Karsten Neuhoff, Anne Schopp, Rodney Boyd, Katerina Stelmakh and Alexander Vasa. *Banking of Surplus Emissions Allowances – Does the Volume Matter?* Discussion Paper 1196, Deutsches Institut für Wirtschaftsforschung, 2013.

In the model the development of the price of allowances must meet three requirements:

1. If there is a surplus of allowances in a given year *t* – i.e. certain actors are saving allowances for later – the price of allowances in the subsequent year *t+1* must be 10% higher than the price in year *t*. At a lower price, saving allowances would not be profitable. Conversely, at a higher price, actors would profit from buying allowances in year *t* and selling them in year *t+1*. This would cause the price in year *t* to rise, until the price difference once again dropped below 10%.

2. If there is no surplus of allowances in a given year *t* – i.e. no one is saving allowances for later – the price of allowances in the subsequent year *t+1* can be no more than 10% higher than the price in year *t*. At a higher price, actors would profit from buying allowances and selling them at a later point.

3. If there is a surplus of allowances in a given year and in all subsequent years, the price of allowances in and after year *t* must be zero. A permanent surplus of allowances entails that some allowance owners do not manage to use or sell their allowances. If the price of allowances is positive, these allowance owners would profit from undercutting the existing market price. This competition would eventually cause the price of allowances to collapse to zero.

According to the model, stability is possible in a situation where the price of allowances meets these three requirements, where emissions follow from the price of allowances given the linear allowance demand function, where allowances are transferred to and released from the MSR as described, and where there is never a negative surplus of allowances.

In order to understand how the model finds stability, the concept period of commitment is introduced. In a period of commitment, 1) emissions during this period must correspond precisely to the quantity of new allowances issued plus the net release from the MSR in the period, and 2) there must be a surplus of allowances in all years apart from the last year of the period. In Figure 4 the first period of commitment e.g. runs from 2017 to 2056. There is a surplus of allowances in all years up until 2056, and in 2056 the surplus reaches zero. This means that all allowances issued up to and including this year are used (or transferred to the MSR). After 2056 most periods of commitment are one-year periods. This means that the supply of allowances in each year corresponds precisely to CO_2 emissions.

Within a period of commitment, the price of allowances increases by 10% each year, cf. the first requirement above. Therefore, if the price of allowances in the first year of the period is known, it is possible to calculate the price of allowances for the entire period of commitment. In Figure 4 the 2017 price of allowances set by the model ensures that the surplus of allowances has disappeared by 2056. In the subsequent one-year periods of commitment the price of allowances is adjusted to ensure that the annual emissions correspond to the total quantity of allowances issued plus any allowances released from the MSR in the year in question.

Figure 12 offers a graphic representation of the model's solution.

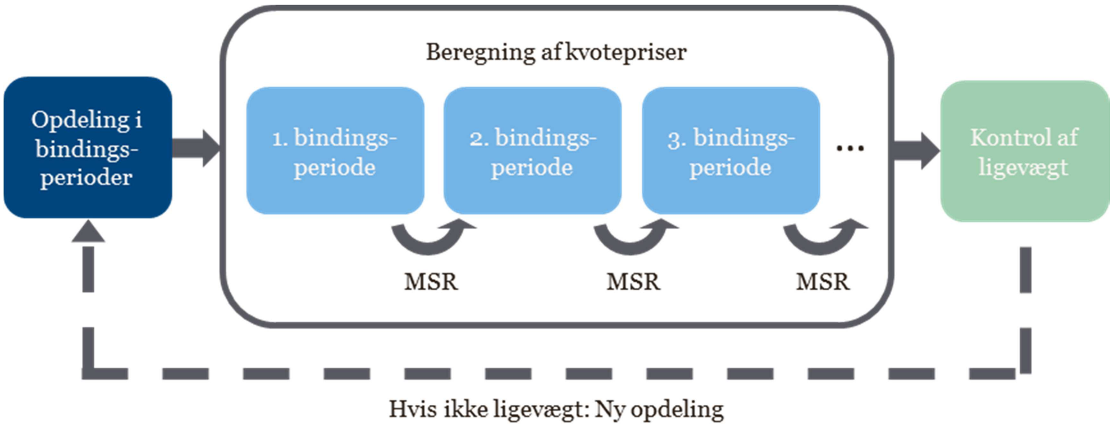

Figure 12Illustration of the Council's simulation model

Initially, the years 2017-2100 are divided into a number of periods of commitment. For the first period of commitment, the price of allowances in the first year of the period which ensures that the surplus of allowances reaches zero in the last year of the period is identified. Now it is possible to determine the level of emissions for the period and to calculate how many allowances held in the MSR are transferred to the next period of commitment. The same method is then used to establish the price of allowances in the next and subsequent periods of commitment, until the price of allowances has been established for all periods of commitment. It is now possible to control for stability. The three above-mentioned requirements must be met, and in addition, the surplus of allowances can at no time be negative. In case of instability, calculations start over with a new division into periods of commitment. Arriving at a stable result may seem like a stroke of luck. However, an algorithm has been incorporated into the model targeting a division that arrives at stability. This algorithm is described in more detail in the working paper.

Figure 13 shows the model's calculation of prices in the two scenarios. Up until 2056 a surplus of allowances is each year transferred to the following year causing the starting price of around EUR 298 per tonne in 2017 to rise by 10% each year and in 2056 to come close to EUR 14,880 per tonne. Subsequently, both scenarios see a fall in the price; from 2060 the fall is greatest in scenario 2. The price fall after 2056 reflects the fact that the surplus of allowances has disappeared, which entails that the demand for allowances in the individual years is now exclusively a result of the annual emissions which continue to drop as the available renewable energy technologies become still more competitive. On the other side, after 2056 a constant supply of allowances corresponding to the 100 million released from the MSR annually are each year transferred to the EU ETS. With a constant supply of allowances and a tendency to declining demands, the price of allowances must fall year by year to ensure that all allowances issued are sold.

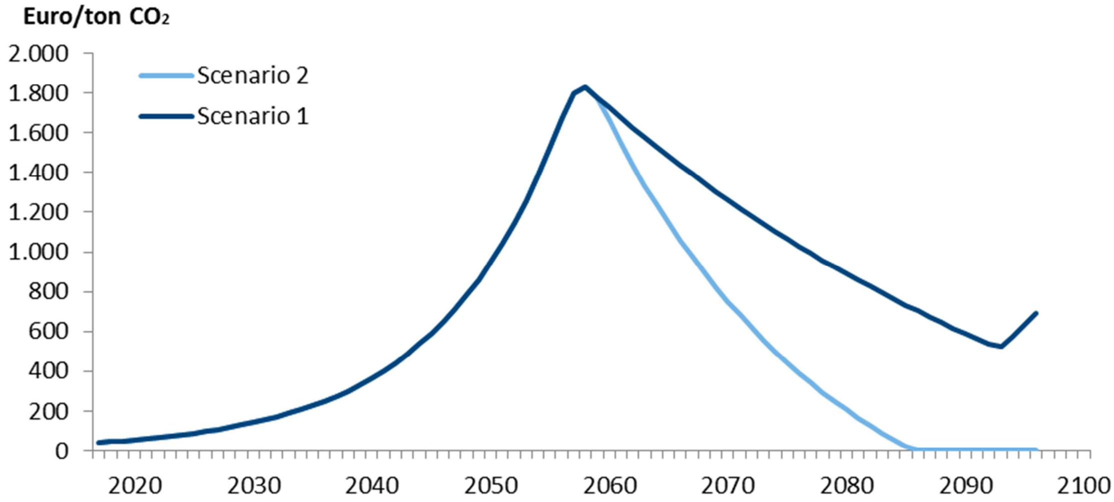

Figure 13 The model's calculation of the price of allowances in the two scenarios in the Council's model

Note: Compared to scenario 1, renewable energy in scenario 2 is more competitive after 2060.

Source: Own calculations.

In scenario 1 the price of allowances drops towards 2093 to around EUR 3,720 per tonne before increasing slightly again. The price rise occurs when the MSR is almost empty. This will cause a shortage of allowances, and some market actors will save a few allowances expecting the price to increase in the following years – and this will cause the price to increase by the previously mentioned 10% each year.

In scenario 2 the price of allowances eventually drops to zero. This reflects the fact that renewable technologies become so cost-effective that the demand for allowances declines, and some allowances will therefore never be used. This causes a permanent surplus of allowances, as shown in Figure 5. It may seem odd that investors will buy and save allowances in the first year of the model knowing that the price of allowances will later drop to zero. The reason is that all investors who save allowances are able to sell them at an earlier point and at a positive price. Allowances that cannot be sold at a positive price after 2086 do not belong to investors, but are held in the MSR, which saves allowances in accordance with a set of clearly defined rules and does not operate with a required return on investment.

It is important to stress that Figure 14 is not an actual projection of the future price of allowances. Many things may change, both politically, financially and technologically, affecting the development in the price of allowances. One may e.g. question whether a price of allowances close to EUR 14,880 per tonne will be accepted politically. It may be added that high prices on allowances may be required in order to use the EU ETS as a main instrument for eliminating greenhouse gas emissions from the ETS sector.

Even though the Council's model is not intended as a projection of the price of allowances, the price estimates of the model are not radically different from actual price projections, which as a rule only consider the period up until 2030. The Council's model arrives at a price of allowances in 2030 of EUR 1,049 per tonne, while Sandbag expects a price of around EUR 1,116 ,[44]

[44] Sandbag, *Comparing options for addressing EU ETS oversupply*, 2016.

and Thompson Reuters Point Carbon a price of EUR 1,339.[45] The EU's reference scenario expects a slightly higher price of EUR 1,674 per tonne in 2030.[46] Thus, the Council's model does not appear to be overestimating the price of allowance in the short term.

Annex B Discounting of CO_2 Emissions

This annex explains the use of discounting for representing horizon preferences with regard to CO_2 reductions.

One way to take into account the preference for present-day emission reductions over future reductions is discounting. Discounting uses a rate to calculate the present value of future costs or benefits. By discounting future values, it becomes possible to compare different measures, the effect of which occur at different points in time, e.g. financial flow in an investment. The present value is calculated using this formula

$$Present\ value = \frac{Future\ value}{(1+r)^t},$$

where r is the discount rate, and t the number of years from today.

Future emissions can be discounted in the same way as future costs and benefits. The idea is that emissions reflect the social costs of damages caused by climate changes. Table 1 in section 5 shows three different time horizons, without discounting emissions though. Discounting emissions will lead to a slightly different result. It is evident from Table 4 that if changes in emissions between 2017 and 2100 are discounted, expansion in renewable energy becomes more favourable compared to cancellation of allowances the higher the discount rate. This is because the CO_2 reduction from expansion in renewable energy occurs at an early point in time, whereas the same reduction from cancellation of allowances would be much later, as shown in sections 4 and 5.

It is evident from Table 4 that at a 4% discount rate the present value of emission reductions in scenario 1 following from expansion in renewable energy is 4.84 million tonnes of CO_2, whereas cancellation of allowances changes emissions by 0.93 million tonnes of CO_2 based on the present value. Thus, the effect of expansion in renewable energy is greatest using this discount rate. This applies as long as the discount rate is 1.3% or higher.

[45] Thomson Reuters Point Carbon, *EU ETS review: Don't mention the price, just get it right*, 2016.

[46] European Commission, *Reference Scenario – Energy, transport, and GHG emissions – Trends to 2050*, 2016.

MT of CO_2 discounted until 2017	0%	2%	4%
Cancellation of allowances	-8.00	-2.40	-0.93
Expansion in renewable energy	0.00	-4.37	-4.84

Table 4 Present value of changes in emissions from 2017 up to and including 2100 at different discount rates, scenario 1

Note: A negative figure means a reduction in emissions. The table lists the results of a simulation, where 0.8 million allowances are cancelled each year in the period 2021-2030 or where the ETS sector sees an expansion in renewable energy, thereby displacing 0.8 million tonnes of CO2 each year in the same period.

Source: Own calculations.

It is a slightly different story for scenario 2. Here expansion in renewable energy provides the best result at all discount rates, as shown in Table 5.

MT of CO_2 discounted until 2017	0%	2%	4%
Cancellation of allowances	-1.98	-1.10	-0.64
Expansion in renewable energy	-6.02	-5.67	-5.13

Table 5 Present value of changes in emissions from 2017 up to an including 2100 at different discount rates, scenario 2

Note: A negative figure means a reduction in emissions. The table lists the results of a simulation, where 0.8 million allowances are cancelled each year in the period 2021-2030 or where the ETS sector sees an expansion in renewable energy, thereby displacing 0.8 million tonnes of CO_2 each year in the same period.

Source: Own calculations.

A main element in discounting is the choice of discount rate. The higher the rate used, the lower the value of future emissions. The Danish Ministry of Finance adopts a socioeconomic discount rate of 4%, which falls to 3% after 35 years and 2% after 70 years.[47] This discount rate is e.g. used in the *Catalogue of Danish Climate Change Mitigation Measures* for discounting greenhouse gas emissions. However, one should be cautious using a discount rate established with a view to discounting figures in EUR to discount emissions measured as tonnes of CO_2. Discounting of physical emissions is meaningful if the relation between CO_2 emissions in a given year and costs of damages resulting from these emissions is more or less proportional. If the costs of damages caused by physical emissions increase gradually with time, the physical emissions should be discounted at a lower rate.[48]

[47] See the Ministry of Finance, *Faktaark – Ny og lavere samfundsøkonomisk diskonteringsrente* (*Fact Sheet – New and Lower Social Discount Rate*), 2013.

[48] The issue of discounting in a context of increasing environmental damage has been examined in more detail by Michael Hoel and Thomas Sterner, *Discounting and relative prices*, Climatic Change 84, 2007. The issue is also discussed in the working paper available on the homepage of the Danish Council on Climate Change.

Annex C Sensitivity of Results

This annex shows how the results of the model are affected by changes in the assumptions. Specifically, it will investigate the effect of an implementation of the European Parliament's and Council of the European Union' proposal for a reform of the EU ETS, the consequences of adjusting the demand for allowances to achieve higher emission levels before 2030 and the consequences of a lower required return for investors.

The European Parliament's and Council of the European Union' Proposal for a Reform of the EU ETS

In the spring of 2017 the institutions of the European Union are negotiating the rules for phase 4 of the EU ETS. In February the European Parliament and the Council of the European Union have each adopted amendments to the proposal of the Commission. In the months to come the three institutions will negotiate the final reform.

The European Parliament proposes two major amendments of consequence to this analysis:

- 800 million allowances held in the MSR will be cancelled permanently.
- From 2019 to 2022 24% instead of 12% of the surplus allowances will be transferred to the MSR.

In addition, the European Parliament's Committee on Environment, Public Health and Food Safety proposed that the amount of allowances issued each year be reduced by 2.4% rather than 2.2%. This amendment was not passed by the parliament, though, although it committed to reconsidering the question in 2024.

The Council has simulated the European Parliament's proposal in scenario 1 of the simulation model. The results show that the price of allowances will only increase by around EUR 0.6 in 2017, a rather insignificant price rise, and by just under EUR 15 in 2050. The price effect depends on the additional (net) amount of allowances transferred to the MSR before 2056, when the cap becomes binding. Before 2056 only the doubling of the rate of intake into the MSR is significant, and it introduces two conflicting effects in relation to the transfer of allowances to the MSR. On the one hand, more allowances are transferred to the MSR at a given surplus of allowances. On the other hand, the surplus of allowances is reduced more quickly, which for a given rate of intake into the MSR means that fewer allowances are transferred to the MSR, just as a surplus of allowances below 833 million allowances, where transfer to the MSR stops, is reached at an earlier point. The latter effect dominates, for which reason the total amount of allowances transferred to the MSR towards 2056 is in fact reduced slightly when the rate of intake is temporarily raised from 12% to 14%. In addition, release of allowances from the MSR also has an effect. The reduced intake into the MSR at 24% causes the surplus of allowances to increase slightly and thus to fall below the limit of 400 million allowances a year later, and 100 million allowances less to be released from the MSR. This entails that the MSR overall is slightly larger in 2056 as a result of the reform, which explained the small price rise.

In the long term, permanent cancellation of 800 million allowances has the largest effect. Cancellation will reduce the amount of allowances in the MSR when the reserve is depleted. Concretely, it means that emissions corresponding to this amount of allowances are cancelled permanently in the years 2086-2096. In total, emissions in the period 2017-2100 are reduced by 800 million tonnes corresponding to the amount of allowances cancelled, but as in section 5 the reduction will not occur until many years into the future. In addition, only scenario 1 will see a reduction of this size – in scenario 2 part of the cancellation will be used for eliminating the surplus of allowances that would never have been used.

The European Parliament's proposal for a reform of the EU ETS therefore neither succeeds in reducing the surplus of allowances nor in forcing the price to rise to a level that can propel the green transition. Implementing the proposal will not affect the previous conclusions of this analysis significantly. Table 5 shows the same model results of Table 1, though taking into account the proposal of the European Parliament. The table thus illustrates the accumulated change in emissions at three different time horizons for cancellation of allowances and expansion in renewable energy, respectively. It is evident from Table 5 that the result – that cancellation of allowances will not have an effect until many years into the future – still holds. E.g. cancellation of allowances merely causes the accumulated reduction in emissions to increase from 0.11 to 0.15 million tonnes of CO_2 in 2030 and from 1.09 to 1.45 million tonnes in 2050.

MT of CO_2	2030	2050	2100
Cancellation of allowances	-0.15	-1.45	-8.00
Expansion in renewable energy	-7.85	-6.55	0.00

Table 5 Accumulated change in emissions from 2017 up to and including 2030, 2050 and 2100, scenario 1, incorporating the European Parliament's proposal for a reform

Note: A negative figure means a reduction in emissions. The table lists the results of a simulation, where 0.8 million allowances are cancelled each year in the period 2021-2030 or where the ETS sector sees an expansion in renewable energy, thereby displacing 0.8 million tonnes of CO_2 each year in the same period.

Source: Own calculations.

The Council of the European Union has decided to support the proposal for increasing the amount of allowances transferred to the MSR.[49] Furthermore, the council proposes an upper limit for how many allowances can be transferred to the MSR. If the amount of allowances held in the MSR exceeds this limit, the surplus allowances will be cancelled permanently. Concretely, the council proposes that the amount of allowances held in the MSR cannot exceed the amount of allowance auctioned off the previous year.

The proposal for an upper limit in the MSR is quite powerful. A simulation of the proposal for scenario 1 arrives at the result shown in Table 6, which to a large extent is similar to the results for scenario 2 (see Table 2). This means that at an expansion in renewable energy only a smaller part of the allowances released will be used for emission elsewhere and at a later time. The majority of the allowances released end up in the MSR, where they are cancelled. The Council's simulation model further shows that the proposal may reduce the total emissions throughout the lifespan of the EU ETS by almost 5 billion tonnes of CO_2, which is a reduction of more than 10%. However, these reductions will not occur until after 2050, and therefore the proposal does not change the fact that the cap does not become binding until the second half of the century.

[49] Council of the European Union, *Revision of the emissions trading system: Council agrees its position*, press release of 28/2-2017.

MT of CO_2	2030	2050	2100
Cancellation of allowances	-0.13	-1.26	-2.28
Expansion in renewable energy	-7.87	-6.74	-5.72

Table 6 Accumulated change in emissions from 2017 up to and including 2030, 2050 and 2100, scenario 1, incorporating the Council of Minister's proposal for a reform

Note: A negative figure means a reduction in emissions. The table lists the results of a simulation, where 0.8 million allowances are cancelled each year in the period 2021-2030 or where the ETS sector sees an expansion in renewable energy, thereby displacing 0.8 million tonnes of CO_2 each year in the same period.

Source: Own calculations.

Therefore, the proposal of the Council of the European Union fails to solve the fundamental challenge of the EU ETS, namely the fact that there will be no shortage of allowances in the short term. According to the simulation model, the market still does not bind until 2056. Therefore, if implemented, the proposal will not affect the conclusions of this analysis significantly. In fact, it will further strengthen its conclusion that expansion in renewable energy is a more effective climate change mitigation measure than cancellation of allowances, just as an increase in the production of renewable energy would lead to the permanent reduction of the amount of allowances held in the MSR, whereas a Danish cancellation of allowances would cause the amount of allowances transferred to the MSR to drop.

Consequences of Increased Emissions in the Short Term

In the Council's simulation model emissions towards 2030 are slightly lower than in Sandbag's baseline scenarios and a lot lower than in the EU reference scenario. The consequence is that the EU ETS binds at a later point in the Council's model, which e.g. means that the reduction in emissions following from a cancellation of allowances also occurs at a later point. Below follows an investigation of the model results if the model is adjusted, placing more emissions before 2030.

First, it is important to understand the calibration of the simulation model. As explained in Annex A, the demand for allowances for emission in a given year is a linear function of the price of allowances with a level parameter a. This a has been set for 2017 to ensure that the model meets Sandbag's estimate for emissions in 2017 at a price of allowances of EUR 298 per tonne. In subsequent years, a is reduced by 2.2% each year, as the calibration finds that this very rate provides a 2017 price of allowances of EUR 298 per tonne. Using this method of calibration, which assumes the reduction rate is constant throughout the period, the assumptions cannot be changed to arrive at a higher level of emissions before 2030.

A possible alternative calibration method operates with a lower reduction rate before 2030 and a higher reduction rate after 2030. Mathematically, it can be described as follows:

$$a_t = \begin{cases} a_{t-1}(1-z) & \text{for } t \leq 2030 \\ a_{t-1}(1-x \cdot z) & \text{for } t > 2030, \end{cases}$$

where z is the reduction rate up to and including 2030, while x is how much the rate increases after 2030. z depends on x and is calibrated to ensure that the 2017 price of allowances is still EUR 298 per tonne. The present calibration corresponds to $x = 1$. The development of a at different x values is evident from Figure 14, which shows that when x increases, a increases in the short term, but decreases in the long term.

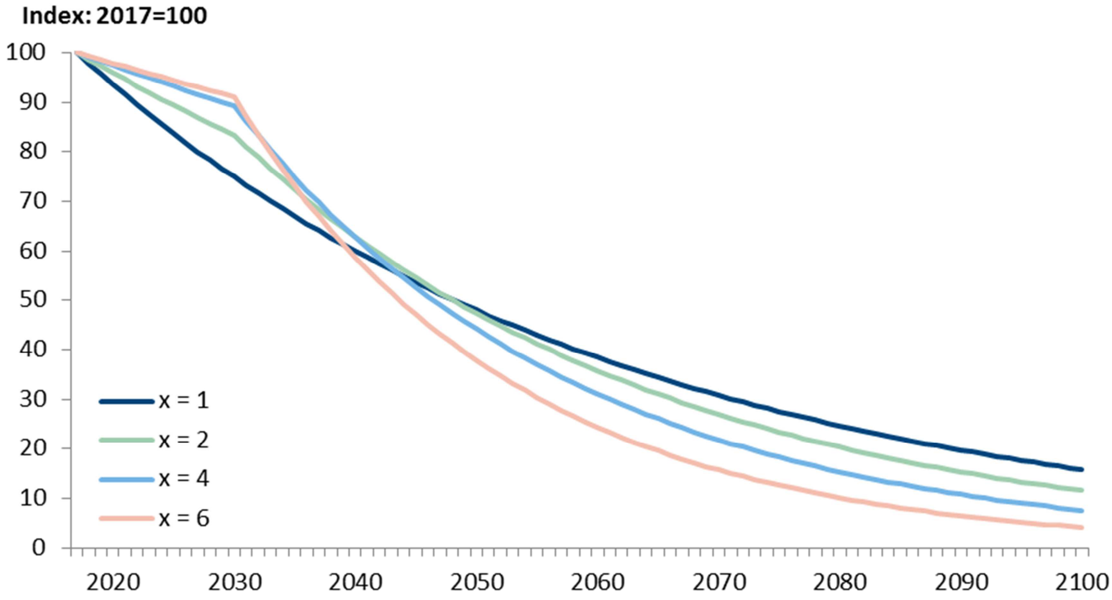

Figure 14 Development in the parameter *a* at different calibration methods

Source: Own calculations.

The Council's simulation model has calculated the consequences in scenario 1 of the different calibration methods shown in Figure 14. Table 7 shows that emissions are reduced towards 2030 and further towards 2050. In all four cases, the speed at which reductions occur must be increased after 2030 if emissions are to remain below the overall limit. This increase is greater the higher x is. One may question whether an increase in the reduction by as much as e.g. $x = 6$ is realistic; however, if you expect to see technological quantum leaps after 2030, you should choose a high x. There is no certainty as to whether such quantum leaps will occur, though, and the Council therefore finds that $x = 1$ is the most natural assumption. By comparison, the EU reference scenario shows a decline in reductions towards 2030 more or less corresponding to $x = 2$, although emissions in the starting year 2017 of this scenario are significantly higher than the Council's.

	$x = 1$	$x = 2$	$x = 4$	$x = 6$
2017-2030	2.52%	1.64%	1.07%	0.91%
2030-2050	4.36%	5.03%	5.70%	5.77%

Table 7 Annual reduction in CO_2 emissions at different calibration methods, scenario 1

Source: Own calculations.

The next question is how the value of x affects the impact of climate change mitigation measures. Figure 15 shows the accumulated change in emissions at cancellation of allowances. The dark blue graph in Figure 15 for $x = 1$ is identical with the stippled graph in Figure 10. It is evident from the figure that cancellation of allowances will not have an effect until well into the future, but that it will occur sooner the higher x is. E.g. emissions up to and including 2030 have been reduced by 0.11 million tonnes at $x = 1$, by 0.36 million tonnes at $x = 2$, by 1.70 million tonnes at $x = 4$ and by 4.25 million tonnes at $x = 6$. The difference is especially a result of the fact that the higher *x* is, the earlier the cap on allowances becomes binding. At the same time, fewer allowances are accumulated in the MSR, and therefore the year at which the MSR is depleted is brought forward.

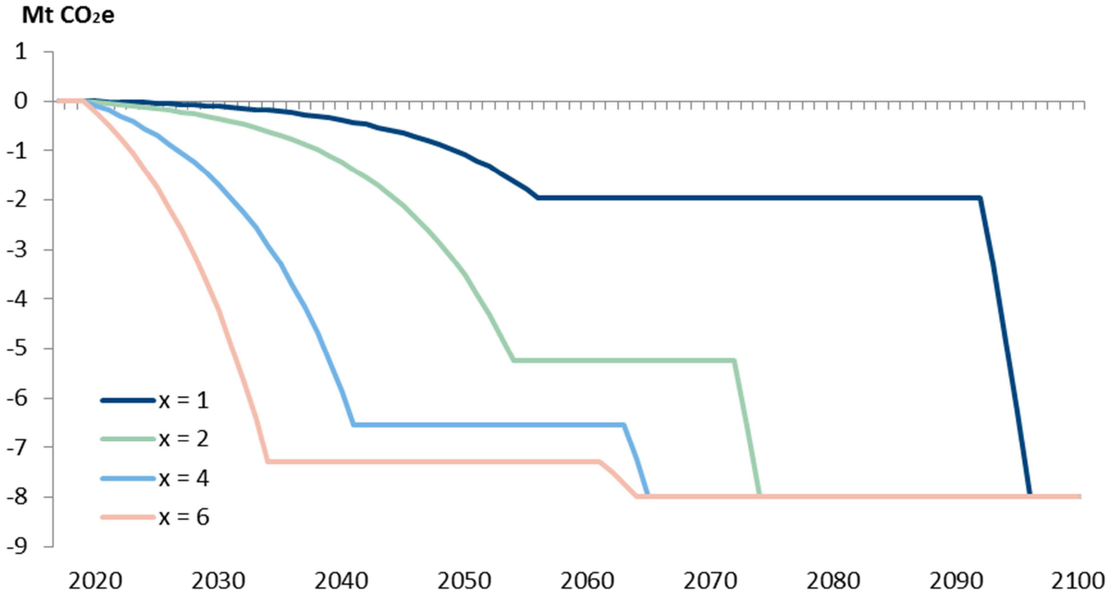

Figure 15 Change in emissions at cancellation of 8 million allowances from 2021 to 2030 at different calibration methods, scenario 1

Source: Own calculations.

Figure 16 shows the same effect for expansion in renewable energy. The dark blue graph for *x* = 1 is identical with the stippled graph in Figure 7. The effect is the opposite of the impact of cancellation of allowances. That means that the phase-out of the climate effect of expansion in renewable energy is faster the higher *x* is.

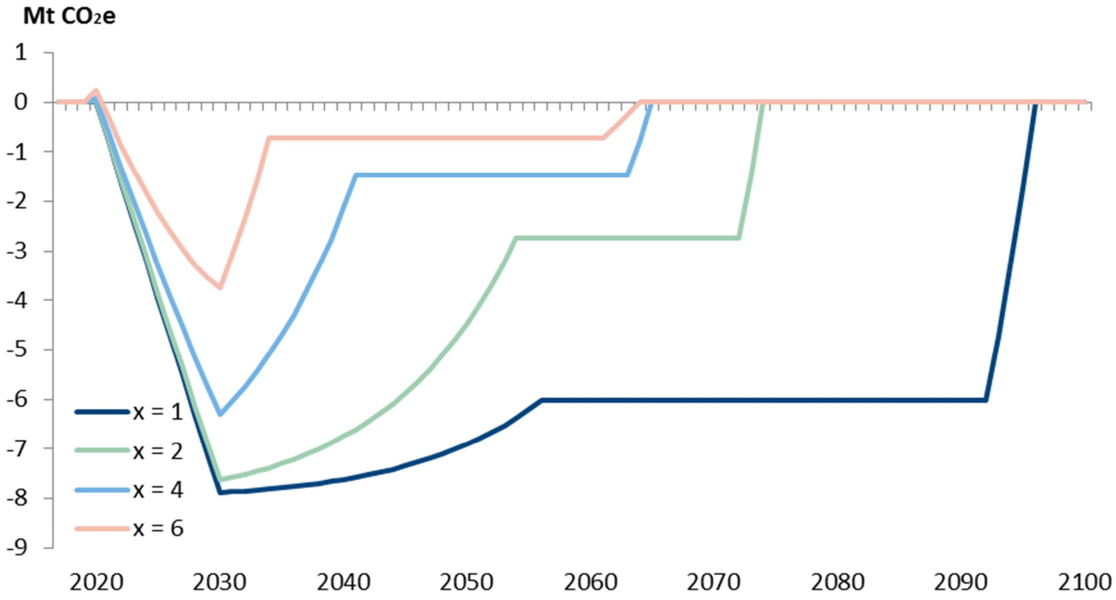

Figure16 Change in emissions at expansion in renewable energy displacing 8 million tonnes of CO_2 from 2021 to 2030 at different calibration methods, scenario 1

Source: Own calculations.

The first break in the curves after 2030 in Figures 15 and 16 occur the first time the cap becomes binding. The second break occurs when the last allowances leave the MSR. These years are listed in Table 8 together with the maximum size of the MSR. It is evident that the amount of allowances held in the MSR remains below 4 billion tonnes, when *x* is larger than or equals 2.

	$x = 1$	$x = 2$	$x = 4$	$x = 6$
Maximum size of the MSR (MT)	5,246	3,905	3,513	3,371
Year of the MSR's depletion	2095	2073	2064	2063
Year the cap becomes binding	2056	2054	2041	2034

Table 8 Maximum size of the MSR and important years at different calibration methods, scenario 1

Source: Own calculations.

Overall, these considerations show that more emissions before 2030 entail that the effect of a measure such as cancellation of allowances will be greater in the short term, while the effect of expansion in renewable energy is reduced. It is evident from Figures 15 and 16 that the more emissions towards 2030, the greater the effect of cancellation of allowances.

If *x* is 2, cancellation of allowances continues to have a limited effect towards 2030 of only 0.36 million tonnes of CO_2; however, by 2050 almost half of the original cancellation of 8 million tonnes will have materialised in reduced emissions. At $x = 6$ cancellation of allowances actually has the greatest accumulated effect in 2030 of the two, as the figure is 4.25 million tonnes of CO_2 at cancellation of allowances compared to 3.75 at expansion in renewable energy. However, a high *x* requires an expected technological quantum leap after 2030, which, in the Council's opinion, is too uncertain to include in a baseline scenario. Therefore, the Council believes it is more realistic to maintain a calibration where the level parameter of demand is reduced by the same rate each year throughout the period. As shown in Table 5, this entails that the rate of CO_2 reductions must almost double after 2030, which in itself may prove a challenge.

Consequences of a Lower Required Return

The Council's simulation model assumes that investors holding allowances for the purpose of resale require an annual return of no less than 10%. This return may seem high if compared to a normal shares portfolio, but it reflects the considerable uncertainty involved in investing in the carbon market. The following will seek to determine the consequences of lowering the required return to 8%.

At a lower required return, the price of allowances will rise at a slower pace. Initially, this means that future prices will be reduced causing the level of future emissions to rise. In order for the demand for allowances to continue to correspond to the constant supply of allowances throughout the lifespan of the EU ETS the current price of allowances must rise until the carbon market has regained stability. Therefore, a lower return entails that the model must be recalibrated to ensure that the 2017 price of allowances remains EUR 298 per tonne. This is done by increasing the rate at which the demand for allowances is phased out. This phase-out is explained in Annex A. Table 10 shows the accumulated change in emissions from 2017 up to and including 2030, 2050 and 2100 and is directly comparable to the results at a 10% required return, as shown in Table 1.

MT of CO_2	2030	2050	2100
Cancellation of allowances	-0.04	-0.28	-0.58
Expansion in renewable energy	-7.96	-7.72	-7.42

Table 10 Accumulated change in emissions from 2017 up to and including 2030, 2050 and 2100, scenario 1 with a required return of 8%

Note: A negative figure means a reduction in emissions. The table lists the results of a simulation, where 0.8 million allowances are cancelled each year in the period 2021-2030 or where the ETS sector sees an expansion in renewable energy, thereby displacing 0.8 million tonnes of CO_2 each year in the same period.

Source: Own calculations.

At cancellation of allowances the accumulated reduction in emissions reduced from 0.11 to 0.04 million tonnes of CO_2 in 2030 and from 1.09 to 0.28 million tonnes in 2050. In the short and the short to medium terms the effect of cancellation is therefore reduced slightly. As always, expansion in renewable energy is a mirror image of cancellation of allowances, and therefore the effect of expansion will be slightly higher.

In the long term there is a considerable difference between a required return of 8% and 10%, respectively. At 10% cancellation of allowances has a full effect with a reduction of 8 million tonnes by 2100, but at 8% the demand for allowances in the long term is so low that it causes a permanent surplus of allowances, which are never used – precisely as in Table 2. The reason is that the demand for allowances is reduced through calibration at a lower required return, resulting in a very low demand for allowances in the long term. Cancellation of 8 million allowances therefore only causes a reduction in emissions of 0.58 million tonnes, whereas expansion in renewable energy displacing 8 million tonnes of CO_2, all things considered, will reduce emissions by 7.42 million tonnes. This shows that a lower required return supports the analysis' conclusions that the climate effect of expansion in renewable is greater than the effect of a comparable cancellation of allowances.

The percentage rate of the required return has the greatest effect on the price of allowances. At a 10% required return the price of allowances reaches a maximum of more than EUR 13,392 per tonne, which is reduced to slightly more than EUR 7,440 per tonne at an 8% required return.