PBL Netherlands Environmental
Assessment Agency

# EVALUATION OF POLICY OPTIONS TO REFORM THE EU EMISSIONS TRADING SYSTEM

## EFFECTS ON CARBON PRICE, EMISSIONS AND THE ECONOMY

POLICY STUDIES

# Evaluation of policy options to reform the EU Emissions Trading System

## Effects on carbon price, emissions and the economy

**Evaluation of policy options to reform the EU Emissions Trading System**
**Effects on carbon price, emissions and the economy**
© PBL Netherlands Environmental Assessment Agency
The Hague, 2013
ISBN: 978-94-91506-36-9
PBL publication number: 934

**Corresponding author**
corjan.brink@pbl.nl

**Author(s)**
Martijn Verdonk, Corjan Brink, Herman Vollebergh and Mark Roelfsema

**Acknowledgements**
The report has benefited from comments by Pieter Boot, Frank Dietz, Robert Koelemeijer, Ton Manders, Jos Nooteboom, Gusta Renes (all PBL), Frans Duijnhouwer, Dennis Holtrop, Linda van Houwelingen, Joost Kolkman, Paul van der Lee (Ministry of Infrastructure and the Environment), Maurits Blanson Henkemans (Ministry of Economic Affairs), Linda Brinke (Ministry of Finance), Rob Aalbers, Johannes Bollen (CPB Netherlands Bureau for Economic Policy Analysis), Erik van Andel, Bas Kroon, Bram Maljaars (Dutch Emissions Authority), Paul Koutstaal (ECN), Coos Overbeeke, Jules Schreurs (Netherlands Court of Audit), Reyer Gerlagh (Tilburg School of Economics and Management), Stefan Weishaar, Edwin Woerdman (University of Groningen), Erik te Brake (VNO-NCW), Annemarie van der Rest, David Hone, Frank van Oordt (Shell), Akshay Patki (European Commission), Bhave Aproop (UK Department of Energy and Climate Change).

**English-language editing**
Annemieke Righart

**Graphics**
PBL Beeldredactie

**Production coordination**
PBL Publishers

**Layout**
VijfKeerBlauw, Martin Middelburg

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# Summary

The EU Emissions Trading System (EU ETS) is a key instrument of EU climate policy, providing a clear reduction pathway for $CO_2$ emissions. Increasingly, doubts are being raised about whether the EU ETS provides a proper price signal for investment in low-carbon technologies that contribute to the long-term EU target for a low-carbon society by 2050; in particular, because of the much lower than expected carbon price and its volatility. This price is likely to remain low for a long time and this fuels doubts about whether the ETS will remain a key policy instrument in the long term. Such doubts also increase investment uncertainty, which is likely to have a negative impact on further investments in low-carbon technologies. The current situation on the ETS market illustrates the weakness of the EU ETS design, as it is not flexible enough to adapt to unforeseen turns of events, such as an economic crisis.

This report evaluates various options to structurally reform the EU ETS, some of which also have been proposed by the European Commission. The impact of these reform options was quantified using WorldScan, a global computable general equilibrium model.

The main findings are:

- Options that aim to reduce the supply of EU ETS allowances would further reduce emissions and, therefore, boost emission prices, but provide only an ad-hoc solution to the fundamental issue of the degree of robustness of the EU ETS in an uncertain world. New unforeseen events (such as a further deterioration of the economic situation) would require further adjustment of the allowance supply.
- A wider scope of the EU ETS may be an indirect way to reduce emissions in order to create a stronger price signal. Expanding the EU ETS by including liquid fuels for road transport would introduce additional scarcity on the carbon market only if the amount of allowances is less than the sector's current emissions. In that case, the carbon price is likely to rise, thus, inducing other sectors to further reduce their emissions. This option improves the overall cost-efficiency of reducing greenhouse gas emissions in the EU, but may be at odds with other policies that aim to stimulate investment in low-carbon technologies within the transport sector.
- An auction reserve price would make the EU ETS more robust against exogenous supply and demand shocks, and would result in more emission reductions if abatement proves to be cheaper than expected. An auction reserve price also would provide a more predictable price path, which is particularly helpful for low-carbon technologies in the face of too much uncertainty about the long-term carbon price.
- A flexible $CO_2$ tax on energy use for all ETS sectors in the Netherlands to imitate the effect of a minimum carbon price would not be very well-geared to the context of EU climate and energy policies. As long as the $CO_2$ tax is only introduced in the Netherlands without any adjustment to the total supply of ETS allowances in the EU, the additional reductions within the Netherlands induced by the higher price on

emissions would be cancelled out by an increase in emissions in other Member States.
- An EU-wide $CO_2$ tax on energy use for all sectors introduces an emission price *in addition* to the price on emissions already obtained through the ETS. The $CO_2$ tax directly induces abatement and thus emission reductions, both within and outside the EU ETS sectors. This, in turn, would considerably reduce demand for EU ETS allowances. If the supply of allowances is left unchanged, the price of EU ETS allowances would collapse.

The macroeconomic impact of the reform options, such as changes in economic welfare and sectoral production, as well as the differences across Member States are generally small for the various reform options. As may be expected, the higher the emission reduction induced by a particular option, the higher the emission price and the larger the decrease in production in ETS sectors; in particular, in the most energy-intensive production sectors, such as those of power generation and base metals. However, ETS reform options would reduce the amount of subsidy required for achieving the EU target for renewable energy and increase the overall auction revenues in the EU.

The evaluation of the various options for a structural reform of the EU ETS does not provide clues as to how much additional emission reduction would be optimal from the perspective of EU ETS reform. However, it does illustrate very clearly that the preferred reform option depends on the appraisal of various arguments, such as the willingness to accept fundamental changes to the ETS, the value attached to predictability and stability of the emission price, and the interaction with other instruments within the EU climate and energy package.

# Evaluation of policy options to reform the EU Emissions Trading System

## Effects on carbon price, emissions and the economy

### EU ETS key instrument for European climate policy

The EU Emissions Trading System (ETS) is one of the most important instruments for European climate policy. Roughly half of all European greenhouse gas emissions are capped under the EU ETS. Its main purpose is to reduce emissions in a cost-effective way through a 'cap and trade' system, providing a clear reduction pathway for industrial greenhouse gas (GHG) emissions up to 2020 and, if extended, also beyond 2020. The EU ETS objective is to internalise the social costs of greenhouse gas emissions into market prices, which also would promote a further investment in low-carbon technologies that contribute to the EU's long-term target of a low-carbon society by 2050, as stated in the *EU Roadmap for moving to a low-carbon economy in 2050*.

### The low ETS price reflects a lack of scarcity on the ETS market

The main purpose of the EU ETS is to reduce 21% of the emissions from sectors included in the scheme, between 2005 and 2020, in a cost-effective and flexible way across Europe. The $CO_2$ price, in principle, is determined by supply and demand. However, as the supply of allowances is fixed at a politically agreed level, the ETS is unable to respond to unforeseen changes in its context. For example, the economic recession of 2008 and 2009 led to lower industrial production and energy consumption, with lower demand for emission allowances as a consequence. Also, the introduction of other elements of the Climate and Energy Package (in particular, national subsidies for renewable energy) led to a further decrease in the demand for allowances. The implementation of a new energy efficiency directive will further put pressure on future demand. Despite this lower demand, the supply of allowances has not been lowered accordingly, but instead increased in 2012 and 2013, due to the start of a new trading period. This combination has contributed to a significant amount of unused allowances and CDM/JI credits, and, consequently, to low-carbon prices of below 5 euros per tonne $CO_2$ in February 2013.

### Debate on the robustness of the EU ETS and its ability to respond to unforeseen events

The current lack of scarcity of allowances and its associated low ETS price has induced a debate as to whether reform would be warranted. Some argue that no reason exists to change the design of the EU ETS because the lower-carbon price merely reflects the fundamental principle behind the ETS, which is an environmental policy governed by principles of cost-effectiveness (EC, 2009). In their view, a low $CO_2$ price is not problematic for the purpose of reducing greenhouse gases up to 2020, because emissions are being capped under the EU ETS which guarantees that emissions will have decreased by 21% by 2020, compared to 2005 levels. Others argue that the design of the EU ETS still has fundamental flaws and that the oversupply and its associated low price signal is an indication that the ETS system is not robust enough against unforeseen demand or supply shocks. Doubts have been raised about whether the EU ETS would provide a correct price signal for investments in low-carbon technologies; in particular, because of its much lower than expected price as well as its volatility. Indeed, more recently introduced cap-and-trade programmes in California and Australia do contain provisions that reduce price uncertainty and improve robustness of the system with respect to unforeseen economic developments, new scientific insights, and the arrival of new technologies.

### Without intervention, EU ETS prices will remain low

Various market analysts expect that without market intervention, prices will remain low, at around 10 euros, up to 2020. The European Commission expected prices to be around 30 euros at the time the EU ETS was revised in 2009. This substantial difference between expected and actual prices has fuelled doubts about whether the ETS will remain the central policy instrument, in the long term. This has increased the existing uncertainty for economic agents and is likely to have a negative impact on further investments in low-carbon technologies. The much lower than expected $CO_2$ allowance price has invoked a discussion within the EU. In response to the weak price signal of the ETS, politicians and various stakeholders have voiced their concerns. In November 2012, the European Commission proposed to adjust the timing of the allowances to be auctioned and put forward six options for a more structural reform of the EU ETS, thus also implying the willingness of policymakers to continue to use the ETS as one of the main $CO_2$ policy instruments. The options proposed vary; from reducing the cap and expanding the ETS to include other sectors, to strengthening the ETS by measures directly affecting allowance prices. The Dutch Ministry of Infrastructure and the Environment (IenM) has asked the PBL Netherlands Environmental Assessment Agency to assess the impact of these options. Such analysis would help the Dutch Government to determine its position in the debate on ETS reform and, more broadly, provide information for the European debate. This report evaluates, in detail, several of the options proposed by the European Commission, as well as alternative options that combine the ETS and a $CO_2$ tax on energy use. These options would reform the ETS in such a way that either the supply of allowances would be reduced or more certainty would be provided on the (minimum) $CO_2$ price level.

### Quantitative analysis illustrates the importance of extending the EU ETS beyond 2020

The impact of various reform options has been quantified using WorldScan, a computable general equilibrium model for the world economy. The quantitative analysis concentrates on the effect on emissions, emission price, economic welfare and sectoral production, compared to a Reference Scenario for the 2013–2030 period, including current legislation on the EU ETS, assuming continuation of the system beyond 2020, and assuming the continuation of current annual emission reductions. This Reference Scenario clearly illustrates that the mere continuation of the EU ETS beyond 2020, in combination with the possibility of banking allowances for future use up to 2030, would increase the demand for allowances and therefore not only would cause an increase in the emission price in the period up to 2030 but also already before 2020.

### Reducing the allowance supply would reduce more emissions and boost emission prices

Reform options that reduce the supply of EU ETS allowances follow the original setup of the EU ETS as an instrument to deliver targets with respect to the quantity of emissions, with the price being decided by the market. A reduction in the supply of allowances can be realised in different ways, such as by a higher annual reduction factor and the setting aside of part of the allowances to be auctioned in the 2013–2020 period. As one might expect, withdrawing more allowances from the total supply during the 2013–2030 period, would increase the impact. Bringing the ETS cap in line with the emission reduction pathway as put forward in the EU Roadmap to 2050 would result in emissions by 2020 being 6% lower than under the Reference Scenario. Our model simulations suggest that emission prices would increase by 33%. These types of reform options, however, only provide an ad-hoc solution to the fundamental issue of the robustness of the EU ETS in an uncertain world. The occurrence of more unforeseen events (such as a further deterioration of the economic situation) would require another adjustment of the allowance supply.

### Expanding the EU ETS scope would provide options for cost-efficiency and would increase scarcity on the ETS market

Another way of increasing the scarcity on the ETS market could be that of expanding the scope of the EU ETS, to include sectors that are underprovided with allowances. Indeed, sectors that are not included in the ETS would not have the choice between abating emissions or buying allowances, which implies less flexibility to exploit cheaper reduction options in other sectors. We analysed an expansion of the EU ETS by including liquid fuels for road transport. The expansion provides road transport, with its relatively expensive abatement options, the possibility to pay for abatement against lower costs. This will introduce additional scarcity on the carbon market; in particular, if the allocated allowances would be less than current emission levels in the road transport sector. The resulting higher carbon price would induce other sectors to further reduce their emissions. In our scenario calculations, the created scarcity was relatively small. This option would reduce emissions by only 2% and raise the emission price only slightly above that of the Reference Scenario. Including liquid fuels for road transport in the EU ETS should be explicitly tailored to combine with other instruments, such as fuel-efficiency standards and fuel taxes. By providing the transport sector with cheaper options for carbon abatement, such an expansion of the EU ETS may be at odds with other policies that aim to stimulate investments in low-carbon technologies related to the transport sector.

### Auction reserve price makes the EU ETS more robust against exogenous supply and demand shocks

An auction reserve price implies that no allowances would be auctioned at below a pre-defined floor price. This changes the current cap-and-trade instrument into a tailored combination of a quantity and price instrument. This option reduces uncertainty regarding emission prices and investment signals, while maintaining the advantages of the trading scheme. In our scenario calculations, the floor price would exceed the price level of the Reference Scenario; therefore, introducing an auction reserve price would induce additional emission reductions. With a floor price increasing to EUR 25/t$CO_2$ in 2020 and EUR 50/t$CO_2$ in 2030, the auction reserve price will reduce emissions by 5% below levels in the Reference Scenario. The auction reserve price would be particularly effective in a period of low economic growth, or of low scarcity of supply due to shocks, as under these types of conditions this option would reduce more emissions than any of the other reform options. Moreover, a minimum floor price would guarantee a more predictable price path, which is particularly important to low-carbon technologies that currently face too much uncertainty about the long-term carbon price. For very similar reasons, a price ceiling would prevent allowance prices from increasing beyond a predefined level in case of positive demand shocks.

### Using different instruments, such as a carbon tax and the ETS, requires tailored combinations

A $CO_2$ tax on energy use imposed on ETS sectors would put an additional price on emissions, in addition to the price already attached through the EU ETS. The $CO_2$ tax would directly induce abatement and, therefore, emission reductions. This, in turn, would considerably reduce the demand for EU ETS allowances. If the supply of allowances is left unchanged, the price of EU ETS allowances would collapse. We analysed the possible introduction of a $CO_2$ tax on energy use for ETS companies in the Netherlands, in combination with emission trading under the ETS. Following ideas applied in the United Kingdom, this combination is tailored in the sense that the level of the $CO_2$ tax is flexible and would depend on the difference between the EU ETS allowance price and a predefined floor price. In such a way, the $CO_2$ tax would guarantee a minimum price on $CO_2$ emissions in the Netherlands. This option, however, is not so well tailored in the context of the EU ETS, because without any adjustment in the total supply of EU ETS allowances, the additional reduction within the Netherlands induced by the higher price on emissions would be outweighed by an increase in emissions in other Member States. Also, an EU-wide $CO_2$ tax on energy use for all sectors would introduce a non-tailored combination of instruments. Because of the emission reductions directly induced by the $CO_2$ tax, the demand for EU ETS allowances would be considerably reduced and the price of EU ETS allowances would collapse. Thus, a separate $CO_2$ tax would simply take over the entire role of the EU ETS, acting as its substitute. For this option to function properly, a tailored adjustment to the EU ETS cap would be required.

### Macroeconomic impacts are generally small

The macroeconomic impact of reform options, such as changes in economic welfare and sectoral production, generally would be small according to our model calculations. The economic welfare losses are based on changes in utility derived from consumption and hence are a partial welfare measure, not taking into account the welfare effects of, for example, environmental changes. The impacts of reform options are not equally distributed over different sectors and different countries. Differences between Member States are small; the impacts on sectors were found to be more substantial. As may be expected, the higher the emission reduction induced by a particular option, the higher the emission price and the larger the decrease in production in ETS sectors, in particular in the most energy-intensive ones, such as power generation and base metal production. Compensating firms for the increased cost related to the ETS by awarding a more generous free allocation, and in addition provide indirect cost compensation, may reduce the impact of ETS reform on these sectors.

### Carbon leakage rate similar for different ETS reform options

The additional emission reductions within the EU indirectly would raise emissions outside the EU, but this impact does not differ much between most reform options. Our model calculations for each Mt $CO_2$ emission reduction within the EU show an increase in emissions outside the EU of about 0.6 Mt $CO_2$. This increase results from lower global energy prices and from the relocation of industrial production to regions outside the EU. A relatively high leakage rate was found for the introduction of an EU-wide $CO_2$ tax, as this would not only apply to ETS sectors, but also to others within the EU.

## Additional greenhouse gas reductions reduce air pollution

Greenhouse gas and air polluting emissions largely originate from the same sources: fossil-fuel combustion and agricultural activities. The ETS reform options were found to result in a reduction in air pollution, mainly in $SO_2$, $NO_x$ and particulate matter. These reductions follow from a decrease in the use of fossil fuel, particularly coal, due to energy efficiency improvements, a shift to renewable energy sources and changes in the sectoral structure of the economy. The European $CO_2$ tax in particular, which not only applies to ETS sectors but to all energy consumption, would significantly reduce air pollution, reducing $SO_2$ emissions by almost 10%. These reductions would lower the costs related to reducing air pollutant emissions below the emission ceilings as set by the EU NEC Directive.

## ETS reform options in relation to EU climate and energy package

Although all policy options that imply adjustments to the current ETS legislation require a decision by European Parliament and the European Council of Ministers, for some options this could be more complex and thus more time consuming than for others. However, a full discussion on the procedural and political aspects associated with reform options was beyond the scope of this study. Our analysis also does not include information on how much additional abatement reduction would be optimal from the perspective of EU ETS reform. However, it does illustrate very clearly that a proper functioning of the EU ETS would strongly depend on the full set of instruments used within the EU climate and energy package. Instruments not only interact, they also often overlap. Our scenario calculations suggest that the ETS reform options reduce the amount of subsidy required for achieving the EU target for renewable energy. The higher the price of emissions, the smaller the required subsidy on renewable energy. According to our scenario calculations, the introduction of a European $CO_2$ tax, in particular, would render subsidies on renewable energy close to unnecessary.

# FULL RESULTS

FULL RESULTS

ONE

# Introduction

## 1.1 Placing EU ETS reform on the agenda

### Substantial oversupply of emission allowances on the ETS market

The functioning of the EU Emissions Trading System (ETS) is under discussion. The market price of $CO_2$ emission allowances has collapsed and is currently far below expectations. By January 2013, prices dropped below five euros per tonne of $CO_2$, whereas at the time the revised ETS directive was adopted, the European Commission had expected prices to be around 30 euros (EC, 2012a). Various market analysts, such as from Point Carbon, Barclays Capital and Deutsche Bank, expect prices to remain at a low level up to 2020 (EC, 2012b; Point Carbon, 2012).

Although also other factors contribute to the current oversupply of allowances, such as the fast penetration of renewables, the main explanatory factor is the economic stagnation in the European Union since the end of 2008. As a consequence, emission levels have been much lower than expected, while the allowance supply has not been adjusted accordingly. The unforeseen drop in the demand for allowances coincided with the new possibility of banking allowances left over from the second ETS trading period (2008–2012) to use in the third trading period (2013–2020). The transition from the second to the third trading period also increased the allowance supply in 2012, with provisions such as the early auctioning of 120 million allowances of the third trading period in 2012, and selling part of the 300 million allowances held in the new entrants reserve of the third trading period to provide funding for the support of innovative technologies (the NER300 programme). These factors have contributed to the current lack of scarcity of allowances on the $CO_2$ market and explain the current low $CO_2$ price.

### Political response to low $CO_2$ prices

The much lower than expected $CO_2$ allowance price has invoked a discussion within the EU. In response to the weak price signal of the ETS, politicians from the European Parliament, the European Commission, various Member States, and the majority of the Dutch House of Representatives, have expressed their concern (Dutch House of Representatives, 2011; Dutch Government, 2012; EC, 2012c; EP, 2012). Also several commercial organisations, such as Eurelectric (2012), the International Emissions Trading Association and the Climate Markets & Investment Association (Point Carbon, Carbon Market Daily, 9 October 2012) have voiced their concerns. Some have even argued to scrap the EU ETS and thus 'make way for real and effective climate and energy policy that reduces emissions in Europe' (http://scrap-the-euets.makenoise.org/).

In April 2012, when the $CO_2$ price was at a historically low level, the European Commission (EC) announced its intention to review the ETS in 2012 (instead of 2013), including a proposal to change the auctioning time profile. In July 2012, the EC proposed an amendment to the ETS directive, explaining why it was aiming to adjust the timing of the allowances to be auctioned for the 2013–2020 period (EC, 2012b). In the accompanying draft Auctioning Regulation, the EC addressed the current oversupply of allowances by reducing a certain amount of auctioned allowances in the initial period (the remainder to be temporarily set aside), and adding these again to the amounts to be auctioned in subsequent periods (backloading). After a brief consultation period, in November 2012, the EC proposed to set aside 900 million allowances in the years from 2013 to 2015 which would then be backloaded in 2019 and 2020 (EC, 2012e).

Shortly after this proposal, the EC also published a review of the functioning of the ETS and put forward options for structural reform (EC, 2012f). These options currently are discussed through public consultation (until March 2013), but the debate will likely continue in 2013 and possibly 2014, the election year for the European Parliament.

The EC's options are (EC, 2012f):
a. increasing the EU reduction target to 30% by 2020;
b. cancellation of a number of allowances in the third trading period;
c. adjustment of the annual linear emission reduction factor;
d. expansion of the scope of the EU ETS, also including other sectors;
e. limiting the access to CDM/JI credits (beyond 2020);
f. discretionary price management mechanisms.

These options are intended for a debate on the EU ETS, rather than that they are legislative proposals. Also, the options are quite general and further discussion will be needed on their actual implementation.

## 1.2 Aim, scope and methods related to this report

### Aim and scope of this publication

The first three options suggested by the EC involve adaptations of the current cap, the overall amount of emission allowances released onto the market, whereas in particular the last option is a so-called hybrid instrument. Such hybrid instruments are tailored combinations of (quantity and price) instruments that have one particular goal in common but avoid overlap in order to prevent efficiency losses (Vollebergh et al., 1997; Hepburn, 2006). Other options to imitate the effect of such tailored combinations also exist, such as the combination of an emissions trading scheme with a (national) carbon tax to imitate the effect of having a minimum emission price. The same holds for options that aim to expand the cap to include other sectors; in particular, if these sectors are already subject to other climate-related policies. The ETS is just one instrument in the overall EU policy mix to combat climate change. Addressing interactions between different instruments in order to prevent poor coordination between policy measures is therefore particularly important (Hepburn, 2006; Aalbers et al., 2013).

This report aims to contribute to the general discussion on structural reform of the ETS by reviewing and analysing several of these options in more detail. The Dutch Ministry of Infrastructure and the Environment (IenM) has asked the PBL Netherlands Environmental Assessment Agency to assess the impact of several policy options that aim to reform the ETS in a structural way. This would help the Dutch Government to determine its position in the debate on reforming the ETS. In particular, the Ministry of IenM requested an assessment of some of the proposed EU options that would change the supply of allowances, such as a tighter cap and a permanent set aside of allowances, as well as an option that would introduce a minimum price on auctioned allowances. In addition, PBL also included a tailored instrument in which the EU ETS is combined with a *national* flexible carbon tax, with the intention of achieving a minimum carbon price in the Netherlands. Finally, we assessed the impacts of an indirect minimum price in the form of an EU-wide carbon tax. The option to limit the access to CDM/JI credits after 2020 has not been included, because in line with the current ETS framework directive we assumed that no CDM/JI credits will be used beyond 2020.

This report provides some background on the appraisal of these proposals, building on recent insights into the appropriate design of emission trading systems. It also presents an assessment of the main impacts of the options for reform, such as the amount of emission reduction, $CO_2$ price in the EU ETS, auction revenues, distributional effects across sectors, carbon leakage and air pollutants. The report builds on a review of the earlier proposal of the EC to backload 900 million allowances (Verdonk and Vollebergh, 2012).

### Methods and sources

Our analysis is based on a review of recent articles, policy documents, scientific literature and recent data from the Dutch Emissions Authority (NEa) and the European Environment Agency (EEA). In our quantitative assessment of the impacts we used the global computable general equilibrium (CGE) model WorldScan. The WorldScan model is a multi-region, multi-sector model with worldwide scope (see Annex I for more details on the model). The WorldScan model is set up to simulate deviations from a reference scenario by imposing specific additional policy measures, such as taxes or restrictions on emissions. The model covers the most relevant anthropogenic emissions of greenhouse gases: carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$). Emissions are related to the combustion of fossil fuels (the main source of $CO_2$), but also included are emissions not directly related to energy use (e.g. $CH_4$ and $N_2O$ from agricultural activities and waste disposal, and $CO_2$ from cement production).

We assessed the effects of the various policy options compared to the PBL Reference Scenario, which was developed using assumptions on energy and macroeconomic development of the Current Policies Scenario of the World Energy Outlook 2011 (WEO-2011, OECD/IEA, 2011). The PBL Reference Scenario also includes current legislation on EU ETS and extends beyond 2020; thus, our analysis also includes the period between 2020 and 2030, which provides a better understanding of the potential impact of the reform proposals.

The model simulations shed light on the static efficiency of the options, taking into account effects on competitiveness and trade. However, one of the drawbacks of CGE models such as the WorldScan model is their inability to properly account for the role of uncertainty in decision-making. Carbon traders and firms such as power plants have to 'price' uncertainty as a crucial factor into their investment decisions. From this perspective, policy commitments on certain instruments as well as their flexibility over time are key issues, as well. Indeed, investors prefer robust instruments that provide credible incentives over time. If the ETS is not designed to properly account for such unforeseen events, it is likely to introduce (intertemporal) inefficiencies. To also take stock on this issue, our assessment provides some background analysis of the most effective design of a robust ETS system, as well as its interaction with other instruments, and how this may impact long-term investment decisions directed at low-carbon technologies.

Our study does not provide a complete assessment of likely policy interactions that may also have an impact on the overall functioning of the ETS system. Uncertainties exist in many dimensions, including interaction with other climate and energy policies, such as future policies on renewables, the implementation of the Energy Efficiency Directive, the inclusion of international aviation in the ETS and the establishment of links with other carbon trading systems, such as the Australian ETS. Although such uncertainties also are likely to have an impact on the ETS price, they cannot be fully anticipated by evaluating policy scenarios using models such as WorldScan.[1] Because, here, the main focus is on ETS reform, our analysis has been concentrated on the relative differences in outcomes between the various options when compared to the Reference Scenario, with other developments remaining constant. Moreover, the consequences of assumptions on these uncertainties were analysed in a sensitivity analysis. Finally, the outcomes were placed in perspective and interpreted in light of recent discussions on the role of uncertainty in ETS design.

Another option that has been put forward is that of dividing the ETS into several smaller cap and trade systems. By doing so, reduction targets could be tailored to the capabilities and ambitions of specific sectors. It is presumed that this would enable ambitious reduction targets being set for the energy sector, while the industrial sector, which is subject to more severe international competition than the energy sector, could take a slower pace. This option is the subject of a study by the Energy research Centre of the Netherlands (ECN) (Sijm et al., in prep.) and was not analysed for this report.

## Reader

Chapter 2 describes the structural developments of the EU ETS in the past and for the coming years, which have led to the current lack of scarcity on the carbon market. Moreover, this chapter describes the economic literature on cap and trade as far as would be relevant to the interpretation of the reform options. It also describes the criteria used in this report in the evaluation of the different reform options. Chapter 3 introduces the supply and demand for EU ETS allowances as assumed in the Reference Scenario. This chapter also presents the evaluated reform options. The results of WorldScan model simulations to assess the impacts of the reform options are presented in Chapter 4. Finally, Chapter 5 includes an assessment of the various reform options in a broader context, including a brief discussion on the role of uncertainties, feasibility and dynamic efficiency.

## Note

1 The Impact Assessment accompanying the proposal to improve and extend the EU greenhouse gas emission allowance trading system brings forward that EU ETS plays a crucial role in achieving the EU's 2020 renewables, but a discussion on the interaction between renewable energy policies and the EU ETS is missing (EC, 2008).

TWO

# EU ETS developments and reform proposals

This chapter, first of all, describes the structural developments during the first two phases of the EU ETS, as well as the important changes in the third phase. Subsequently, the current lack of scarcity on the carbon market is described, as well as the factors responsible for this oversupply. This is followed by a review of the economic literature behind cap-and-trade programmes and why reform may be warranted. The final section discusses the criteria used in the evaluation of the various reform options.

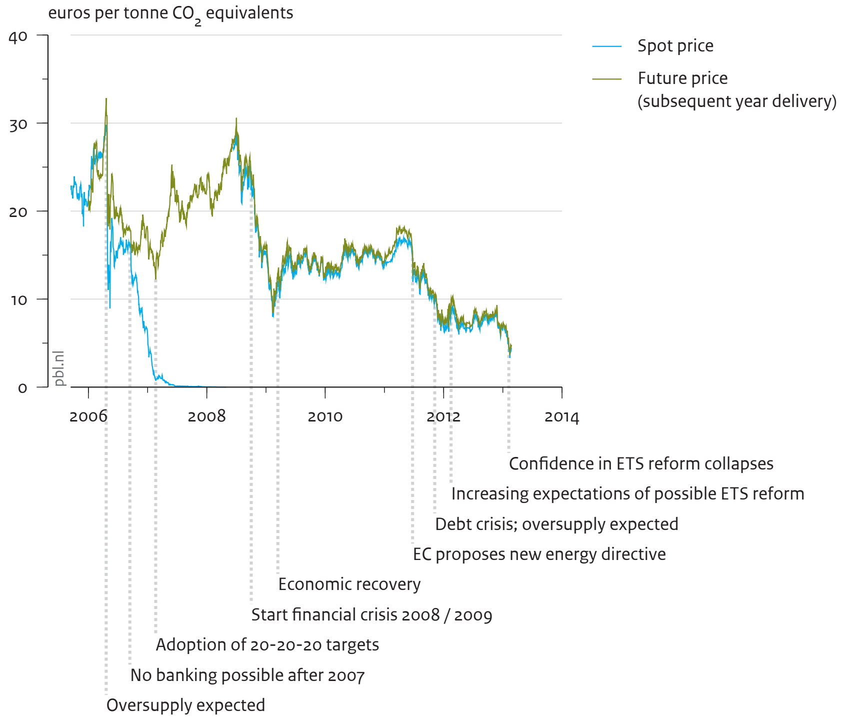
## 2.1 Structural developments in the EU ETS

### The ETS from a historical perspective

The EU Emissions Trading System is one of the most important instruments for European climate and energy policy. Roughly half of all European greenhouse gas emissions are capped under the EU ETS. Its main purpose is to reduce emissions in a cost-effective way through a 'cap and trade' system. According to the traditional approach to tradable emission allowances, the government restricts emissions relative to the status quo and allows agents to trade with the remaining quantity through what for the EU ETS are called 'allowances'. Thus, under the ETS, polluters face an absolute cap on their (historical) emissions, and may subsequently decide to either reduce their emission levels, buy additional allowances on the $CO_2$ market or opt for a combination of both.

The first ETS trading period, which ran from 2005 to 2007, was mainly intended as a pilot. This phase was characterised by a generous cap (the total amount of allowances exceeded the verified emissions by 2.3% (Abrell et al., 2011)), allocation of free emission allowances and implementation through National Allocation Plans. Because no banking was allowed, the $CO_2$ price dropped to zero at the end of this trading period. The second trading period ran from 2008 to 2012. The cap was aligned with the European emission reduction target as agreed under the Kyoto Protocol. The implementation of the cap was similar to the first trading period, i.e. through National Allocation Plans drawn up by the Member States themselves. Also the allowances were still almost entirely allocated for free or 'grandfathered' (i.e. polluters would receive their allocated allowances for free).[1] Finally, any surplus could be banked for use during the following trading period. Also, a link with the flexible mechanisms of the Kyoto Protocol was established enabling EU-ETS companies to acquire and surrender credits from Clean Development Mechanism (CDM) and Joint Implementation (JI) projects. This so-called linking directive provided access to low-cost reduction options for European industries, while promoting sustainable development abroad. On an installation level, ETS companies were allowed to surrender emission credits from CDM and JI projects up to roughly 10%[2] of their allocation over the entire 2008–2012 period.

Figure 1
**Price of EU ETS allowance**




Source: Point Carbon

At the beginning of the second trading period, in 2008, companies mostly were short of allowances which was reflected in a carbon price of about 20 euros. However, due to the economic crisis at the end of 2008, demand for allowances was reduced considerably and prices began to fall: in 2008 to 15 euros and in 2009 to 8 euros. For 2010, a modest recovery was found reflecting the economic recovery, but prices fell again in 2011 and 2012 (down to 6 euros) (see Figure 1).

Explanations for the further collapse of the ETS price are the EC proposal of a draft Energy Efficiency directive (spring 2011) which stipulated economy wide energy-saving obligations. Moreover, the euro crisis became apparent during the course of 2011, leading to a further decline in $CO_2$ prices. By April 2012, the $CO_2$ price was at a record low of 6 euros per tonne. The market was now convinced that a substantial surplus of allowances had been built up and could last beyond 2020. During the spring and summer, prices increased up to 8 euros, in the expectation that the EC would propose to reform the third trading period of the ETS, running from 2013 to 2020. By autumn however, as the euro crisis triggered a recession in the Eurozone, the price went down again to under 6 euros per tonne of $CO_2$. By then, optimism on the market about any quick intervention in the ETS (i.e. backloading) has faded. In January 2013, prices fell below 5 euros, as the volume of allowances being auctioned was increased due to the implementation of ETS legislation for the third trading period, while a quick implementation of the backloading proposal was missing.

## Significant changes to the supply and allocation of allowances after 2012

The design of the EU ETS has changed considerably, again, for the third trading period from 2013 to 2020. First of all, the total amount of allowances for the whole period – the cap – will be reduced from about 2 billion tonnes of $CO_2$ equivalent emissions in 2012 to roughly 1.77 billion tonnes at the end of the period (i.e. by 2020[3]). This reduction follows a linear reduction factor of 1.74%, annually.

Secondly, this trading period will also include more installations (mainly industrial) and some non-$CO_2$ gases, so that more greenhouse gases will be subject to the EU-ETS scheme. This expanded scope implies that the scope of non-ETS companies and greenhouse gases has decreased correspondingly. International aviation has been included in the ETS since 2012. For that purpose, 213 million aviation allowances were added in 2012 and 210 million from 2013 onwards (EC, 2012c). Aircraft operators receive 82% of their allocated allowances for free, which are calculated using a $CO_2$ benchmark. Of the total amount of allowances available to aviation, 15% is auctioned and 3% is reserved for later distribution to fast growing airlines and new entrants.

Thirdly, free allocation of allowances to all participants in the EU-ETS is no longer standing practice for initial allowances. Power plants (with minor exceptions for heat production facilities and economies in transition) are required to buy all their allowances at an initial auction or on the market. Most auctions are organised at a European auction platform[4]. The allocation of allowances to industrial installations currently is based on European harmonised $CO_2$ benchmarks per type of product. This benchmark is determined according to the average emission level of the 10% most efficient installations. Less efficient installations receive fewer allowances, based on that benchmark, resulting in a stimulus for them to improve efficiency or to buy additional allowances. In 2013, 80% of the thus calculated allowances will be allocated for free. This figure will decrease to 30% by 2020 and to 0% by 2027. Industries that are vulnerable to competition from outside the EU, receive all of their calculated allowances for free in order to prevent carbon leakage. Thus, virtually all energy-intensive industries (e.g. steel and chemical plants) continue to receive a considerable part of their allowances for free.

## 2.2 Lack of scarcity on the current ETS market

The low ETS price reflects a lack of scarcity on the ETS market. There are three main reasons for this. The first reason is the unanticipated impact of the economic crisis that started in 2008. This exogenous shock destabilised the macro-economy and has had a lasting effect on production and GDP, particularly within the EU. This impact was not taken into account in any of the model predictions used to assess the functioning of the ETS in the third phase.

Table 1 summarises market developments during the second trading period of the ETS. The first two rows show that grandfathering of allowances was by far the most important way of allocating new allowances. Still, only 4% of the 2,094 new allowances were auctioned in 2011. Because demand collapsed due to the recession that started at the end of 2008, production by electricity producers and industries has fallen and their emissions along with it. Consequently, the small shortage of EU-ETS allowances and CDM/JI credits in the beginning of the second trading period in 2008 rapidly changed into an annual surplus, as is clear from the last two rows of Table 1.

The second reason for the lack of scarcity is related to other, deliberate policy measures, such as the use of the Clean Development Mechanism (CDM) and Joint Implementation (JI) projects, but also the rapid implementation of renewable energy to achieve the 20% target by 2020. These instruments interact with the EU ETS, either directly, such as in the case of CDM/JI projects with a system of transferable credits, or indirectly, such as the reduced demand for allowances due to the increase in the use of carbon-free technologies such as solar and wind. Table 1 also shows the sharp increase in the use of CDM/JI credits during the 2008–2012 period. ETS companies were assumed to surrender 881 million credits from CDM and JI projects up to 2012.[5] In 2011, these rights increased the supply over 12% which is about half of the surplus.

The last reason for the large current oversupply of allowances is due to several special impacts related to the transition towards the third phase that started in 2013 (Verdonk and Vollebergh, 2012). First of all, unused allowances from the New Entrants Reserve (NER)[6] over the 2008–2012 period became available. We assumed this to be 125 million allowances which were auctioned by Member States in 2012 (EC, 2012a). Secondly, 300 million allowances from the NER for the third trading period will be monetised before the end of 2013, creating a fund that should stimulate carbon capture and storage (CCS) and renewable energy projects. The first tranche of 200 million allowances was already auctioned in 2012 (EIB, 2012). It is assumed that the rest will be auctioned in 2013. Finally, 90 million allowances from the third phase were auctioned by the end of 2012 (also known as 'early auctioning') to facilitate power producers hedging their forward sales of electricity in the first years of the third trading period.[7] These early auctioned allowances will be deducted from the supply for 2013 and 2014.

The overall picture shows that a large surplus has been built up in the second phase of the ETS. This will have a strong impact on the third phase of the ETS market due to the banking provisions. In total, the surplus is expected to amount to more than 1.8 billion allowances and CDM/JI credits. This amount almost equals the emissions from all ETS installations together, in a single year. When the maximum use of CDM/JI credits up to 2020 is taken into account[8], the surplus will amount to roughly 2.7 billion.

Table 1

**Supply and demand for EU ETS allowances and CDM/JI credits, 2008–2012 (million tonnes of $CO_2$, excluding international aviation)**

| | 2008 | 2009 | 2010 | 2011 | 2012* | Total |
|---|---|---|---|---|---|---|
| Initial allocation | 2008 | 2046 | 2090 | 2094 | 2094 | 10334 |
| - free allocation | 1958 | 1974 | 1998 | 2001 | 2001 | 9934 |
| - auctions | 50 | 72 | 92 | 93 | 93 | 400 |
| | | | | | | |
| Surrendered CDM&JI credits | 83 | 81 | 137 | 255 | 255 | 811 |
| | | | | | | |
| Left over from NER | | | | | 125 | |
| NER300 | | | | | 200 | |
| Early auctioning | | | | | 90 | |
| | | | | | | |
| Total supply | 2091 | 2127 | 2227 | 2349 | 2764 | 11560 |
| | | | | | | |
| Emissions | 2120 | 1880 | 1939 | 1898 | 1898 | 9734 |
| | | | | | | |
| Surplus | -28 | 248 | 289 | 451 | 866 | 1825 |

Source: EEA (2012), EC (2012a), EIB (2012) and PBL

* *Assumed similar to 2011*

### $CO_2$ price did not reach zero, despite surplus

With such a significant surplus of allowances, it may seem rather surprising that the carbon price on the ETS market has not dropped to zero. Apparently, individual traders (in particular, those currently already short on allowances) choose to hedge against (unforeseen) developments in the future. Moreover, the possibility to bank unused allowances to use in subsequent trading periods (allowed since the second phase) has created further flexibility, including the fact that banking may also be allowed in the fourth trading period (Neuhoff et al., 2012).Investors generally face huge uncertainties when making investment decisions. Uncertainty not only relates to general considerations on the future, but also on whether and how policymakers will revise the ETS market in the future, and other regulatory instruments that have indirect impacts on the ETS market, such as the implementation of the Energy Efficiency Directive and national measures to comply with the Renewable Energy Directive (e.g. feed-in tariffs). Finally, uncertainty also exists with respect to the future development of energy prices, in particular of fossil fuels. Investors form expectations on how coal, gas and oil prices will develop and how that will have an impact on their business cases for investing in different technology options. Although the market was aware of a substantial oversupply, investors were willing to pay a price of around 7 euros per EU allowance during 2012.

## 2.3 Background of reform proposals

### Current design of the ETS not robust enough to respond to unforeseen events

The current lack of scarcity of allowances and its associated low ETS price has induced a debate on whether reform of the ETS would be warranted. Some argue that no reason exists to change the ETS design because the lower carbon price merely reflects the fundamental principle behind the ETS, which is an environmental policy governed by the principles of cost-effectiveness (EC, 2009). In other words, the carbon market works well. A low $CO_2$ price is not problematic for the purpose of reducing greenhouse gases up to 2020 because emissions are being capped under the EU ETS which guarantees that emissions will decrease by 21% by 2020, compared to 2005 levels.

Others, however, argue that the design of the EU ETS still has fundamental flaws despite significant improvements in the transition from the second towards the third phase (Grubb, 2012). The oversupply and its associated low price may also be a sign of the ETS system not being sufficiently robust in terms of its response to demand or supply shocks. Indeed, if the future is likely to differ considerably from the projections that were modelled at the time the targets were set, reform may be warranted. The low price level of allowances may also imply that the real (marginal) costs of abatement have been overestimated, considerably, *ex ante* (Burtraw et al., 2010). The design of

## 1 Emerging cap-and-trade systems around the world

The EU ETS currently is the largest carbon market in existence in the world. Since its launch in 2005, various emission trading systems have emerged or are planned to be launched outside the EU. This text box gives a brief overview of the main characteristics of these systems.

The **New Zealand** ETS, in place since 2010, is being implemented in phases. In 2015, it will cover all greenhouse gas emissions included under the Kyoto Protocol, from industry, agriculture, forestry, energy and transport. Hence, the sectoral scope of the NZ ETS is more comprehensive than that of the EU ETS. The emission target is in line with international commitments to reduce 10% below 1990 by 2020, or 20% if global agreement is established. The NZ ETS provides for a price ceiling at NZD 25 (about EUR 15), which was to expire in 2012, but will most likely be continued, as proposed by the New Zealand Government. Subject to some restrictions, participants can use international carbon credits for compliance (http://www.climatechange.govt.nz/).

**Australia**'s Carbon Pricing Mechanism (CPM) was started in July 2012. This Australian emission trading system commenced with a three year fixed price period with a carbon price that started at AUD 23 (about EUR 17) in 2012 and will increase to AUD 25.4 in 2015. After 2015, the system will change into a flexible price cap-and-trade emission trading scheme with the price being determined by supply and demand. A price floor will apply for the 2015–2017 period, starting at AUD 15 in 2015, and a price ceiling will start at AUD 20 in 2015 and rise by an annual 5% in real terms. As from 2015, the CPM also will allow the banking of allowances. The Australian system covers more sectors than the EU ETS, as it also includes fugitive emissions, emissions from waste and from fuels used in domestic aviation, shipping and railway traffic. International carbon credits can be used for up to 50% of allowed emissions, which includes the use of EU-ETS allowances.

Finally, although the long-term objectives to reduce emissions by 5% to 25% and 80%, compared to 2000, in 2020 and 2050, respectively, must be achieved, the CPM allows a flexible annual cap setting. The cap will be established five years in advance (http://www.cleanenergyfuture.gov.au/).

In 1990, the **United States** launched the $SO_2$ allowance trading system, which was the world's first large-scale market-based initiative. Currently, the outlook for a Federal carbon market is not very promising (Schmalensee and Stavins, 2013). On a state level, carbon markets are still on the agenda. The *California* Cap-and-trade Program started in January 2012 and is expected to have a large impact on US emissions. California is the leading member of the Western Climate Initiative (WCI), a collaboration between 10 Western United States and Canadian Provinces. The Californian programme will cover about 85% of its greenhouse gas emissions, and includes the providers and suppliers of fuels for road transport, and is aimed to help put California on the path to meet its goal of reducing greenhouse gas emissions to 1990 levels by 2020, and ultimately achieving an 80% reduction from 1990 levels by 2050. The programme provides a reserve of allowances (up to 7% in 2020) available at a fixed price, which functions as a safety valve to protect participants from unforeseen price changes (http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm).
The *Regional Greenhouse Gas Initiative* (RGGI) is a cap-and-trade scheme covering fossil-fuel power plants across nine north-eastern United States. This scheme aims to stabilise $CO_2$ emissions from power plants up to 2014, and to reduce emissions by an annual 2.5% between 2015 and 2018. States sell nearly all emission allowances through auctions and invest proceeds in energy efficiency, renewable energy, and other clean energy technologies (http://www.rggi.org/).

In 2011 **China** announced pilot emission trading schemes in five cities and two provinces (IETA, 2012) with a view to develop a national emission trading scheme later this decade. All seven regions are in the final stages of designing their market rules, but none have been finalised. The various schemes develop their own rules and standards, but have to comply with general standards. Some pilot programmes also try to capture indirect emissions; for example, those from large electricity users such as manufacturing companies and public buildings that do not burn coal directly (IETA, 2012).

**South Korea** passed legislation in 2012, announcing the launch of an emission trading scheme to begin in 2015 which will apply to large installations. The absolute emission cap of the ETS is expected to be in line with their international emission reduction pledge of 30% below baseline emission levels by 2020. In order to prepare for the national ETS system, South Korea introduced a 'Target Management System' (TMS) in 2012, covering 60% of total emissions. Legislation passed in 2012 specifically banned the use of Kyoto offsets until the end of 2020 (Kossoy and Guigon, 2012).

the ETS should allow for adjustments over time in response to unforeseen economic developments, new scientific insights, and the arrival of new technologies.[9] Thus, there must be some room for discretion to make policy adjustments. Text box 1 illustrates that most cap-and-trade systems that are emerging in other parts of the world include certain provisions to deal with uncertainties.

Uncertainty and flexibility are key issues when using the ETS as a policy instrument, in particular in relation to the wider EU climate and energy package to stimulate long-term investments in low-carbon technologies.[10] Cap-and-trade systems such as the EU ETS also allow investors to hedge against future uncertainties. This 'option value' is the value of an option contract for future delivery of allowances and reduces the willingness of investors to actually invest in low-carbon technologies (Laffont and Tirole, 1996; Taschini, 2013). In other words, the EU ETS not only caps emissions but also provides investors with an option to delay their actual investment in low-carbon technologies.[11] This impact of the EU ETS is probably further enhanced by the current increase in regulatory uncertainty, i.e. the uncertainty with investors about the policy response to the current lack of scarcity on the ETS market. This option value may be considered an argument in itself for the design of an EU ETS that provides a sustainable and predictable carbon 'price collar' in order to stimulate the desired long-term investments.

### Setting the cap at a socially acceptable level

The reform options presented by the European Commission reflect most of the various proposals that have been discussed in the literature to deal with potential inefficiencies of cap-and-trade programmes (Hepburn, 2006; Burtraw et al., 2010; Grüll and Taschini, 2011; Wood and Jotzo, 2011). A key element of any cap-and-trade system is the cap itself. It guarantees the level of emission reduction that would be socially acceptable for the expected, marginal costs and benefits of reducing emissions. Although the cap is not necessarily based on a social cost-benefit analysis, the policy-making process to determine the cap always takes into account the trade-off between the costs and benefits of reduction. When shocks occur, such as an economic slump, an efficient response would be to seek a new optimal cap[12] (see Text box 2).

### Options for reforming the EU ETS

To deal with these types of dynamic effects, various economists have argued in favour of building *ex post* flexibility into emission trading systems (Hepburn et al., 2006; Burtraw et al., 2010; Fankhauser and Hepburn, 2010; Wood and Jotzo, 2011). Several responses are available to increase the flexibility of an ETS system, as already mentioned in Section 1.2. This report distinguishes four main categories:

i. Adapting the existing cap, or reducing the number of allowances;
ii. Expanding the ETS scope (i.e. increasing the number of ETS sectors);
iii. Changing the current cap-and-trade instrument into a tailored combination of a quantity and price instrument (e.g. by guaranteeing a long-term 'price collar' through a policy commitment to sell allowances if the price ceiling is reached, and to buy allowances if the floor price is reached);
iv. Combinations of *different* instruments (e.g. the combination of options using a national carbon tax to imitate the effect of a price floor).

Most of the options proposed by the EC in November 2012 contain interventions that directly reduce the number of allowances over time and therefore aim to increase the carbon price indirectly. The EC also considers price management mechanisms that may directly affect the price level on the carbon market, which, in turn, would provide a more stable 'price collar' for emission reduction, in the long term. In addition, this study also considers multiple-instrument solutions, such as combining the EU ETS with a carbon tax, comparable to that in the United Kingdom, where a variable carbon tax has been implemented to establish a $CO_2$ price floor. Chapter 3 describes our policy options, including their assumptions, in more detail.

## 2.4 Assessment criteria for evaluating reform proposals

This study used the following standard criteria to assess the impact of the options:

i. Allocative effectiveness and (dynamic) efficiency;
ii. Distributional effects.

Allocative effectiveness and (dynamic) efficiency address the question of whether a reform proposal would actually contribute to the objective for which it was designed, and whether it would help to achieve this objective as efficiently as possible. Allocative effectiveness and efficiency take into account the correction of market failure and externalities (see Text box 2). Market failure

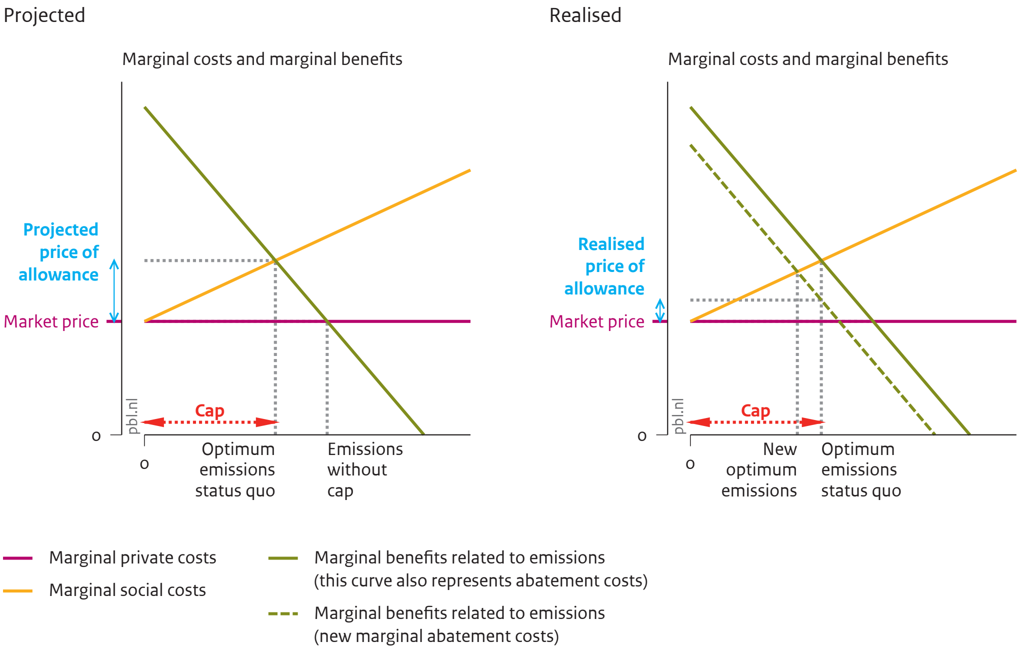
## 2 Adapting cap and trade after an sudden collapse of demand

Figure 2 is a simple representation of an emission trading market. The starting point would be a situation where emissions from production cause environmental damage. The curve for marginal social costs represents the marginal private costs plus the marginal damage of emissions, which increases with rising emission levels. The curve for marginal benefits in relation to emissions reflects the private benefits from consumption. As reducing these emissions would imply that these benefits will be foregone, this curve also represents the marginal abatement costs. Per unit of emission these costs increase with larger emission reductions. Without policy intervention, the market price reflects the market outcome, with the marginal benefits of consumption causing emissions that equal the marginal private costs of production. This results in the emission level without a cap. The market price, however, does not take into account the environmental damage. This damage is included in the marginal social costs. As marginal social costs exceed marginal benefits in relation to the emissions, reducing these emissions will increase welfare. The optimal emission level is the point where the benefit of further damage reduction no longer offsets the further loss of (net) private benefits.

One of the instruments to reach this optimal emission level a cap-and-trade system with the cap being equal to the expected optimal emission level (status quo). For such an optimum, the sum of the marginal private costs and the projected price of the emission allowance on the market should equal the marginal costs of abatement. The price of the emission allowance has to be paid for each unit of emissions from production, which then leads to a full internalisation of the environmental damage in the new market price due to the cap-and-trade system.

As argued in the main text, the exact costs of emission reduction are often not known beforehand, and may turn out to be higher or lower than anticipated. When the actual abatement cost (reflecting the demand for emission allowances) appear to be at a lower level, say the new marginal abatement costs curve, the emission price would be lower than anticipated as well, in this case the realised price of emission allowance. However, the cap also no

Figure 2
**Optimal cap and trade**




Source: PBL

longer reflects the socially optimal emission level. With lower than expected marginal abatement costs, welfare can be increased by further reducing the cap to the new optimal emission level. This would result in a price for emission allowances that is higher than the realised price, but lower than the projected price of emission allowances. In case of lower than anticipated marginal abatement costs, a price floor will have a similar effect, keeping emission levels closer to the new optimal emission level than without a price floor (see Hepburn, 2006).

(imperfect, weak or absent markets) is the main cause of environmental decline, as prices often do not adequately account for the costs of environmental resource use. The absence of markets is a well-known phenomenon. Correcting this kind of market failure requires adequate government intervention, and cap and trade is a useful instrument in this context.[13] Such market corrections need not be harmful to long-term economic growth, provided they are carefully designed and timed (Aalbers et al., 2012b; Acemoglu et al., 2012).

The different reform proposals clearly build on a regulatory programme (the EU ETS), which is already addressing market failures that lead to an overproduction of carbon emissions. So, the current reform proposals basically build on existing inefficiencies of a system that is apparently not yet sufficiently robust and/or credible. Therefore, it is particularly important that the reform proposals contribute to a further improvement of the effectiveness and efficiency of the EU ETS. In particular, reform proposals such as the design of hybrid instruments call for a careful analysis of the policy objective and potential other instruments for achieving this objective. We assessed the impact of the different policy options on the change in emissions, emission prices, auction revenues and carbon leakage. We also evaluated the influence of the policy options on the robustness of the ETS in relation to unforeseen events, such as negative shocks in demand. As also explained in Chapter 1, we did not evaluate all dimensions of the dynamic efficiency of such changes to the EU ETS. Such an assessment would require an analysis that also includes the other elements of the climate and energy package as well as the timing of climate change policies; all of which are outside the scope of our study.

With regard to *distributive effects*, 'the polluter pays' is usually the guiding principle of environmental pricing, which implies a focus on the contribution to pollution by agents, not on their ability to pay. A complicating factor is that polluters often have *de facto* property rights over their environmental resource use, and therefore the right to pollute was the status quo, i.e. before regulation was implemented. Pollution rights auctioned under cap-and-trade programmes explicitly place property rights with the government (Fullerton and Metcalf, 2001). Pollution rights allocated for free leave those property rights with the polluters, but provide them with an option at the margin to either abate pollution or buy emission allowances. In other words, free allocation subsidises the polluters, which is even more problematic if the free allowances are not linked to historical emissions, but are linked to actual output instead (Bovenberg and Vollebergh, 2008; Bollen et al., 2011).

Although ETS reform need not lead to an overall increase in regulatory burden, it will generally change the *distribution* of the burden. To assess the distributive impacts of the different options, we not only considered differences between EU Member States but also between sectors; in particular, between sectors exposed to international competition and those that are not. In addition, the impact on air pollutants was also considered. Emissions of $CO_2$ and air pollutants largely originate from the combustion of fossil fuels. Reforming the ETS may have implications for the use of fossil fuels and, thus, the emission of air pollutants. Therefore, the reform proposals may also offer co-benefits. We did not consider potential redistributive policies using auction revenues, such as by lowering income or corporate taxes, because we assumed these revenues to be returned to citizens and businesses in lump sum payments.

## Notes

1 This practice has been shown to suffer from considerable inefficiencies because the criteria for allocation under the National Allocation Plans result in perverse behavioural effects (Bovenberg and Vollebergh, 2008).
2 On average; some slight deviations on Member State level.
3 These amounts exclude additional allowances for international aviation.
4 Germany, the United Kingdom and Poland organise the auctioning on their own platform
5 Up to 2011, almost 550 million CDM/JI credits were surrendered for compliance by EU-ETS companies (EEA, 2012). For 2012, we assumed a similar use as in 2011. This is considered to be a conservative assumption as it is estimated that the use of CDM/JI credits has increased further in 2012, partly because of a further increase in supply, low prices and the ban of using certain types of international credits from 2013 onwards.
6 The New Entrants Reserve (NER) refers to a certain amount of allowances put in a reserve for new installations that enter the ETS. Allocation of allowances from this reserve mirrors the allocation to corresponding existing installations.
7 The EC decision on early auctioning allowed for 120 million phase-three allowances before the start of the third trading period in 2013. Due to delays in the implementation of early auctioning in some Member States, only 90 million phase-three allowances have been auctioned by the end of 2012. The remaining 30 million allowances will be auctioned in 2013.
8 Limited to 1.7 billion credits for the 2008–2020 period, excluding use by aviation (EC, 2012a). Assuming that 811 million CDM/JI credits have been surrendered up to 2012, an additional 900 million credits may still be surrendered in the remaining years up to 2020.
9 Kelly and Vollebergh (2012) summarize these arguments in relation to the inflexibility of the present EU air quality policy, drawing from the wide experience with tradable permits under US $SO_2$ and $NO_x$ trading schemes.
10 Creating a 'carbon price signal to trigger the necessary investments' is one of the considerations mentioned in the 2009 revision of the ETS directive from 2003.
11 Note that this is not the case with regulatory options such as standards or environmental taxes.
12 Note that this works two ways: lower demand could lead to a lower cap, while higher demand could call for an alleviation of the cap.
13 However, cap and trade is certainly not the only option. Regulation through emission standards or non-tradable quotas as well as environmental taxes also put a 'price' on environmental pollution.

THREE

# Reference Scenario and policy options

This chapter introduces our implementation of options to reform the EU ETS that were evaluated with the WorldScan model. It also explains the Reference Scenario in detail. In order to have a better understanding of the long-term impacts of the reform proposals, we also looked beyond the third trading period (2013–2020). The first section discusses the supply of allowances between 2013 and 2030, following implications of current legislation. Section 3.2 presents assumptions with respect to the overall demand for allowances, based on the Reference Scenario. Section 3.3 describes how supply and demand are assumed to be balanced in the EU ETS market in both trading periods. Finally, Section 3.4 presents the policy options in more detail.

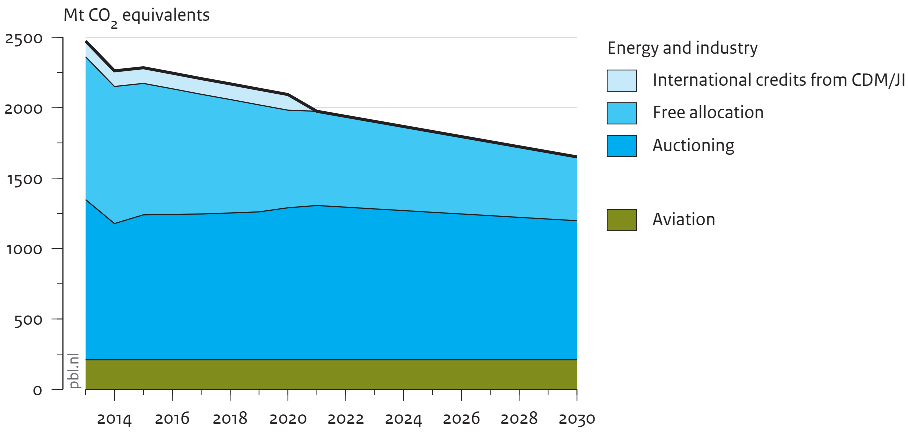
## 3.1 Supply of allowances up to 2030

### Assumed supply of allowances

Figure 3 summarises our assumptions about the supply of ETS allowances within and beyond the third trading period. In line with current legislation, we assumed the EU ETS will be extended for a fourth trading period, covering the 2021–2030 period, with full banking options for the third trading period (2013–2020). Corresponding with the current linear reduction factor of 1.74%, the annual supply of EU allowances will decrease between 2013 and 2030 by 37 million allowances, annually. International aviation will be supplied with an annual 210 million aviation allowances in the 2013–2020 period. We assumed the supply of allowances for international aviation beyond 2020 to remain the same as in the 2013–2020 period[1]. The potential use of credits from CDM projects is based on the assumption that the maximum use of credits from CDM and JI projects in the 2008–2020 period will be limited to 1.7 billion credits (EC, 2012a). In line with the current ETS framework, we assumed that the use of CDM/JI credits will not be allowed beyond 2020. Finally, it must be noted that the strong decline in the supply of allowances between 2013 and 2014 reflects the impacts of arrangements related to the transition from the second to the third trading period (i.e. the NER300 programme and 'early auctioning', see also Section 2.2 and Annex II for an elaboration on supply assumptions).

Table 2 presents our assumptions with respect to the way allowances are distributed over the various sectors; in particular, for energy & industry and international aviation. It also shows how many of the allowances are assumed to be allocated for free, how many are auctioned and how many are kept in the New Entrants Reserve (NER). Overall, about half of the total supply of allowances in the third trading period will be auctioned.

Figure 3
**Supply of EU ETS allowances and international credits in the Reference Scenario**




Source: EC (2012a); EEA (2012); PBL calculations

Table 2
**Supply of EU ETS allowances from 2013 to 2020 and in 2030**

| million allowances | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2030 |
|---|---|---|---|---|---|---|---|---|---|
| Energy & industry | 2263 | 2051 | 2073 | 2035 | 1996 | 1959 | 1921 | 1883 | 1440 |
| - free allocation | 1015 | 973 | 933 | 892 | 850 | 806 | 760 | 693 | 453 |
| - auctioning | 933 | 908 | 972 | 977 | 982 | 990 | 1000 | 1031 | 911 |
| - NER | 204 | 59 | 57 | 55 | 53 | 52 | 50 | 48 | 76 |
| - CDM/JI credits | 111 | 111 | 111 | 111 | 111 | 111 | 111 | 111 | - |
| | | | | | | | | | |
| Aviation | 214 | 214 | 214 | 214 | 214 | 214 | 214 | 214 | 210 |
| - free allocation | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 |
| - auctioning | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| - NER | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| - CDM/JI credits | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | - |
| | | | | | | | | | |
| Total | 2477 | 2266 | 2288 | 2250 | 2211 | 2174 | 2136 | 2098 | 1651 |

Source: EC (2012a); EEA (2012); PBL calculations
*Figures include corrections for transitional allocation of free allowances to power plants, early auctioning and NER300.*

## 3.2 Demand for allowances: Outlook for 2020 and 2030

The demand for emission allowances strongly depends on the underlying assumptions about economic development and energy demand and supply, not only in the EU but also in the rest of the world. Our Reference Scenario builds on assumptions about energy and macroeconomic developments in the Current Policies Scenario of the World Energy Outlook 2011 (WEO-2011, OECD/IEA, 2011).[2] To create our Reference Scenario in the WorldScan model, we used basic inputs from the WEO-2011, such as growth rates for population and GDP per region, energy use per region and energy carrier, world fossil-fuel prices per energy carrier, and the shares of fossil fuel, nuclear energy, biomass, wind, and hydropower in the power generation in each of the regions. For the world, the WEO-2011 assumes an average annual GDP growth of 3.6% for 2009 to 2035, whereas for the EU this is 1.9%. Total primary energy demand annually increases by 1.6%, globally, and by 0.4% in the EU. These assumptions may be too optimistic, as economic development has deteriorated even further over the course of 2012, but a more up-to-date set of consistent projections was not available at the time of our calculations.[3]

Based on these macroeconomic assumptions, first a baseline scenario was defined that did not include climate policies, which subsequently was adjusted in several ways to construct the PBL Reference Scenario as used in this study. First, we included the main current global climate policies. For the United States, Japan and other OECD countries, we assumed greenhouse gas emissions by 2020 to have been reduced according to the countries' unconditional Copenhagen pledges (UNFCCC, 2010). For the period beyond 2020, the relative reduction in emissions, compared to the WEO-2011 baseline scenario, was assumed to continue. In accordance with their Copenhagen pledges, China and India were assumed to have reduced their carbon intensity per unit of GDP, by 2020, by 40% and 20%, respectively, compared to 2005 levels. Beyond 2020, the carbon intensity was kept on a constant level. For Australia, we implemented their emission trading scheme, reducing emissions by 5% below 2000 levels by 2020, and a further reduction in emissions beyond 2020 to about 30% below 2020 levels by 2030, according to the projections of the Australian Government (Australian Department of Climate Change and Energy Efficiency, 2012).

Second, as the WEO-2011 does not present information on specific countries within the EU, we used the Baseline 2009 scenario that has been developed for the European Commission with the PRIMES model (PRIMES2009, Capros et al., 2010) to further disaggregate the developments for the EU. For the Netherlands, we used developments of GDP and energy use as included in the Referentieraming 2012 (Verdonk and Wetzels, 2012). We combined these different sources of information by scaling the country-specific assumptions on GDP development and energy use from PRIMES2009 and the Referentieraming, to fit within the total on the EU27 from the World Energy Outlook 2011 (WEO-2011).

Third, we made certain assumptions related to EU climate policies, and distinguished between climate policies related to ETS and non-ETS sectors. Specific provisions in the current EU ETS Directive were taken into account, such as the timing of the auctioning, the distinction between auctioning and free allocation and the possibility of banking.[4] The ETS was implemented in our Reference Scenario according to current policies as described in Section 2.2. Under current ETS legislation, $CO_2$ emissions from international aviation are included in the scope of the ETS. As international aviation is not well represented as an economic sector in the WorldScan model, the demand for allowances related to international aviation was added exogenously to the ETS market. This demand was calculated assuming an annual emission growth of 2% between 2012 and 2030 (Kolkman et al., 2012)[5]. Because the supply of allowances was kept at an annual 214 million allowances (see Section 3.1), inclusion of international aviation in the ETS would result in a net demand for allowances of 412 million between 2013 and 2020 and 1.025 billion between 2021 and 2030 (see Annex III for an explanation).

An additional source of demand for EU ETS allowances comes from the link between the EU ETS and Australia's carbon pricing mechanism. In the process to establish a full two-way link between the two cap-and-trade systems by 2018, an interim link has been established enabling Australian businesses to use EU allowances to help meet emission reduction targets under the Australian emissions trading scheme from 1 July 2015. As the negotiations on a full two-way link have not yet started, we assumed in our Reference Scenario only a one-way link. In line with the limitations on international linking described in the Australian Government's climate change plan (Australian Government, 2011), the total use of international credits by Australian firms is restricted to 50% of their annual liability.[6] The carbon pricing mechanism in Australia commences with a three-year fixed-price period with a carbon price starting at AUD 23 in 2012 and increasing to AUD 25.4 in 2015. From 2015, the system will change into a flexible price cap-and-trade emissions trading scheme. A price floor will apply for the 2015–2017 period, starting at AUD 15 in 2015.[7] As from 2015, the Australian emissions trading system also will allow the banking of allowances. Considering the fixed price level in the 2012–2015 period, in our model simulations we assumed the price of allowances in Australia from 2015 onwards to be somewhat higher than the floor price and to start at $EUR_{2010}$ 14/$tCO_2$ in 2015.

For greenhouse gas emissions from non-ETS sectors (e.g. transport and households), we assumed the implementation of the national emission reduction targets of the Effort Sharing Decision for the 2013–2020 period. For the period beyond 2020 we assumed the relative reduction in non-ETS emissions, compared to the baseline, to remain at 2020 level. This implies a decrease in overall emissions of about 0.1%, annually. According to the Effort Sharing Decision, Member States will be allowed to meet their non-ETS targets in a flexible way; for instance, by transferring part of their annual emission allocation for any given year to other Member States[8]. This is not current practice. Actually, Member States currently are implementing specific national policies and measures. Consequently, the marginal costs of greenhouse gas emission reduction differ between Member States and possibly also between sectors. However, it was beyond the scope of this study to include specific national policy measures that are planned for non-ETS emissions. We therefore assumed that Member States would use the possibility of flexibility in achieving overall reductions in non-ETS emissions. This would result in a uniform emission price for the various non-ETS emission sources within the EU, and hence in a cost-effective reduction to achieve the overall non-ETS emission target of the EU.

Fourth, we included policies in complementary areas which also affect the demand for the EU ETS. This is mainly the case for policy measures under the Renewable Energy Directive and the recently adopted Energy Efficiency Directive. The Renewable Energy Directive was included in the Reference Scenario by (i) a requirement of a 10% share of renewable energy in the transport sector by 2020, and (ii) introducing a uniform subsidy on renewable energy in power generation within all EU27 Member States to meet the EU target for renewable energy (a share of energy from renewable sources in gross final energy consumption of 20% by 2020) in a cost-efficient way. For the 2020–2030 period we assumed the share of renewable energy in the transport sector to further increase, in line with PRIMES2009. Subsidies on renewable energy in power generation were assumed to be kept constant, at the level needed by 2020 in order to achieve the 20% target, which will increase the share to 23% by 2030. This subsidy will be about 3% to 8% of production costs of renewable energy. Although the approach with a uniform subsidy throughout the EU is not consistent with the national targets in the Renewable Energy Directive, the resulting renewable energy shares in the Reference Scenario are close to the national targets in the directive. As a result of the subsidies on renewable energy, the use of fossil fuels in power production will decrease, reducing the demand for allowances.

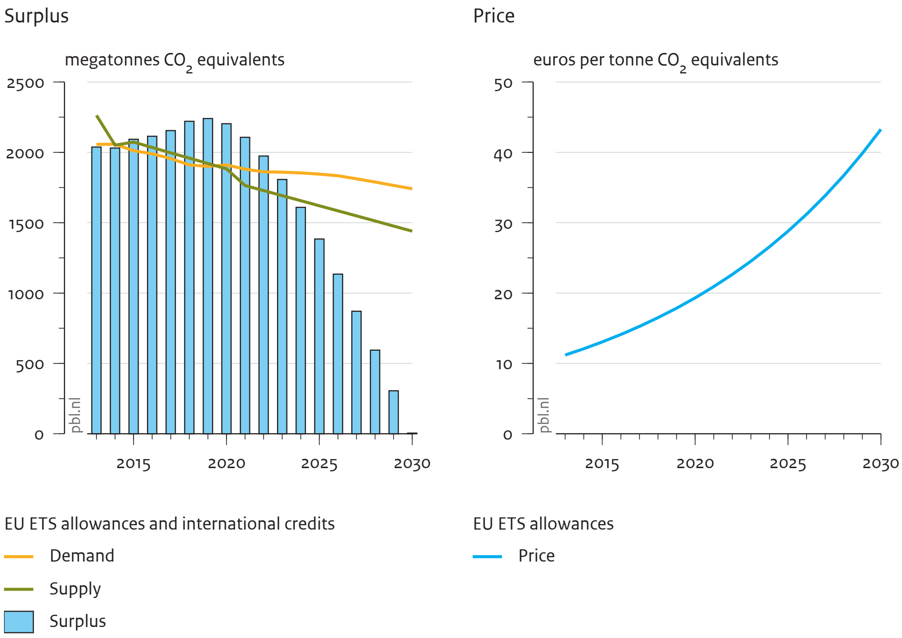
The new Energy Efficiency Directive (EED), adopted in October 2012, was not taken into account in the Reference Scenario. Because this directive aims to reduce energy consumption within the EU, greenhouse gas emissions will also decrease. Emissions from sectors covered by the ETS will be affected as well, both directly and indirectly (e.g. by a changing demand for electricity). The directive *'establishes a common framework of measures for the promotion of energy efficiency within the Union'* and the actual implementation is left to the Member States. As it is not yet clear what will be the national energy efficiency targets and what specific policy measures will be implemented by Member States to promote energy efficiency improvements, the consequences for the emissions from ETS sectors are highly uncertain. For example, national policies primarily focusing on energy savings in heating are estimated to have much less impact on ETS emissions than policies aiming at savings in electricity consumption. Altmann et al. (2013) conclude that the impact of the EED on the EU ETS is likely to be limited because Member State policies directed at energy efficiency will mainly apply to non-ETS sectors. In the impact assessment of the EED (EC, 2011a), the impact on $CO_2$ prices in the EU ETS resulting from calculations by different models ranges from a limited decrease by 10% to 15% to a decrease down to EUR 0/t$CO_2$. Overall, the demand for allowances is likely to end up lower under implementation of the Energy Efficiency Directive than without (EC, 2011a), which implies that our calculations tend to overestimate the demand for allowances.

## 3.3 Balancing supply and demand on the EU ETS market

A final step in our analysis was that of deriving an ETS price path that convincingly would imitate the impact of the various supply and demand forces over the whole range, from 2013 to 2030. First of all, our supply and demand analysis showed that the current lack of scarcity of allowances on the carbon market is likely to continue, at least up to 2020. This is in line with a recent report by the Centre for European Policy Studies (Egenhofer et al., 2012), which concluded that – despite some variance in assumptions, timing of assessments and resulting figures – wide agreement exists on the assumption that the supply of allowances in the ETS, under the current EU-wide 20% emission reduction target, is likely to exceed the demand up to 2020. This implies that effectively there will be no need for further abatement measures in the EU to achieve this target. This 'long tail' of the current surplus of 1.8 billion allowances and credits is also reflected in our Reference Scenario.

Second, although no fundamental reason exists for not extending the EU ETS beyond 2030, we limited our evaluation to 2030. Allowing for an EU ETS extension beyond 2030 would have required further expansion of our study to also include assumptions on emission reduction targets and marginal abatement cost beyond 2030. However, generally can be stated that if emission reduction targets would be extended beyond 2030, it presumably would be profitable to bank allowances for use in that period as well. This also would increase the value of allowances in the period before 2030, which, in turn, is likely to have an impact on emission prices, as well. Extending the EU ETS ad infinitum will even further

Figure 4
**Surplus and price of EU ETS allowances in the Reference Scenario**




Source: PBL

increase prices, but the impact would become (much) smaller due to the positive discount rate. Because uncertainties on emission reduction targets and marginal abatement cost are likely to grow over time, we assumed full depletion of the total supply of EU ETS allowances by the end of 2030, not only in the Reference Scenario, but also in the various policy option scenarios.[9]

Profit-maximising firms with perfect foresight will apply banking in such a way that the discounted value of the marginal costs of emission reduction would be the same over the whole time period (for a review of banking in the context of the EU ETS, see Chevallier, 2012). This implies that the carbon price will increase over time by the discount rate.[10] Annex IV explains, in more detail, how the forward-looking behaviour of firms was modelled. In particular, we assumed that the value of the banked allowances would increase at a rate equal to the rate of return on capital in the WorldScan model.[11] Because capital depreciates with 2.7% annually, and the compensation for entrepreneurial risk is 1.5% in the WorldScan model (Lejour et al., 2006), the annual rate of return would be about 8%. In addition, in our analysis, we assumed that the total amount of allowances available over the whole period (i.e. the surplus from the second trading period plus the cumulative supply of allowances during the 2013–2030 period) will be used before 2030. In other words, we no longer allowed for banking of allowances beyond 2030.

Together with the demand for allowances that follows from our economic development assumed in the Reference Scenario, these assumptions led to an emission price path with a (starting) value of EUR 11/t$CO_2$ for 2013.[12] Afterwards prices would rise to EUR 19/t$CO_2$ in 2020 and EUR 43/t$CO_2$ in 2030. Figure 4 reflects the allowance price in our Reference Scenario during the 2013–2030 period and shows the surplus development according to this emission price. After 2013, the supply of allowances will gradually decrease, as the annual ETS cap continues to decline. Despite this reduction in supply, however, the emission price will keep emissions below the annual supply of EU ETS allowances and CDM/JI credits until 2019. As a result, the built up stock of allowances would increase further to about 2.2 billion by 2020. Only beyond 2019 emissions would be above the annually available allowances and CDM/JI credits and the surplus of allowances would start to decline. This picture is broadly in line with findings by the EC suggesting that a surplus will persist at least until 2025 (EC, 2012a). As economic prospects further deteriorated during 2012, we may even have overestimated the demand and the oversupply may last even longer.

Table 3
**Main characteristics of the Reference Scenario**

| average annual growth (%) | 2010–2020 | | | 2020–2030 | | |
|---|---|---|---|---|---|---|
| | World | EU27 | NL | World | EU27 | NL |
| GDP | 3.4 | 2.0 | 1.5 | 2.7 | 1.8 | 1.3 |
| Energy consumption | 2.0 | 0.3 | 0.3 | 1.4 | -0.1 | 0.0 |
| – Coal | 1.5 | -4.4 | 3.1 | 1.6 | -3.3 | -3.3 |
| – Oil | 1.2 | -0.5 | -0.2 | 0.8 | -0.6 | -0.1 |
| – Natural gas | 1.9 | 0.6 | -2.4 | 1.6 | 0.2 | -0.4 |
| – Nuclear energy | 2.5 | -0.3 | -0.9 | 1.1 | -0.2 | 5.5 |
| – Renewable energy | 4.7 | 5.6 | 7.2 | 2.5 | 1.9 | 2.7 |
| Emissions | | | | | | |
| – Greenhouse gas | 1.4 | -1.0 | 0.0 | 1.0 | -1.0 | -1.1 |
| – Greenhouse gas, ETS | | -1.9 | -0.6 | | -2.1 | -3.3 |

| Energy prices | 2010 | 2020 | 2030 |
|---|---|---|---|
| – Oil (EUR 2010/barrel) | 58.9 | 89.1 | 101.5 |
| – Coal (EUR 2010/tonne) | 74.8 | 82.2 | 87.4 |
| – Natural gas (EUR 2010/million Btu)* | 5.7 | 8.3 | 9.5 |

* *Gas prices are weighted averages expressed on a gross calorific-value basis (see OECD/IEA, 2011).*

Our emission price in the Reference Scenario is somewhat higher than the range mentioned by others. Market analysts such as Barclays Capital and Point Carbon expect prices of around 7 euros by 2020 without policy interventions and around 10 euro including the set aside and backloading of 900 million allowances (EC, 2012b). In the impact assessment accompanying the Roadmap 2050, the EC calculated a $CO_2$ price of EUR 36 per tonne, by 2030, in their Reference Scenario. However, this price level can be considered as relatively high which is due to the underlying model analyses that were performed in 2010 when economic stagnation was thought to be less pervasive.

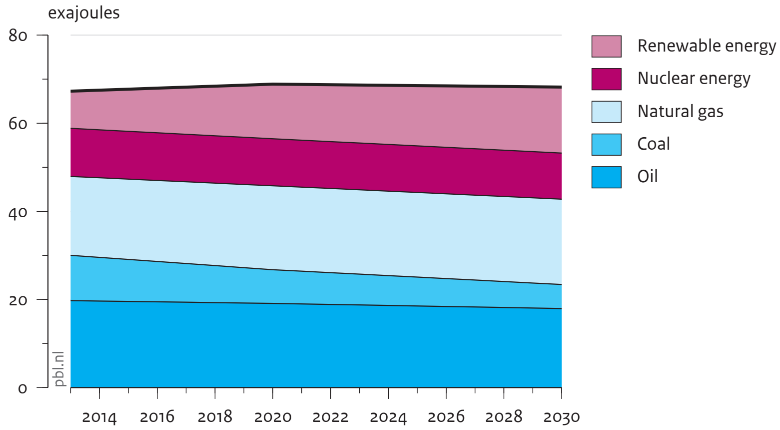
The somewhat higher price for EU ETS allowances in our Reference Scenario compared to the actual price on the carbon market can be explained by the lack of uncertainty about the future. In our model set up the market is assured of an emission cap that further decreases up to 2030 and thus guarantees the value of allowances up to 2030. In other words, policy commitment is such that traders and investors can rely on a risk-free future as far as regulatory uncertainties are concerned.

If traders and investors presume that ambitious greenhouse gas reduction targets beyond 2020 are not very likely to be maintained, this expectation will be reflected in a lower emission price, as this would cause banked allowances to be worth less beyond 2020. In the real world, the market value of allowances reflects the degree to which traders believe that extension of the ETS beyond 2020 is unlikely (including the possibility of banking). Moreover, they also attach some value to regulatory risks, such as related to the interaction with the use of other policy instruments. For instance, uncertainty in the current market exists about the design of the Energy Efficiency Directive, which may also keep emission prices down and was not taken into account in our analyses. Moreover, demand for allowances in our Reference Scenario may exceed that expected by the market, because assumptions about future economic developments and fossil-fuel prices may be more optimistic or pessimistic than current market sentiments.

These considerations are perfectly in line with the fact that current allowance prices have not dropped to zero, despite the large oversupply on the market. This is also in line with hedging strategies in combination with expectations that allowances may be banked for use in the fourth trading period, i.e. beyond 2020. The fact that even with the significant surplus of allowances the current price on the $CO_2$ market is positive reflects the fact that traders are still holding on to unused emission allowances for use in future years, as their future value may exceed that of today. Indeed, flexibility within the carbon market has been strongly increased by extending the trading period as well as by allowing expiration dates of allowances to extend beyond the various phases of the EU ETS.

Table 3 summarises the main characteristics of the Reference Scenario, including the average growth rates of GDP, energy use and emissions for the EU27 as a whole and the Netherlands in particular, as well as for the entire

Figure 5
**Energy use in the EU27, per energy carrier, in the Reference Scenario**




Source: PBL

global economy. These growth rates all result from our assumptions on macroeconomic development and energy use based on data from the WEO-2011 and PRIMES2009 *and* the assumptions on implementation of climate and renewables policies as described above. In contrast with the overall development in the EU, coal use in the Netherlands is assumed to increase significantly between 2010 and 2020 as the result of coal-fired power plants coming into service in this period (Verdonk and Wetzels, 2012). Furthermore, policies on renewable energy both in the EU and outside, will result in a significant increase in the use of renewable energy sources, particularly between 2010 and 2020. The annual increase over this period will be relatively large in the Netherlands (7.2%) because of its small share of renewables in 2010. In addition, there will be a significant increase in the use of nuclear energy in the Netherland between 2020 and 2030, following from a doubling of nuclear capacity, as assumed in PRIMES2009 for this period. This high growth rate, however, applies to a relatively small share of the total use of nuclear in the Netherlands, which will be only 2.5% of total electricity production in 2020. Table 3 also presents our assumptions on fossil-fuel prices, which were directly based on the WEO-2011.[13]

Figure 5 gives a graphical representation of the energy mix as calculated for the Reference Scenario for the EU27. It clearly shows an increasing share of renewable energy in total energy use, whereas coal consumption appears to mainly decrease over time.

## 3.4 Policy options

As described in Section 1.1, in November 2012 the European Commission presented a number of proposals to structurally reform the EU ETS. For this study, we assessed the impact of some of these proposals as well as two additional options for structural reform of the ETS. To enable analysis of the effects of the EU proposals, using the WorldScan model, we drafted several specific options, making assumptions with respect to their possible implementation. This section describes the options for ETS reform (which are analysed in more detail in subsequent chapters) and summarises the assumptions about the supply of EU ETS allowances and emission prices. The results of our quantitative assessment are presented in Chapter 4.

Options to adjust the supply of allowances:

1. Increasing the ETS target:
   a. A stricter linear reduction factor with the same allocation of free allowances and no indirect cost compensation for industry
   b. A stricter linear reduction factor with free allocation for all industries (except the power sector) and indirect cost compensation
2. Permanent set aside
3. Permanent set aside and increasing the ETS target

One option to adjust the scope:

4. Inclusion of liquid fuels for road transport

One option to introduce a price management mechanism:

5. Auction reserve price

Table 4

*Supply of EU ETS allowances under different reform proposals (million allowances)**

| | 2013 | 2014 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| **Reference Scenario (linear reduction factor 1.74%)** | | | | | |
| ETS cap for stationary installations | 2152 | 1940 | 1962 | 1772 | 1440 |
| ETS cap total | 2362 | | | 1982 | 1651 |
| **1a. & 1b. Increasing ETS target (linear reduction factor 2.52%)** | | | | | |
| ETS cap for stationary installations | 2152 | | | 1652 | 1141 |
| ETS cap total | 2362 | | | 1862 | 1351 |
| **2. Permanent set aside** | -400 | -300 | -200 | | |
| ETS cap for stationary installations after set aside | 1752 | 1640 | 1762 | 1772 | 1440 |
| ETS cap total after set aside | 1962 | 1850 | 1972 | 1982 | 1651 |
| **3. Permanent set aside and increasing ETS target** | -400 | -300 | -200 | | |
| ETS cap for stationary installations | 2152 | 1940 | 1962 | 1772 | 1221 |
| ETS cap total | 1962 | 1850 | 1972 | 1982 | 1431 |
| **4. Inclusion of liquid fuels for road transport** | | | | | |
| ETS cap for fuels used in road transport | 877 | | | 789 | 664 |
| ETS cap total | 3239 | | | 2772 | 2315 |
| **5. Auction reserve price (EURO/t$CO_2$)** | 15 | | | 25 | 50 |
| **6. National flexible tax combined with the ETS (EURO/t$CO_2$)** | 15 | | | 25 | 50 |
| **7. European $CO_2$ tax (EURO/t$CO_2$)** | 15 | | | 25 | 50 |

** All variants include a correction for NER300 and early auctioning, excluding CDM/JI credits, and allowing an ETS cap of 210 million for aviation, in all years.*

Options to provide a $CO_2$ price incentive, supplementary to the ETS:
6. National flexible tax in combination with ETS
7. European $CO_2$ tax

Table 4 summarises the main consequences of the different EC proposals for the amount of allowances in the ETS market.

## 1) Increasing the ETS target

Currently, the ETS cap for stationary installations decreases annually according to a Linear Reduction Factor (LRF) of 1.74%, which corresponds to an annual reduction of roughly 37 million allowances. For this policy option, the LRF was set at 2.52%, corresponding to an annual cap decrease of roughly 54 million. This LRF is based on the Roadmap 2050 that describes emission reduction targets that aim to limit global warming by 2 °C. According to the European Commission, an emission reduction of 43% to 48% and 88% to 92% by 2030 and 2050, respectively, would be required from ETS sectors (including aviation) compared to 2005 levels (EC, 2011c). This trajectory is also compatible with an EU policy that increases the 20% reduction target to 30% (of which 25% within the EU and 5% using CDM/JI credits). In this policy option the cap for aviation would remain unchanged at an annual 210 million allowances.

This option can be considered a combination of the first and third proposal by the EC in November 2012. Compared with the proposal about backloading (EC, 2012e), the adjusted cap in this option would comparable to a permanent set aside of 487 million allowances up to 2020. Table 4 presents the cap in the Reference Scenario and the adjusted cap. The ETS cap for 2013 was calculated using figures presented by the EC (EC, 2012a).[14]

**Two variants for free allocation to industry**

Under current legislation, sectors and sub-sectors that face competition from industries outside the EU, which are not subject to comparable climate legislation, receive part of their allowances for free (100% of the calculated allowances using benchmarks). Also, some Member States have provisions to compensate firms for their indirect costs, i.e. additional cost firms may face in the form of higher power bills because the power sector passes on the cost of emission allowances to its consumers. These measures apply to sectors with a significant risk of carbon leakage due to these indirect costs. The EU ETS Directive allows the possibility of subsidy measures.

For this option, we analysed two variants:

1a *Increasing the ETS target* – current provisions with the same share of free allowances while indirect costs are not compensated;

1b *Increasing the ETS target together with cost compensation* – all installations, except those for power production, receive 100% of their allowances for free using existing benchmarks. Moreover, sectors that have been indicated to be exposed to a significant risk of carbon leakage are compensated for the indirect cost of the ETS.

Variant 1b contains larger compensation measures than currently applied. In our model, the compensation was implemented as a subsidy on current electricity use. It must be noted that this is a more 'generous' compensation than the measures described in the 'Guidelines on certain State aid measures in the context of the greenhouse gas emission allowance trading scheme post-2012' (EC, 2012g), which allows the compensation of indirect costs based on the average production level in the 2005–2011 period.

### 2) Permanent set aside

Another proposal put forward by the EC is to permanently cancel the allowances that are set aside in the early years of the third trading period. In their proposal on backloading, 900 million allowances that would have been auctioned instead are set aside (in total) in the years 2013, 2014 and 2015. These set-aside allowances are then backloaded through auctioning in 2019 and 2020. In this option, we assumed that the set-aside allowances are not backloaded but permanently cancelled, leading to a lower allowance supply in the 2013–2020 period. Beyond 2020, the annual supply of allowances will be the same as in the Reference Scenario.

### 3) Permanent set aside and increasing the ETS target

In addition to the permanent cancellation of 900 million allowances in the third trading period, starting in 2021 the LRF will be increased in such a way that the ETS cap will be reduced linearly to 90% by 2050. This approach is comparable to the option presented above: 'Increasing the reduction target of the ETS' the only difference being that the increase in the LRF would start from 2021 instead of 2014, and that, in order to meet the 90% reduction target by 2050, the LRF in this option is set at a higher level, namely that of 2.71%.

### 4) Including liquid fuels for road transport

Another way of increasing the scarcity on the ETS market is by expanding the scope of the ETS by including a sector that is underprovided with allowances. Indeed, sectors that are not covered by the ETS do not have the option of choosing between abating emissions or buying allowances, which implies less flexibility to exploit cheaper reduction options in other sectors. This larger flexibility is the main reason for expanding the EU ETS; increase efficiency by exploiting the cheapest abatement options to reduce the cost of $CO_2$ emissions. By expanding the EU ETS to also include sectors that face relatively expensive abatement options, while reducing their amount of allowances relative to the base line, additional scarcity is introduced on the carbon market and the carbon price may rise.

In this option we included the $CO_2$ emissions from liquid-fuel consumption by road transport. In order to reduce overall emissions, the cap was set below the emission level for fuel consumption by road transport in our Reference Scenario[15]. We derived a reduction level from the global action scenario in the impact assessment of the Roadmap 2050 of the EC, reducing EU-wide emissions to 80% to 95% below 1990 levels by 2050. $CO_2$ emissions from transport (excluding aviation and maritime shipping) will be 26% below 2005 levels by 2030. We used this reduction level to determine our ETS cap on road transport fuels, as presented in Table 4.

The expansion of the scope of the ETS with fuel consumption by road transport is implemented in an indirect way; not the consumers themselves are 'added' to the scope of the ETS but rather the suppliers of these fuels. This helps to keep the ETS manageable and reduces total transaction costs. It is assumed that the costs of allowances are passed on to consumers, thus creating an incentive to curb the consumption of fossil fuels. Note that existing policies with respect to road transport, such as the Fuel Quality Directive, are preserved, so this option cannot be considered as a tailored combination of instruments (see also Section 1.2). We also assumed existing taxation and levies on the consumption of fossil fuels to be unaltered. Because suppliers of liquid fuels for road transport, similar to power producers, hardly experience non-EU competition, they would acquire all of their initial allowances at auction.

### 5) Auction reserve price

As explained in Section 2.3 we also included one option that adjusts the $CO_2$ price by using an auction reserve price, which implies that no allowances would be auctioned at below a pre-defined floor price. If this floor price would exceed the allowance price – which reflects the scarcity of allowances on the market created by the amount of allowances supplied – it will cause demand to be less than the total supply of allowances. Allowances that are not auctioned are kept in a reserve, and hence will not enter the market until participants are prepared to pay at least the floor price. Note that the auction reserve price not only affects the value of auctioned allowances, but also the value of the surplus and of the allocated free allowances. As the market anticipates that it cannot do without auctioned allowances unless marginal cost will exceed the price floor, agents are not willing to sell allowances below the reserve price. The desired effect of an auction reserve price is to make investments in low-carbon technologies relatively more attractive by reducing downside price uncertainty (Hepburn, 2006; Grüll and Taschini, 2011; Wood and Jotzo, 2011). A minimum price on auctioned allowances would result in a higher and more stable $CO_2$ price, given the current oversupply of allowances. We assumed a linearly increasing floor price level, starting with EUR 15 per allowance by 2013[16], EUR 25 by 2020 and EUR 50 by 2030. These price levels are in the middle of the price range calculated by the European Commission for their Roadmap 2050 scenarios (EC, 2011c)[17]. Under this option, allowances that are not sold at these minimum prices are kept in a reserve and will be auctioned when the minimum price level is expected to be made.

### 6) National flexible tax in combination with the ETS

Member States could also introduce a national flexible tax on $CO_2$ emissions from the combustion of coal, oil and natural gas. The option for a national flexible carbon tax is a tailored combination of the ETS with a $CO_2$ tax on energy use. This combination is tailored in that the level of the $CO_2$ tax is flexible and depends on the difference between the EU ETS allowance price and a predefined floor price. The $CO_2$ tax guarantees a minimum price for $CO_2$ emissions. This analysis follows ideas developed within the United Kingdom and which is part of an overall package including contracts for designing a proper power market (HM Treasury, 2010). Our option is that of a flexible $CO_2$ tax in the Netherlands, reflecting the difference between the EU ETS allowance price and a predefined floor price. Unlike in the United Kingdom, in our case, the level of the $CO_2$ tax applies to all ETS companies in the Netherlands. The price floor in the United Kingdom starts at GBP 16 per tonne of $CO_2$ and follows a linear path to the target of GBP 30/t$CO_2$ in 2020 and GBP 70/t$CO_2$ in 2030 (in 2009 prices) (HM Treasury, 2010)[18]. In our analysis, we set the price floor at EUR 15/t$CO_2$ by 2013, linearly increasing to EUR 25 by 2020 and EUR 50 by 2030, as in the previous two options.

### 7) European $CO_2$ tax

The policy options discussed, so far, are all adjustments within the ETS framework itself. A guaranteed minimum price, however, could also be implemented using other instruments, such as carbon taxation. This would be an example of a tailored combination of *different* instruments (see Section 2.3). Currently, the Energy Taxation Directive is under revision, as well. This proposal to revise the current Energy Taxation Directive, however, aims to tax only the $CO_2$ content of fuels used by *non*-ETS sectors (EC, 2011b). In contrast, our analysis assumes introduction of a $CO_2$ tax for all sectors in coexistence with the ETS. This option assumes taxation of $CO_2$ emissions from the combustion of coal, oil and natural gas, through an *additional* European carbon tax to be added to existing energy taxes and the ETS. The assumed tax rate is equal to the minimum price level for auctioned allowances, as assumed in the minimum price option, i.e. a linearly increasing rate starting at EUR 15/t$CO_2$ in 2013, to EUR 25 in 2020 and EUR 50 in 2030. In this way, we were able to compare the results with the other options that aim to reform the ETS.[19]

## Notes

1 When reducing ETS emissions by 90% by 2050, compared to 2005 levels, while maintaining the allowance supply for aviation at 210 million, would leave only 33 million allowances for stationary installations. However, it must be noted that in our Reference Scenario emissions from international aviation are assumed to increase by 2.5%, annually, whereas emissions from other sectors tend to increase at a much lower pace or even decrease.

2 Although the central scenario of the WEO-2011 is the New Policies Scenario, we used the Current Policies Scenario. This scenario assumes no new policies are added to those in place as of mid 2011. This scenario with the least policies implemented fits our purpose best to evaluate differences in design for different EU ETS options.

3 In November 2012, the World Energy Outlook 2012 was published (OECD/IEA, 2012), which assumes somewhat lower GDP growth rates (average annual growth rates for 2010 to 2035 are 3.5% for the world and 1.8% for the EU). As a result, energy use would increase less (average annual growth rates for 2010 to 2035 of 1.5% for the world and 0.1% for the EU).

4 Auction revenues of EU ETS allowances are redistributed lump sum, i.e. without influencing decisions by firms or households (see Annex I).

5 In their study, Kolkman et al. mention growth rates from various studies. They took the average of those rates (3.5%) for the annual growth in volume and assumed an efficiency improvement of 1%, annually. They found that, with a carbon price of EUR 10/tonne $CO_2$, the annual growth in volume would reduce to between 2.6% and 3.3%. Based on this range, we assumed an annual growth in volume of 3%, which combined with an annual efficiency improvement of 1% would result in an annual increase in emissions of 2%.

6 This limitation is valid until 2020 and will be reviewed in 2016. For our analyses, however, we extended this to the period beyond 2020, as the Australian Government has stated that 'any restrictions placed on the acceptance of international units will be to ensure the stability and ongoing credibility of the carbon pricing mechanism, the environmental integrity and effectiveness of the carbon pricing mechanism, and consistency with Australia's international objectives and obligations.' (Australian Department of Climate Change and Energy Efficiency, 2012).

7 With an average exchange rate in 2012 of AUD 1 (EUR 0.80), this corresponds to an emission price of about $EUR_{2010}$ 12/ $tCO_2$.

8 See Effort Sharing Decision, Articles 3.2, 3.4 and 3.5.

9 This assumption has no impact on the relative performance of the different policy options which was the main focus of our evaluation.

10 Uncertainty will give rise to additional motivations to bank allowances, such as firms holding allowances as insurance for maintaining compliance in case of unforeseen increases in demand for allowances, e.g. because of weather conditions (Amundsen et al., 2006; Chevallier, 2012).

11 If this capital market equilibrium condition would not hold, all capital would flow either into or out of the carbon market.

12 With this price path, the demand from Australian firms will total an amount of about 600 million EU ETS allowances. This external demand for EU ETS allowances reduces the amount of allowances available for European firms, inducing them to reduce their emissions more than implied by the ETS cap on emissions.

13 The WEO-2011 takes into account the effect on fuel prices from improved prospects for the commercial production of unconventional gas (shale gas). The WorldScan model assumes a globally uniform development in the price of distinct fuels; therefore, it was not possible to take into account regional differences in the development of fuel prices resulting from these developments. See also the discussion of this issue in Section 5.2.

14 The cap may end up slightly higher due to new entrants, closures and opt-outs that occurred in the years 2011 and 2012 (Hermann and Matthes, 2012). Moreover, the cap can be adjusted during the entire trading period, as new entrants, installations, opt-outs and plant closures may occur.

15 In the Reference Scenario, $CO_2$ emissions from road transport will have declined by 20% by 2020 and by 22% by 2030, compared to 2005 levels. This includes the effect of existing policies with respect to road transport, such as the Fuel Quality Directive.

16 The starting price of EUR 15 in 2013 is based on Grubb (2012)

17 The mid-range prices were chosen in order to have higher prices than in the Reference Scenario. It must be considered, however, that the Roadmap 2050 scenarios did not take into account a recession in 2012 nor the new energy efficiency directive.

18 This equals a trajectory that starts at EUR 15 to EUR 29 by 2020 and EUR 67 by 2030 (using the GBP–EUR exchange rate of 1 January 2009). The rate is calculated for two years in advance.

19 If only non-ETS sectors would be confronted with a $CO_2$ tax, this would have little impact on the functioning of the ETS.

Four

# Evaluation results

This chapter presents the results from our evaluation of the options to reform the ETS, using WorldScan, the global CGE model and the evaluation criteria introduced in Section 2.4. First, it assesses the allocative efficiency of the options by presenting the direct effects, i.e. the resulting change in emissions, emission prices, auction revenues and carbon leakage. Next, the chapter focuses on the distributional effects, presenting changes in emissions and economic welfare across various Member States, and changes in production and employment in various sectors. Subsequently, the chapter discusses the effects on co-benefits, in terms of reduced emission of air pollutants. Here the results from the model simulations are presented, covering the 2013–2030 period. Note that the focus is on relative differences in outcomes between the various options, rather than on the absolute levels of the results. Therefore, results are presented as deviations from the Reference Scenario. Finally, the effect of changing several assumptions on the simulation results is discussed in a sensitivity analysis.

## 4.1 Direct effects on ETS emission reductions and prices

Table 5 presents changes in greenhouse gas emissions, emission prices and auction revenues from the various options for the ETS sectors only. Because of our banking assumptions (see Section 3.3 and Annex IV), the development of the emission price over time is similar for the various options, i.e. the emission price increases from year to year by the rate of return on capital and relative differences between emission prices are constant over time. The auction revenues are presented as a net present value of the revenues over the 2013–2030 period.

Results show remarkable differences between the options for reforming the ETS. Additional emission reduction ranges from 0 for the introduction of a Dutch national tax (6) to up to 8.5% in 2030 for the options that increase the ETS target irrespective of whether additional cost compensation is included (variants 1a, 1b). Intermediate reductions are obtained with the options that use either an auction reserve price (5) or a broad based $CO_2$ tax (7). Both options 5 and 6 result in emission reductions that would be smaller in 2030 than in 2020, relative to the Reference Scenario. This lower overall reduction is caused by a decreasing relative difference between the emission price in the Reference Scenario and the price floor and the $CO_2$ tax. In 2020, the price floor and $CO_2$ tax would be 30% above the emission price in the Reference Scenario, whereas in 2030 this would be reduced to 16%. Including liquid fuels for road transport (4) also reduces additional emissions; in particular, by the end of the period, which is not much different from the permanent set aside option (2).

The overall picture is that the options that reduce the supply of EU ETS allowances the most, also cause the largest allowances price increase. This is hardly surprising because of the possibility to bank allowances after the

Table 5

**Effects on ETS greenhouse gas emissions*, emission price and auction revenues**

| | Greenhouse gas emissions compared to Reference Scenario (%) | | | | Emission price (EUR $_{2010}$/t$CO_2$) | | | Auction revenues (billion EUR $_{2010}$)[(a)] |
|---|---|---|---|---|---|---|---|---|
| | 2013 | 2020 | 2030 | Cumulative 2013–2030 | 2013 | 2020 | 2030 | 2013–2030 |
| Reference Scenario | | | | | 11 | 19 | 43 | 268 |
| 1a. Increasing the ETS target | -4.6 | -5.8 | -8.5 | -6.2 | 15 | 26 | 58 | 297 |
| 1b. Increasing the ETS target combined with cost compensation | -4.5 | -5.7 | -8.5 | -6.2 | 15 | 26 | 58 | 275 |
| 2. Permanent set aside | -1.4 | -1.8 | -2.9 | -2.0 | 12 | 21 | 47 | 282 |
| 3. Permanent set aside & increasing the ETS target | -3.2 | -4.1 | -6.3 | -4.5 | 14 | 24 | 53 | 291 |
| 4. Inclusion of liquid fuels for road transport[(b)] | -1.2 | -1.4 | -2.7 | -1.7 | 12 | 21 | 47 | 451 |
| 5. Auction reserve price | -4.4 | -5.1 | -3.9 | -4.7 | 15 | 25 | 50 | 309 |
| 6. National flexible tax combined with the ETS | 0.0 | 0.0 | 0.0 | 0.0 | 11 | 19 | 43 | 265 |
| 7. European $CO_2$ tax[(c)] | -3.3 | -3.5 | -1.0 | -2.8 | 1 | 1 | 3 | 18 |

* *Emissions include emissions from EFTA countries included in the ETS; emissions from international aviation are not included.*

(a) *Net present value in 2013, using a discount rate of 4%.*

(b) *For comparability, changes refer to emissions from ETS sectors excluding the transport sector. Under this option, emissions from road transport will be reduced by 4% (2020) and 6% (2030) compared to the Reference Scenario.*

(c) *Note that emission prices presented refer to the price of EU ETS allowances, which are additional to the $CO_2$ tax on energy use of EUR 15/t$CO_2$, EUR 25/t$CO_2$ and EUR 50/t$CO_2$ in 2013, 2020 and 2030, respectively. Auction revenues do not include revenues from the $CO_2$ tax, the estimated net present value of which is about EUR 940 billion.*

third period up to 2030 (see also Annex IV). An optimal intertemporal allocation with a reduced overall supply of allowances over the whole period implies that the emission price should increase along the entire price path starting in 2013. The higher price path will induce more emission reductions, such that the demand for allowances will meet overall supply in the entire period. As the reduction in the total supply of allowances is largest in the variants 1a and 1b (2.6 billion EU ETS allowances), the emission price also increases most under these options relative to the Reference Scenario in 2030.

The inclusion of liquid fuels for road transport in the EU ETS does not lead to strong emission reductions. Although the total supply of allowances will increase in this policy option, the additional supply is less than the level of emissions from road transport in the Reference Scenario. Interestingly, the costly reductions in emissions from road transport will partly be replaced by other, less costly abatement options *outside* the transport sector. Indeed, the ETS provides road transport with the option to buy additional allowances, which, in turn, drives up the price of EU ETS allowances. Hence emissions from road transport are reduced by up to 6% compared to their emissions in the Reference Scenario, while emissions in other ETS sectors would decrease by almost 3% in 2030.

The impact of the price management options on the amount of emission reduction is also very interesting. An auction reserve price implies that allowances will be auctioned only if at least the floor price will be paid. Allowances not auctioned will be kept in a reserve and may be auctioned in later years if the market is short of supply and the price tends to rise above the (rising) floor price. Because in our simulations the floor price exceeds the price level of the Reference Scenario as from 2013, no allowances will be auctioned at all in the beginning. As a consequence, total supply of allowances will be determined by the free allocation of allowances plus the allowances taken from the surplus, as long as the emission price stays below the floor price. The surplus of allowances from the previous trading period (2008–2012), thus, would be completely depleted by 2015. From 2015 onwards the demand for auctioned allowances would become positive, causing the emission price to increase up to the floor price level.[1] Nevertheless, demand would be smaller than the total supply of allowances for the whole period. Consequently, part of the allowances would not be auctioned at all and kept in a reserve. This reserve would increase to about 2.1 billion allowances by 2030, which is exactly the reduction in emissions relative to the Reference Scenario accumulated over the 2013–2030 period.[2]

Up to 2020, the emission reduction pathway closely follows that of the option of increasing the ETS target (1a). The price path is a little lower because the price floor is also somewhat below the prices in the option of increasing the ETS target. Beyond 2020, the difference between the emission prices in the two options will increase, with the price floor increasing at a lower rate than the emission price under the option of increasing the ETS target. This price difference also explains why emission reduction would be considerably less in 2030 with an auction reserve price than under variants 1a, 1b and option 3. Obviously, the auction reserve price would result in a different development of emission reductions over time as well as in accumulated emissions over the 2013–2030 period. The auction reserve price would reduce emissions by 5% relative to the situation under the Reference Scenario, whereas increasing the ETS target (1a and 1b) and the permanent set aside in combination with an increasing ETS target (3) would reduce emissions by 6% and 4%, respectively.

The simulation results from implementing a national $CO_2$ tax in the Netherlands clearly illustrate the waterbed effect of using not very well tailored combinations of instruments. Because such a national tax would imply a high price for emissions in the Netherlands, this would provide incentive to the national ETS sectors to reduce emissions as well as reduce their demand for EU ETS allowances. However, the overall supply of EU ETS allowances would not change, which implies that emissions in other Member States could increase. Scarcity on the ETS market even would decrease slightly as a result, leading to an allowance price that would be about 1% below that under the Reference Scenario.

Our final reform option uses a combination of different instruments by combining the ETS with an EU-wide carbon tax. The idea behind the introduction of a European $CO_2$ tax on energy use is to introduce an emission price without making any direct changes to the EU ETS. However, this option clearly would be less effective in reducing emissions than that of introducing an auction reserve price. Although the price path would follow a similar pattern as the floor price, considerably fewer emissions would be reduced, in particular in the period between 2020 and 2030. The main reason being that this combination of instruments is less tailored to the specific issue it aims to address. The auction reserve price would reduce the supply of EU ETS allowances, as described above, whereas the introduction of a European $CO_2$ tax would not affect this supply. Because the carbon tax does not place a cap on emissions and the cap-and-trade programme in this option is less strict than, for instance, under variants 1a and 1b, additional emission reduction can no longer be guaranteed under this scheme. Emissions accumulated over the 2013–2030 period would be reduced by 3%, relative to the Reference Scenario, which is less than under variants 1a and 1b, and options 3 and 5. This is also nicely reflected by the ETS price which is expected to have collapsed by 2020. The $CO_2$ tax already would provide an incentive to reduce emissions and this, in turn, would strongly reduce the demand for EU ETS allowances. Only a very small positive allowance price would remain, which reflects the need for a small incentive to reduce the types of emissions that are not affected by the $CO_2$ tax (i.e. emissions from non-energy sources).

Compensating firms for the costs related to the EU ETS – as in variant 1b – would hardly affect the overall impact on the EU ETS. Compensation, however, would change the distribution of effects over the various sectors (see also Section 4.2).

Table 5 also presents current net values of the overall auction revenues in the EU. Notwithstanding the smaller number of allowances that would be auctioned under variants 1a and 1b, and options 2, 3, and 5, revenues would increase because of the higher price of the remaining allowances auctioned. This is consistent with Grubb (2012), who argues that there is a strong relationship between price and volume. Auction revenues would increase the most under option 4, because all of the additional supply of EU ETS allowances resulting from the expansion of the ETS by adding emissions from road transport is assumed to be auctioned. Note that with the introduction of an auction reserve price there will be no auction revenues before 2015, as no allowances would be auctioned at an emission price below the auction reserve price. Such a loss in revenue, however, would be more than compensated by higher auction revenues after 2020. Introducing a European $CO_2$ tax would substantially reduce the price of allowances and hence also the auction revenues. Furthermore, the tax would also generate huge revenues by itself, as it would apply to all sectors and not only to the ETS sectors.

### Impacts of reform options on non-ETS sectors

Interestingly, the reform options not only have an impact on ETS sectors, but also on non-ETS sectors. Indeed, due to the higher $CO_2$ price, prices of output from ETS sectors (such as electricity) would increase, which, in turn, would affect the production costs for non-ETS sectors and likely reduce demand for their output. Table 6 shows that more stringent policies within the ETS sector also would have

Table 6

**Effects on ETS and non-ETS emissions in EU27 in 2020**

| | 1a. Increasing the ETS target | 1b. Increasing the ETS target combined with cost compensation | 2. Permanent set aside | 3. Permanent set aside & increasing the ETS target | 4. Inclusion of liquid fuels for road transport[a] | 5. Auction reserve price | 6. National flexible tax combined with the ETS | 7. European $CO_2$ tax |
|---|---|---|---|---|---|---|---|---|
| *Greenhouse gas emissions compared to Reference Scenario (%)* | | | | | | | | |
| ETS EU27[b] | -5.8 | -5.7 | -1.8 | -4.1 | -1.4 | -5.1 | 0.0 | -3.5 |
| Non-ETS EU27 | -0.1 | -0.1 | 0.0 | -0.1 | -1.2 | -0.1 | 0.0 | -5.7 |
| Total EU27 | -2.7 | -2.7 | -0.8 | -1.9 | -1.3 | -2.4 | 0.0 | -4.9 |

[a] *For comparability, emissions from road transport are included in the figures presented for non-ETS EU27.*
[b] *These figures correspond with the figures for 2020 in Table 5.*

Table 7

**Effects of EU ETS reform options on renewable energy policies and production**

| | Renewable energy subsidies granted in the EU27 (billion EUR $_{2010}$)[a] 2013–2030 | Change in total production of electricity from renewable energy sources (% to Reference Scenario) |
|---|---|---|
| Reference Scenario | 86 | |
| 1a. Increasing the ETS target | 11 | -3% |
| 1b. Increasing the ETS target combined with cost compensation | 9 | -3% |
| 2. Permanent set aside | 63 | -1% |
| 3. Permanent set aside & increasing the ETS target | 33 | -2% |
| 4. Inclusion of liquid fuels for road transport[b] | 62 | -1% |
| 5. Auction reserve price | 19 | -4% |
| 6. National flexible tax combined with the ETS | 87 | 0% |
| 7. European $CO_2$ tax | 1 | -4% |

[a] *Net present value in 2013, using a discount rate of 4%.*

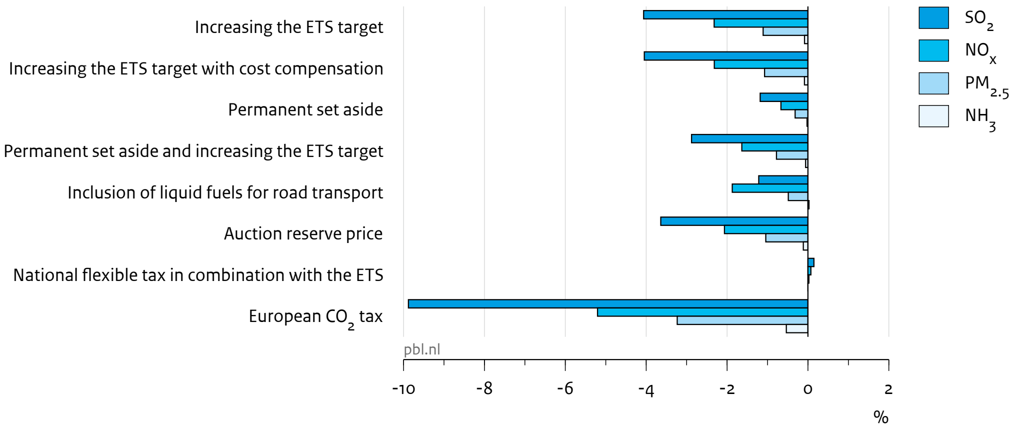
indirect repercussions on the non-ETS sector although these impacts usually would be quite small. For those options that directly change the ETS, we found a substantial effect only for the inclusion of liquid fuels for road transport, because this option would directly affect emissions from road transport that are included in the figure for non-ETS emissions.

The introduction of an EU-wide $CO_2$ tax also applies to energy use in sectors not covered by the ETS, and therefore would reduce emissions throughout the entire economy. In fact, this option induces a more significant reduction in the use of fossil fuels and associated emissions in the non-ETS sectors, such as the transport sector. Reduction as a percentage relative to the Reference Scenario is even more substantial in the non-ETS sector, compared to the ETS sector, and therefore would have the largest overall impact on the economy-wide reduction in $CO_2$ emissions (see last row of Table 6).

## Effect reform options on renewable energy policies

Our model simulation also showed the impact of the ETS reform options on the renewable energy policies. Table 7 shows that the various adjustments of the EU ETS generally make it easier to achieve the target for 2020, i.e. a smaller subsidy on renewable electricity could accomplish the required share of 20% renewable energy under the EU Renewable Energy Directive. Obviously, a higher carbon price would reduce the cost difference between fossil-fuel-based electricity and electricity from renewable energy sources. Moreover, a higher emission price would reduce total consumption of fossil-based

Figure 6
**Change in emissions of air pollutants compared to the Reference Scenario, 2020**




Source: PBL

energy and thus would make it easier to achieve the 20% share of energy from renewable energy sources in gross final energy consumption. Indeed, none of the reform options are assumed to increase the total production of renewable electricity, but most options would induce a decrease in the required production of renewable energy. In general, our simulations showed that the higher the price on emissions, the smaller the required subsidy on renewable energy. In particular, the introduction of a European $CO_2$ tax would make subsidies on renewable energy almost unnecessary.

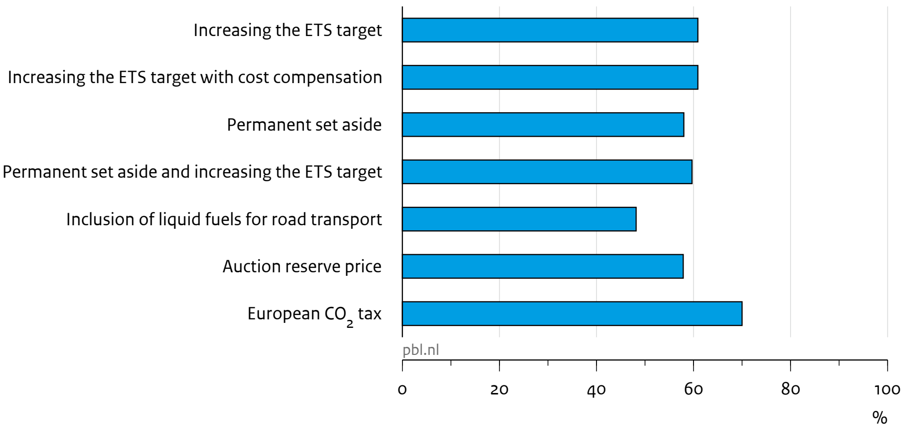
## Co-benefits for air pollution

Emissions of greenhouse gases and air pollutants largely originate from the same sources: fossil-fuel combustion and agricultural activities. Figure 6 shows that the ETS reform options analysed here would lead to a reduction in air pollution, mainly in the emissions of $SO_2$, $NO_x$ and particulate matter. These reductions follow from a reduction in fossil-fuel use, particularly coal, due to energy efficiency improvements, a shift to renewable energy sources and changes in the sectoral structure of the economy. In particular, the European $CO_2$ tax, which would not only apply to ETS sectors but to all energy consumption, would significantly reduce air pollution. A reduction in air pollution would yield health benefits by reducing mortality, but also would result in reduced damage to ecosystems. Emissions of air pollutants in the EU, however, are restricted by the EU National Emission Ceilings Directive. Therefore, in effect, the ETS reform options will not likely result in additional health benefits, but they will reduce the abatement costs for reducing air pollutant emissions to these emission ceilings (for a more elaborate discussion of the interaction between climate policies and policies on air pollution in Europe, see Bollen and Brink (2012)).

## Carbon leakage

Changes in EU climate policies would not only have an effect within the EU. Through international trade relations also indirect effects may occur in other parts of the world. These indirect effects of climate policies in the EU may cause emissions in the rest of the world to increase ('carbon leakage') (Böhringer et al., 2010; Bollen et al., 2012). This may happen i) as a result of lower world energy prices, as the demand for energy in the EU decreases, leading to a higher demand for energy in the rest of the world; and ii) as a result of industry relocating from the EU to other regions. The more countries outside the EU have climate policies which result in a binding restriction on emissions, the less the possibility of leakage. As described in Section 3.2, for countries outside of the EU, we assumed emissions to be restricted to the levels indicated by the low pledges in the Copenhagen Accord. For the United States, Japan, Australia and other OECD countries, this implies an absolute cap on emissions, which means that no carbon leakage towards these countries can occur. China and India, however, pledged a relative emission reduction, i.e. an improvement of the emission intensity of their economy. This implies that their emissions would be allowed to increase if their economy also increases. Hence, leakage to these countries is to some extent possible. Moreover, because in our Reference Scenario the emission target for Russia is not binding and for other regions no emission

Figure 7
**Carbon leakage related to EU emission reduction, 2013 – 2030**




Source: PBL

*No additional carbon leakage would occur with the national flexible tax with the ETS (6) because, overall, EU emissions would not change from those in the Reference Scenario.*

target was assumed, greenhouse gas emissions also may leak to these regions.

Figure 7 shows the overall carbon leakage resulting from the simulations of the various reform options in the WorldScan model.[3] It presents the carbon leakage rate accumulated over time, relating the cumulative increase in emissions outside Europe to the cumulative reduction within Europe, both relative to the Reference Scenario. Apparently, the leakage rate would be about 60% and hardly differs for most options. This carbon leakage rate implies that, on average, for each Mt $CO_2$ eq reduction within Europe, an increase in emissions of about 0.6 Mt $CO_2$ eq is projected to occur outside Europe. This finding is comparable with the carbon leakage rates reported by Aalbers et al. (2012a). As explained in Bollen et al. (2012), the most important reason for the carbon leakage to occur is that the decrease in demand for energy in the EU leads to lower world energy prices. In our model simulations, this effect explains more than half of the leakage found.

The somewhat lower rates for the inclusion of liquid fuels in road transport can be explained by the different impacts of this option on the world prices for the different fuels. This option would affect oil prices more than coal prices, in comparison with the other options. The somewhat lower price of oil on the world market increases the global demand for oil. Because oil has a lower carbon content than coal, global $CO_2$ emissions will be less affected, which explains the somewhat smaller impact on carbon leakage for this option. In the case of the European carbon tax, the leakage would be greater because of its broader scope also outside the ETS, which in turn has a larger impact on all fossil fuels, in particular also on the coal price.

## 4.2 Distributional effects

### Effects on the distribution of emission reductions over sectors and EU Member States

The impacts of reform options would not be equally distributed over the various countries. Table 8 presents the distribution of the effects on emissions in 2020 for specific EU Member States. The table shows that emission reductions would be relatively large in the rest of the EU27 (which includes central and eastern European Member States). In these countries, the relatively large share of coal and natural gas in power generation, in our model, would offer relative cost-effective opportunities for $CO_2$ emission reduction. The emission reductions within the Netherlands are just below the EU average, but in most cases larger than in the large Member States such as Germany, France and the United Kingdom. According to the model simulations, the ETS reform options would have a relatively large impact on production in the energy intensive sectors in the Netherlands. This can be explained by the relatively large share of export in total production of these sectors. Under a national flexible tax in combination with the ETS in the Netherlands, emissions would decrease by more than 8%. With the

Table 8

**Effects on ETS emissions in EU Member States in 2020**

| | 1a. Increasing the ETS target | 1b. Increasing the ETS target combined with cost compensation | 2. Permanent set aside | 3. Permanent set aside & increasing the ETS target | 4. Inclusion of liquid fuels for road transport | 5. Auction reserve price | 6. National flexible tax combined with the ETS | 7. European $CO_2$ tax |
|---|---|---|---|---|---|---|---|---|
| *Greenhouse gas emissions compared to Reference Scenario (%)* | | | | | | | | |
| ETS* | -5.8 | -5.7 | -1.8 | -4.1 | -1.4 | -5.1 | 0.0 | -3.5 |
| Germany | -3.1 | -3.1 | -0.9 | -2.2 | -0.9 | -2.8 | 0.2 | -0.8 |
| France | -3.0 | -3.2 | -0.9 | -2.1 | -3.3 | -2.6 | 2.1 | -2.4 |
| United Kingdom | -2.9 | -2.9 | -0.9 | -2.0 | -0.8 | -2.6 | 0.1 | -1.1 |
| Italy | -2.2 | -2.0 | -0.7 | -1.5 | -0.5 | -1.9 | 0.1 | -1.6 |
| Netherlands | -5.0 | -5.0 | -1.6 | -3.6 | -1.3 | -4.5 | -8.2 | -4.3 |
| Other EU15 | -4.9 | -4.7 | -1.5 | -3.4 | -1.3 | -4.3 | 0.3 | -3.1 |
| Poland | -4.8 | -4.7 | -1.5 | -3.4 | -1.4 | -4.2 | 0.2 | -1.2 |
| Rest of EU27 | -8.4 | -8.6 | -2.6 | -6.0 | -2.4 | -7.4 | 0.4 | -4.6 |

* *ETS emissions include emissions from ETS sectors in EFTA countries*

Table 9

**Effects on economic welfare cost in 2020**

| | 1a. Increasing the ETS target | 1b. Increasing ETS target combined with cost compensation | 2. Permanent set aside | 3. Permanent set aside and increasing the ETS target | 4. Inclusion of liquid fuels for road transport | 5. Auction reserve price | 6. National flexible tax combined with the ETS | 7. European $CO_2$ tax |
|---|---|---|---|---|---|---|---|---|
| *Economic welfare (%)[(a)]* | | | | | | | | |
| EU27 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.1 |
| Netherlands | -0.1 | -0.1 | 0.0 | -0.1 | -0.1 | -0.1 | 0.0 | -0.1 |
| EU15 (excl. Netherlands) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 |
| Rest of EU27 | -0.2 | -0.2 | 0.0 | -0.1 | 0.0 | -0.5 | 0.0 | 0.1 |

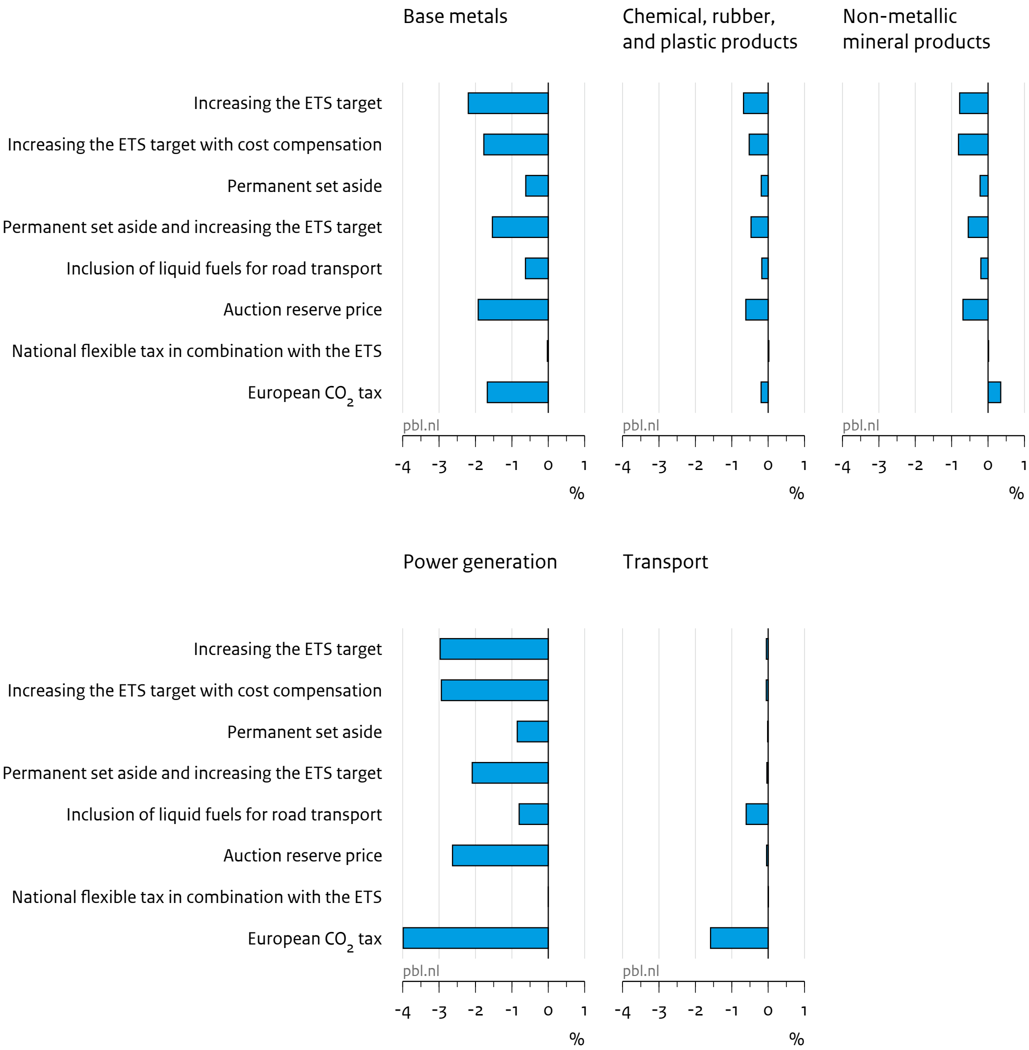
[(a)] *Hicksian Equivalent variation as % of national income in the Reference Scenario; this measure does not account for environmental benefits, such as reductions in global warming and air pollution.*

overall cap on ETS emissions unaffected, this would allow emissions in other Member States to increase by the same amount, leaving overall emissions unchanged.

## Effects on economic welfare

Table 9 presents the change in welfare due the reform options compared with the Reference Scenario[4]. These welfare effects only include the welfare cost to society by giving up resources to take the given course of action. This clearly is a partial measure of social welfare effects, as the benefits of emission reductions (such as reduced global warming and less air pollution) are not included. Increasing the ETS target would lead to welfare losses of generally less than ±0.05% for most options. The national flexible tax combined with the ETS, in the Netherlands, implies a higher national carbon price (the combination of the EUA price and the tax) than in other Member States, causing welfare losses in the Netherlands while other Member States would gain, compared to the Reference Scenario. Welfare losses in the Netherlands, however, would be small (less than 0.05%). With this option, emission prices in the Netherlands, including the additional tax, would be close to emission prices that result from other options. Welfare losses in the Netherlands due to a national flexible tax combined with the ETS (6), which would only affect the Netherlands, would even be smaller than under other options. Although production would decrease more than under

Figure 8
**Change in production in the EU27 compared to the Reference Scenario, 2020**




Source: PBL

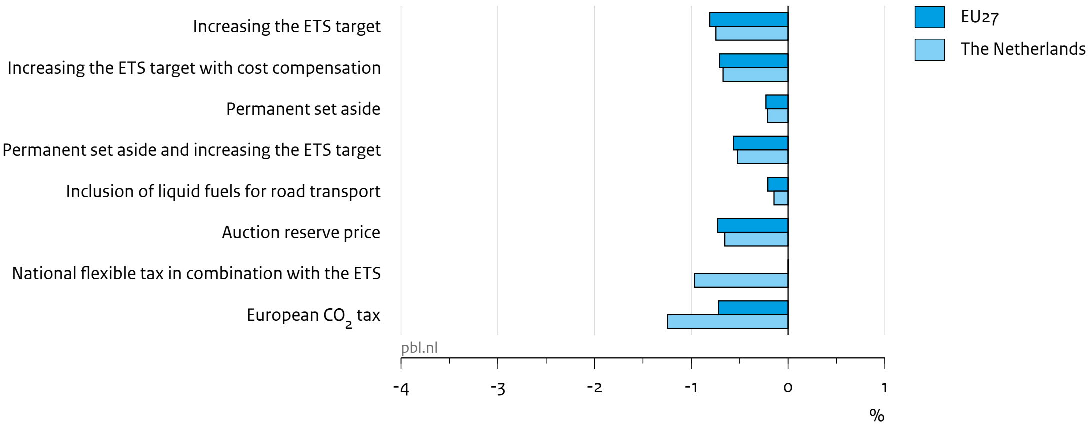
other options, the Dutch economy would profit from somewhat lower import prices resulting from a small decrease in the emission price for ETS sectors in other EU Member States, compared with the Reference Scenario. Small welfare gains are found for the rest of the EU27 with the introduction of a European $CO_2$ tax, indicating that, in the model simulations, the reform options resulted in a small shift in the welfare cost from these countries to the EU15.

### Effects on sectoral production

Figure 8 shows the effect on production in ETS sectors and in the transport sector in the EU27. The decrease in production in ETS sectors in the various options ranges from 0% (national flexible tax combined with the ETS) to about 0.8% (increasing the ETS target) on average for all sectors covered by the ETS. In general, sectors with fossil-fuel-intensive production are affected the most; in particular, those of electricity generation and base metals. However, impacts are much smaller for chemical, rubber, and plastics products, non-metallic mineral products and transport sectors.

As before, the options with the largest impact on emission reductions and prices also have the largest impact across sectors. The options of increasing the ETS target and the auction reserve price have the largest impact. Of course, the option under which liquid fuels for road transport are also included into the EU ETS would have a significant impact on the transport sector, but also

Figure 9
**Change in production in ETS sectors compared to the Reference Scenario, 2020**




Source: PBL

on power generation and base metals. Indeed, the additional demand from the transport sector would induce a higher ETS price.

The pattern for a European $CO_2$ tax is very different across the various sectors. This tax would reduce electricity output – not only directly, but also indirectly because of its much larger impact on electricity demand in all sectors of the EU economy. Because all fossil-fuel use would be taxed under this option, also output by the transport sector would be reduced, considerably. However, because non-energy emissions would not be taxed under this option, we even found a small increase in production in the mineral products sector. The share of non-energy emissions also explains the smaller reduction in the production of base metals and chemicals due to the tax on energy-related $CO_2$ emissions.

Finally, results also illustrate that compensating the cost of the ETS does not seem to have much of an impact on the main indicators (see also Table 5). Both emissions and the emission price only slightly differ for the option with cost compensation (variant 1b) compared with the option without compensation (variant 1a). Variant 1b also would have a small impact on production losses in the different compensated sectors, as shown in Figure 8. In particular, the effect of ETS reform on the production of base metals and chemicals would be slightly mitigated.

## Tax options would have the largest impact in the Netherlands

Figure 9 shows that the effect on production levels in ETS sectors for the options that directly aim to improve the ETS, on average, would be somewhat smaller for the Netherlands than for the EU27. The reduction in base metal production and production in the chemical sector, however, would generally be larger in the Netherlands than in the EU as a whole. Although the two tax options would have a much more negative impact on the production in the ETS sectors. A Dutch national flexible tax combined with the ETS would only reduce production levels within the Netherlands, without hardly any effect in the rest of the EU or in non-ETS sectors. A European $CO_2$ tax, however, would have a much more detrimental effect on production within the Netherlands than on that in the EU as a whole. This can be explained by the relatively small share of non-energy-related greenhouse gas emissions from ETS sectors in the Netherlands, compared to those in the EU as a whole. A $CO_2$ tax on energy-related emissions, therefore, on average, would have a larger impact on Dutch industry than elsewhere within the EU.

## Limited impact on employment

In sectors that face decreasing production levels, employment will also decrease. This would be particularly the case for the production of base metals and for power generation. The overall effect on employment in the EU27 would be limited, however. The majority of the labour force is employed outside the ETS sectors, such as in the services sectors. Moreover, we did not include any impacts from using the auction or tax revenues to alleviate potential negative employment impacts.

## 4.3 Sensitivity Analysis

### Sensitivity analysis on modelling assumptions

The assumptions in our Reference Scenario and policy options obviously affected the results of the model simulations. Therefore, first a sensitivity analysis was performed for the following fundamental assumptions:

- the rate of economic growth in the EU;
- the continuation of the EU ETS beyond 2020;
- the discount rate used for future emission prices.

Furthermore, we included some sensitivity analyses on assumptions directly related to recent changes as considered for the current functioning of the EU ETS system:

- how to include international aviation into the ETS;
- whether or not the link between the EU ETS and the Australian emission trading system will be established.

Finally, we include a sensitivity analysis specifically related to only one option:

- the price floor level in the auction reserve price option.

Motivation and implementation of this sensitivity analysis differed across these cases. First of all, the Reference Scenario assumes GDP in the EU to increase annually by 1.8% on average. Because of the current economic situation in the world, and in particular within the EU, this level may be somewhat optimistic. Therefore, we assessed the potential impact of a lower economic growth rate (i.e. 1.3%) in the EU on the reform options. We applied our low growth scenario by adapting the macro total factor productivity (TFP) growth rate in the WorldScan model for the EU in such a way that a lower GDP growth rate would be realised.

Second, the Reference Scenario shows the relevance of a continuation of the ETS beyond 2020, combined with the possibility of banking, to the generation of demand for EU ETS allowances and related influence on the emission price, also before 2020 (see Section 3.3). The current low market value of allowances, however, is likely to reflect that traders also consider the possibility of the ETS not being extended beyond 2020. Therefore, we also assessed the potential impacts of not continuing the EU ETS beyond 2020.

Third, the possibility of banking allowances for future use was implemented in our model by assuming that a cost-efficient allocation of emission allowances over time would require the emission price to increase annually at a rate equal to the 8% rate of return on capital in the model. Neuhoff et al. (2012), however, argue that different actors require different rates of return and therefore the discounting of future carbon prices may range from 5% to between 10% and 15%. Therefore, we assessed the impact of using a lower (5%) and a higher (12%) discount rate on the emission reduction and emission prices in our model simulations.

The following two sensitivity analyses refer to current debates on including international aviation and linking the EU ETS to the Australian system. To analyse the consequences of how to include international aviation into the EU ETS for our modelling results, we assessed the impact of the assumption that only the emissions (and corresponding allowances) related to flights within the EU ('intra-EU flights') would be included. Finally, the Reference Scenario assumes a one-way link between the Australian carbon pricing mechanism and the EU ETS. Negotiations on a two-way link between the two systems, however, have not yet started. To reflect this uncertainty we analysed the consequences for the model results of not taking into account the demand for EU ETS allowances by Australian firms.

The last sensitivity analysis considers the level of the floor price, which is the most important factor with respect to the introduction of an auction reserve price. Here, we explored the effect of not using the middle of the price range from the Roadmap 2050 scenarios from the European Commission (EC, 2011c) (of EUR 15 in 2013, increasing to EUR 25 in 2020 and EUR 50 in 2030), but instead we used the lower end of this price range, which implies price levels of EUR 10 in 2013, EUR 16.5 in 2020 and EUR 36 in 2030.

### Changes to Reference Scenario

Adjusting the assumptions not only affected the simulation results for the reform options, but also those for the Reference Scenario. To show the impact on the Reference Scenario, Table 10 compares the cumulative amount of emissions over the 2013–2030 period for the original Reference Scenario to that under the Reference Scenario, adjusted for the various assumptions considered in the sensitivity analysis.[5] Interestingly, changes in the main assumptions did not change the cumulative amount of emissions except for the case with a low discount rate.[6]

Obviously, cumulative emissions did not change for the low economic growth scenario. The same mechanism that frustrates current functioning of the EU ETS applies, but even more strongly. With lower GDP growth, the demand for allowances substantially decreases and as long as total supply of EU ETS allowances does not change, the allowance price will drop significantly.

Table 10
**Sensitivity analysis – effects on ETS emissions* and emission prices in the Reference Scenario**

| Original Reference Scenario | Sensitivity analysis: Lower economic growth: 1.3%/yr | No ETS beyond 2020 | Lower discount rate: 5% | Higher discount rate: 12% | International aviation: intra-EU only | No link with the EU ETS of Australia |
|---|---|---|---|---|---|---|
| *Cumulative emissions in the EU ETS 2013–2030 (original Reference Scenario = 100)* | | | | | | |
| **100** | 100 | 129 | 102 | 100 | 103 | 102 |
| *Emission prices in 2020 (EUR $_{2010}$/t$CO_2$)* | | | | | | |
| **19** | 10 | 6 | 20 | 17 | 16 | 18 |

* *Emissions include those from EFTA countries under in the ETS; emissions from international aviation are not included.*

Without a continuation of the ETS beyond 2020, emission prices will decrease. The scarcity on the ETS market which in our Reference Scenario mainly results from an expected demand for allowances in the period beyond 2020, would thus largely evaporate.

Changing assumptions on the discount rate, initially, altered the development of the emission price path over time in the model simulations (see Annex IV). Because of our assumption that the total supply of EU ETS allowances would be depleted by the end of 2030, an adjusted discount rate also changed the level of the emission price in 2013. A lower discount rate resulted in a higher emission price in 2013 but in a lower emission price in 2030. The opposite applied to a higher discount rate (see Annex IV). Around 2020, emission prices would be about the same for the different discount rates.

The 2% higher emissions in the low discount scenario relative to the original Reference Scenario can be explained by the change in the demand for EU ETS allowances by Australian firms. Because of the higher price in 2013, the price of EU ETS allowances is higher than the allowance price of the Australian emission trading system.[7] In contrast to the original Reference Scenario, no Australian demand for EU ETS allowances exists in the low discount rate scenario. With this price level, it would be more efficient for Australian firms to reduce emissions domestically. These EU ETS allowances (about 600 million in total) then would stay within Europe, allowing European firms to emit about 2% more than in the original Reference Scenario. A higher discount rate would result in a lower price for allowances in 2013 and would not affect the (restricted) Australian demand for EU ETS allowances. Therefore, the total amount of emissions in the Reference Scenario is the same in both the original version and the high discount rate scenario.

The two cases for current adaptations of the design of the EU ETS (i.e. including international aviation and linking the EU ETS with the Australian system), clearly would have an impact on the ETS market. Assuming that inclusion of international aviation in EU ETS would only apply to intra-EU flights would limit the net demand for EU ETS allowances from international aviation to only 26% of the net demand in the Reference Scenario (EC, 2012a).[8] Indeed, with net demand for EU ETS allowances by international aviation reduced by about 1.1 billion, the emission price would decrease and emissions in this Reference Scenario would be 3% higher than in the original Reference Scenario.

The impact of *not* taking the demand for EU ETS allowances by Australian firms into account has a very similar effect. This more limited scope would also reduce demand for EU ETS allowances. Its smaller impact on emissions and the emission price would be due to demand for allowances decreasing by a smaller amount (about 600 million). Consequently, the price of allowances would decrease to EUR 18/t$CO_2$ and emissions would be 2% higher than in the original Reference Scenario.

## Impact of the reform options

Table 11 shows the effects on emissions and emission price, for our sensitivity analysis for two policy options only: that of increasing the ETS target (1a) and the auction reserve price (5). These two options not only reflect the most pronounced effects on emissions and emission price, but also reflect a fundamental difference in their approach to ETS reform; variant 1a leaves the basic principle of the ETS as a quantity instrument intact, whereas option 5 changes ETS into a tailored combination of a quantity and price instrument. Subsequently, the impact is discussed of the differences in assumptions between both policy options relative to the adjusted Reference Scenario. Results are presented for both options relative to the adjusted Reference Scenario (first column is similar to the results presented in Table 5).

Table 11

**Sensitivity analysis – effects of ETS reform on ETS emissions[a] and emission price**

| Original scenario | | Sensitivity analysis | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Lower economic growth: 1.3%/yr | No ETS beyond 2020 | Lower discount rate: 5% | Higher discount rate: 12% | International aviation: intra-EU only | No link between the EU ETS and Australia | Lower end price range Roadmap 2050[b] |
| *Change in cumulative emissions (% to adjusted Reference Scenario)[c]* | | | | | | | | |
| Increasing the ETS target (1a) | **-6.2** | -8.1 | -2.7 | -8.0 | -8.1 | -6.1 | -8.0 | -6.2 |
| Auction reserve price (5) | **-4.7** | -15.3 | -16.7 | -6.5 | -4.6 | -7.8 | -6.5 | 0.0 |
| *Emission price 2020 (EUR $_{2010}$/t$CO_2$)* | | | | | | | | |
| Increasing the ETS target (1a) | **26** | 17 | 8 | 27 | 26 | 22 | 26 | 26 |
| Auction reserve price (5) | **25** | 25 | 25 | 25 | 25 | 25 | 25 | 19 |

[a] *Emissions include those from EFTA countries included in the ETS; emissions from international aviation are not included.*

[b] *This relates to changing assumptions on the auction reserve price, which does not affect the results for the Reference Scenario and for the option of increasing the ETS target.*

[c] *The change in emissions relates to those in the Reference Scenario, which has been adjusted according to the relevant assumptions.*

## Lower economic growth

It is particularly interesting to observe the impact of both policy options under the low growth scenario relative to their respective Reference Scenario. In fact, they show similar, though still somewhat different impacts compared to their impact under the original assumptions, and the impact is much more pronounced under low growth for the auction reserve price. First of all, increasing the ETS target (1a) would induce larger reductions relative to the low-growth scenario at lower ETS prices. This is surprising on the face of it because the supply of allowances does not differ between the original assumptions on economic growth and the low growth case. The linkage to the Australian emission trading system creates an additional option, however, and therefore higher demand from Australian firms to buy EU ETS allowances. Indeed, at the relatively high allowance price of EUR 26/t$CO_2$ with the increasing ETS target under the original assumption on economic growth, no demand exists from Australian firms for EU ETS allowances. In the low-growth scenario, the much lower allowance price of EUR 17/t$CO_2$ would induce Australian firms to buy EU ETS allowances instead of reducing emissions themselves. Due to this external demand for EU ETS allowances, European firms would have to reduce more of their emissions than according to the ETS cap. This impact is restricted to 600 million EU ETS allowances which is the total that Australian firms are allowed to use over the 2015–2030 period.

Second, our sensitivity analysis for the auction reserve price also reconfirmed the large difference between both policy options. Because the price floor does not change in this case, the auction reserve price (option 5) has a much stronger impact in the low growth scenario and induces much more emission reduction relative to a Reference Scenario with a lower GDP growth rate. Emissions accumulated over the 2013–2030 period decrease by 15% relative to the low-growth Reference Scenario, whereas under the original assumptions on economic growth this was only 5%.

## No ETS beyond 2020

Our results for the scenario without an ETS beyond 2020 indicate that increasing the ETS target would be of little help to improve the EU ETS. Due to the large surplus of allowances passed on from the second trading period (2008–2012), increasing the ETS target would only result in a small increase in allowance scarcity and cause the emission price to remain relatively low. As with lower economic growth, the effect of the auction reserve price would be significantly different, because the price floor does not change. Compared to the Reference Scenario without ETS beyond 2020, the auction reserve price would more than quadruple the emission price by 2020. As a result, this option would lead to a significant emission reduction. The auction reserve would bring emissions down by almost 17% relative to the Reference Scenario without an ETS beyond 2020.

## Discount rate

Our results for both options (i.e. increasing the ETS target and the auction reserve price) proved to be almost insensitive to variations in the discount rate (see Table 11).

The slight difference in cumulative emissions between the policy options, relative to their respective Reference Scenario, is only due to the role of a link between the EU ETS and the Australian system. We already know that a lack of demand from Australia would explain the larger reduction in emissions relative to the original Reference Scenario for the low discount rate. This would not change under the reform option of increasing the ETS target. As in the case of the original assumption on the discount rate, increasing the ETS target would result in an EU ETS allowance price higher than that in the Australian emissions trading system. Therefore, despite the fact that the emission *level* with an increasing ETS target would be the same in both the original and the low discount rate scenario, relative to the original Reference Scenario *with* demand from Australia this implies a reduction of 6%, whereas relative to the low discount rate Reference Scenario *without* demand from Australia this implies a reduction of 8%. The difference in the ETS price reflects the different development of the emission price over time, as discussed before.

For a high discount rate, this would be the exact opposite. In that case, the EU ETS allowance price would fall below the Australian allowance price, even under the option of increasing the ETS target (1a). Because of the Australian demand for allowances, European firms would reduce more emissions than without such a demand.

Under the option of an auction reserve price, the overall level of emission reductions over the 2013–2030 period would hardly differ between the original Reference Scenario and the low or high discount rate scenarios. Reductions relative to the Reference Scenario would only be due to differences in Australian demand.

### Demand for allowances by international aviation

The impact of both policy options in this particular case is in line with expectations. Under the option of increasing the ETS target (1a), cumulative emission reduction relative to the Reference Scenario would remain similar to the effect under the original assumptions, but with lower prices, whereas the opposite holds for the auction reserve price. The relative reduction in emissions under this option would be similar, because net demand for EU ETS allowances by international aviation would decrease under the adjusted Reference Scenario, as it would under the option of policy reform. Due to the reduced demand, this reduction is associated with a lower EU ETS allowance price than under the original assumptions. This also explains why an auction reserve price (option 5) would result in larger emission reductions; because the price floor remains at EUR 25/t$CO_2$, the difference with the allowance price under the adjusted Reference Scenario with less demand from international aviation (EUR 16/t$CO_2$) would be larger than under the original Reference Scenario (EUR 19/t$CO_2$).

### Australian demand for EU ETS allowances

Under the particular condition that no link with the Australian ETS would be established, we found no impact on EU ETS prices. As described before, with the original assumptions, the option of increasing the ETS target (1a) already would result in no Australian demand for EU ETS allowances because of the high price. Hence, the emission level and prices found for this option are not affected by adjusting the assumption on having a link with the Australian system. As the emission level under the adjusted Reference Scenario would be higher without the Australian link than under the original Reference Scenario, emission reductions *relative to* this adjusted Reference Scenario would be higher. This also holds for the option of having an auction reserve price (option 5).

### Price floor level

Obviously, changing the level of the auction reserve price only affects the results for the auction reserve price (5) option. Because, in the case of a lower auction reserve price, the price floor would be below that of the Reference Scenario, the introduction of a price floor would have no effect on emissions relative to the Reference Scenario. With this level of price floor, it is no longer binding and emissions are auctioned at a price that is above the price floor. This result clearly confirms the importance of the chosen price floor level because of its impact on the market.

### Sensitivity analysis also illustrates the importance of a well designed EU ETS

Our sensitivity analysis clearly illustrates that the functioning of the EU ETS strongly depends on its design, and that the differences between options for structural adjustments are of great significance. In particular, analysis of the low-growth scenario confirms that an auction reserve price would lead to considerable additional emission reduction, and its implementation would also be justified to deal with demand shocks (see Text box 2). Although increasing the EU ETS target also would induce more emission reduction, its impact would be much smaller under a low-growth scenario. Such an adjustment in the supply of allowances would not entirely compensate for the much lower demand for allowances. This impact of having an auction reserve price was also found for other cases of low levels of demand in the adjusted Reference Scenario, albeit less pronounced.

Differences in discount rates did not seem to have much of an impact on our results. We did find some differences – in particular, under the low discount rate scenario, but these impacts are mainly due to the interaction between the EU ETS and the Australian ETS. Our main findings were hardly affected by these differences. However, their impacts in fact do illustrate another aspect of design, which was also visible in the other scenario that relates to the scope of ETS, namely the inclusion or exclusion of liquid fuels from road transport (see Section 4.1). A wider scope usually offers participants the option of being able to choose between abating emissions or buying allowances, and this implies more flexibility for them to exploit cheaper reduction options. This increased flexibility is exactly the reason to use the EU ETS: the exploitation of cheaper abatement options to reduce the costs related to $CO_2$ emissions.

## Notes

1 The share of free allocation of allowances in the total supply of EU ETS allowances decreases over time (see Annex II).

2 With a fifth trading period, i.e. beyond 2030, this reserve would flow back into the market. This is likely to keep EU ETS at its (rising) minimum floor price.

3 As the pattern of emission reductions over time is not the same for the various options, presenting the carbon leakage for a specific year is not informative.

4 The Hicksian Equivalent Variation of a policy case measures the amount of money by which the income of households in the Reference Scenario should change to attain the same change in utility level as caused by the policy measures in this case (see also Annex I).

5 Obviously no differences exist with respect to the cumulative impact as well as price in the Reference Scenario for the sensitivity analysis of the price floor assumption.

6 Note that this indicator on cumulative emissions does not take different time profiles of the emissions into account. Such different profiles might be important from a cost-benefit perspective but fall outside the scope of the analysis in this report.

7 As emission prices are assumed to increase by the same rate in EU ETS as in the Australian emissions trading system, the EU ETS allowance price remains above the Australian emission price during the entire 2013–2030 period.

8 Note that the demand for allowances related to international aviation has been added exogenously to the EU ETS market in the simulations with the WorldScan model (see Section 3.2). Total net demand over the entire 2013–2030 period in the original Reference Scenario amounts to 1.4 billion allowances (see Annex III).

FIVE

# Discussion

The previous chapters have evaluated the impacts of a number of options to structurally reform the EU ETS. This chapter discusses the results from model simulations and puts them into a broader perspective. First, the main findings from our modelling exercise with respect to the Reference Scenario are assessed, followed by the simulation results for the various options for reform, along the lines of the four categories mentioned before:

1. Adaption of the existing, agreed upon cap, or reduction in the amount of allowances;
2. Expanding the ETS scope (i.e. increasing the number of ETS sectors);
3. Changing the current cap-and-trade instrument into a tailored combination of a quantity and price instrument (e.g. by guaranteeing a long-term 'price collar' or using a national flexible carbon tax);
4. Combinations of *different* instruments (e.g. combining the options that use a carbon tax to imitate the effect of having a minimum price floor).

First, the extent to which these categories would make the EU ETS more robust is discussed, followed by an evaluation of the relative importance of these structural changes for the functioning of the ETS from a broader perspective.

## 5.1 Main findings from a quantitative assessment of the various options

### The Reference Scenario illustrates the importance of extending the ETS beyond 2020

To quantitatively assess the effects of reform options using the WorldScan model, we defined a Reference Scenario for the 2013–2030 period. As described in Section 3.2, this Reference Scenario builds on a consistent set of assumptions about macroeconomic developments and fossil-fuel prices of the World Energy Outlook (WEO-2011) of the International Energy Agency (IEA). Moreover, it includes the main aspects of the current EU ETS; in particular, including taking over a large surplus of allowances from the second trading period, the supply of allowances in the 2013–2020 period and between 2020 and 2030 as well, and the possibility of banking allowances for future use, although not beyond 2030. This assumption implies above all that also the emission reductions follow the policy targets as reflected by the development of the cap.

Our Reference Scenario clearly illustrates that the mere continuation of the ETS beyond 2020 in combination with the possibility of banking would generate demand for allowances and would increase the emission price to a level of EUR 43/t$CO_2$ by 2030. Notwithstanding the increasing surplus of allowances up to 2020, due to the large oversupply from the second trading period, the allowance price is expected to increase from EUR 11/t$CO_2$

in 2013 to EUR 19/t$CO_2$ by 2020. The main reason for this would be that firms anticipate an increasing allowance scarcity beyond 2020. This also indicates that current low EU ETS prices not necessarily reflect a structural lack of scarcity, but also uncertainty in the ETS market about the continuation of the ETS beyond 2020. Indeed, others also indicate the importance of certainty about the range of emission reductions required, in the longer term (e.g. Fankhauser and Hepburn, 2010; Grubb, 2012).

Our sensitivity analysis, using a low growth scenario, indicated that, even with a fourth EU ETS trading period, the current ETS design would not be robust enough to adapt to substantial exogenous shocks, such as a much slower economic growth rate than expected. Although the amount of emission reductions realised would not be affected, a significant slowdown of the economy will have a large negative impact on the emission price.

### Reducing the allowance supply would reduce more emissions and boosts emission prices

By adjusting the quantity of allowances, the options that reduce the EU ETS cap follow the original setup of the EU ETS as a quantity-only instrument. Not surprisingly, the impact differs according to the amount of allowances withdrawn from the total supply during the 2013–2030 period. For instance, the options that would bring the ETS cap in line with the emission reduction pathway as put forward in the EU Roadmap 2050 (1a and 1b) induce the largest decline in emissions as well as the highest emission price. The price in this case would increase to EUR 58/t$CO_2$ by 2030.

Different ways of reducing the supply of allowances, either through a higher annual reduction factor which applies to the entire 2013–2030 period or the setting aside of part of the allowances that would have been auctioned in the 2013–2020 period, would have similar impacts. The only thing relevant for their actual impact on both emissions and carbon price would be the total amount of allowances withdrawn.

The sensitivity analysis shows that these kinds of reform options only address the fundamental issue of the robustness of the ETS, in an uncertain world, in an-ad hoc fashion. A negative demand shock from an economic recession would always require some (exogenous) supply adjustment to compensate for the much lower demand for allowances.

### Expansion of the ETS scope provides options for cost efficiency but requires tailored adjustment of existing policies

A wider scope of the EU ETS is only an indirect way to reduce emissions in order to create a stronger price signal. Indeed, sectors not yet included in the ETS do not have the option to choose between emission abatement or buying allowances which implies less flexibility to exploit cheaper reduction options in other sectors. This larger flexibility is exactly the reason to expand the EU ETS: exploit cheaper abatement options in order to reduce the cost of $CO_2$ emissions. So, by expanding the EU ETS to include sectors that face relatively expensive abatement options while also reducing their amount of allowances relative to those under the Reference Scenario, additional scarcity is introduced on the carbon market, and this may cause the carbon price to rise.

This study analyses one important way of expanding ETS scope, namely by including liquid fuels for road transport. As the created shortage in this sector is relatively small (compared with the options reducing supply of allowances), the impact on emissions and emission price would also be relatively small. Overall cost-effectiveness of reducing greenhouse gas emissions in the EU is likely to increase. Indeed, including road transport in the EU ETS would introduce the option of buying abatement at lower cost. This standard cap-and-trade impact has also been illustrated for two cases in our sensitivity analysis in Section 4.3, i.e. international aviation and the linkage with Australia. The larger the scope of the system, the larger the abatement options, and the more likely it is that expensive sectors benefit from cheaper options elsewhere in the system.

### An auction reserve price would make the EU ETS more robust against exogenous supply and demand shocks

Changing the current cap-and-trade instrument into a tailored combination of a quantity and price instrument may reduce uncertainty regarding emission prices and investment signals, while maintaining the advantages of the trading scheme. Indeed, the economic literature provides well-established ideas about hybrid instruments, for example Vollebergh et al. (1997), Hepburn (2006), Fankhauser and Hepburn (2010) and Wood and Jotzo (2011). As long as the floor price exceeds the price level in the Reference Scenario, the introduction of an auction reserve price would induce additional emission reductions. Our analysis shows that an auction reserve price is particularly effective in a period of low economic growth or low scarcity of supply due to shocks. The minimum floor price guarantees a more predictable price path which is particularly helpful for low-carbon technologies facing too much uncertainty with respect to the long-term carbon price. We found that under these conditions the floor price would induce more emission reduction in a period with oversupply relative to a period without.

Our sensitivity analysis also confirmed that the price management option would provide the most certainty on a minimum price signal from the ETS. At a certain level of scarcity on the EU ETS market, an auction reserve price would be redundant and will not have any effect on the EU ETS. However, an auction reserve price would help the ETS to deal with unforeseen events, such as negative demand shocks due to lower economic growth, whereas options that reduce supply would have a much smaller impact in these circumstances. The sensitivity analysis also clearly showed that the level of the floor price is a decisive factor. Note that, for very similar reasons, this tailored combination of instruments would also require a price *ceiling* to prevent allowance prices from increasing above a predefined level in case of positive demand shocks (see also Fankhauser and Hepburn, 2010; Wood and Jotzo, 2011).

### Using combinations, such as of a carbon tax and the ETS, requires these to be tailor-made

One of the main insights resulting from our analysis of indirect or different instruments to create price incentives on the ETS market is that tailored combinations are essential. Both of our tax–ETS combinations proved to be highly ineffective in improving the EU ETS. For instance, the option for a national flexible carbon tax is a tailored combination of the ETS with a $CO_2$ tax on energy use by all ETS sectors in the Netherlands only, but it is still not so well tailored in the context of the EU climate and energy policy because the $CO_2$ tax is only introduced in the Netherlands without any adjustment in the total supply of ETS allowances in the EU. As a result, the additional reduction within the Netherlands induced by the higher price on emissions would be cancelled out by an increase in emissions in other Member States. Also, the other option of an EU-wide $CO_2$ tax on energy use for all sectors in fact would introduce a non-tailored combination of instruments. This option introduces an emission price *besides* the price on emissions already obtained through the ETS. The $CO_2$ tax directly induces abatement and therefore emission reductions. This, in turn, considerably reduces demand for EU ETS allowances. If the supply of allowances is left unchanged, the price of EU ETS allowances collapses. So, the separate carbon tax simply takes over the entire role of EU ETS unless the emission reduction pathway for the allowances would be reduced *in addition*. Although the idea behind the introduction of a European $CO_2$ tax on energy use is to introduce an emission price without directly changing the EU ETS, the option simply acts as a substitute. Moreover, our calculations show that this option is clearly less effective in reducing emissions than the auction reserve price. Note that this combination could still function properly, but only if the cap within the EU ETS would be reduced considerably as well.[1]

## 5.2 Towards structural ETS reform?

### Reform necessary for the ETS to remain a key EU instrument to reduce $CO_2$ emissions

With its clear reduction pathway for $CO_2$ emissions up to 2020 and beyond, the EU ETS is a key instrument of EU climate policy. It provides a cost-effective way of reducing industrial greenhouse gas emissions from a variety of sources. The EU ETS is intended to internalise the social costs of $CO_2$ emissions at least partly in market prices which also promotes further investment in low-carbon technologies that contribute to the EU's long-term target of a low-carbon society by 2050 (EC, 2011c).

However, the economic downturn in Europe, but also impacts from complementary policies on renewable energy and energy efficiency through subsidies and standards have had a strong downward pressure on the price. Increasingly, people raise doubts whether the EU ETS provides a proper price signal for investments in low-carbon technologies, in particular because of its much lower than expected price and its volatility. Moreover, the price is likely to be low for a long time which fuels doubts whether the ETS will remain the central policy instrument in the long term. This may, in turn, increase existing uncertainty and is likely to have a negative impact on further investments in low-carbon technologies.

The current situation at the ETS market illustrates that the EU ETS design is not robust because ETS is not flexible enough to adapt to unforeseen events, such as a lower demand due to disappointing macroeconomic development, changing relative fuel prices and the effect of complementary policies (see also Grubb, 2012). Other, comparable cap-and-trade programmes that were introduced more recently (e.g. California and Australia) do contain provisions that reduce price uncertainty (volatility). Our analysis has shown that several options for structural reform do exist at relatively small macroeconomic costs.

### Auction reserve price is the best reform option from an efficiency perspective

The various reform options in our analysis have in common that they reduce emissions and cause the emission price to increase, but to a different extent. Moreover, differences exist between categories of reform options in their contribution to the robustness of the EU ETS. Reducing the supply of EU ETS allowances through adaptation of the cap would further reduce emissions and boost emission prices as a consequence, but provide only ad-hoc solutions to the fundamental issue of the robustness of the EU ETS in an uncertain world. A new occurrence of unforeseen events (such as a further deterioration of economic situation) again requires an adjustment of allowance supply. Expanding the scope of the EU ETS may be useful to improve cost efficiency of reducing overall (ETS and non-ETS) greenhouse gas emissions in the EU, but is less effective in providing a structural solution for the robustness issue. Only a long-term 'price collar' (floor and ceiling) provides a more predictable price path while maintaining the advantage of a cap-and-trade system in delivering the required emission reduction in a cost-effective way. A price floor (e.g. effectuated by an auction reserve price) makes the EU ETS more robust against shocks that reduce scarcity at the ETS market. A carbon tax on energy use also reduces uncertainty about the prevailing emission price. The combination of a uniform carbon tax on fossil fuel inputs and the ETS, however, is not tailored and therefore ineffective in improving the EU ETS. The carbon tax may even take over the entire role of the ETS.

Moreover, a major effect of introducing a floor price is not covered in our model calculations. By reducing uncertainty in the market about the emission price, a floor price not only causes an increase in the emission price itself, but also affects risk expectations of firms which is likely to have an additional effect on investment behaviour of firms. Indeed, the EU ETS basically offers investors the option *not* to invest in low-carbon technologies if the expected price of allowances is low enough, because they can always buy allowances (Grüll and Taschini, 2011). This implies that with current low allowance prices, the EU ETS poses in itself an additional hurdle to investment in low-carbon technologies. This might require a design of policy instruments that reduce this type of policy uncertainty by 'built-in' commitment (Gerlagh and Liski, 2011). 'Price collars' seem to provide such a commitment because they contain ex ante information about the intentions of the policymakers in the long term. This reduces policy uncertainty, which is likely to result in lower risk premiums on investments in emission reduction measures. Both a higher carbon price and a lower risk premium will make investment in low-carbon technologies more attractive. As uncertainty is not addressed in our model, we are likely to underestimate this effect on emissions.

We conclude that an auction reserve price is the reform option that provides the best opportunity to structurally reform the EU ETS and make it more robust for unforeseen events. Also other cap-and-trade systems in the world, such as in California and Australia, have a minimum price. Moreover, price floors (and ceilings) for emission trading have a sound scientific basis.

### Macroeconomic and distributional impacts of reforming the EU ETS

Our analysis of the reform options has also shown that the macroeconomic impact of the reform options is rather limited in terms of changes in economic welfare and shifts in sectoral production. The welfare costs measured as loss in utility derived from consumption are generally not larger than 0,1% in 2020 for the various reform options. Differences between Member States can be more substantial, however, and vary between the different options. Obviously also the impact on different sectors varies and depends mainly on the level of the emission price. In general, a higher emission price also implies a larger decrease in production in the polluting ETS sectors. In general the sectors with fossil-fuel-intensive production are affected the most; in particular, those of power generation and base metals. Non-ETS sectors, to some extent, are also indirectly affected by the ETS reform options, mainly due to the increased cost of electricity, but the effects are generally small.

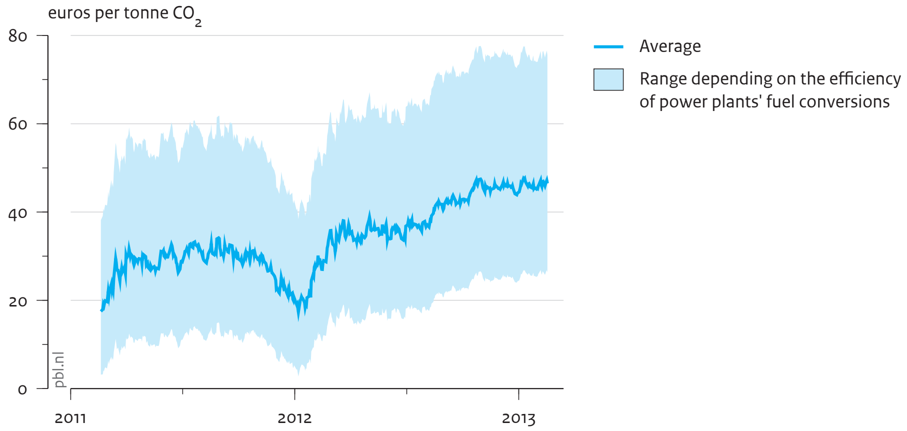
The additional emission reduction within the EU indirectly affects emissions outside the EU. Indirect emission-reduction effects of EU climate policies are likely to cause emissions in the rest of the world to increase. Although this impact may have been somewhat overestimated by models such as WorldScan (Fullerton et al., 2011), for most reform option, we found an increase in emissions elsewhere that would equal about 60% of the reduction achieved within the EU. The only option that would cause a larger leakage effect would be the introduction of an EU-wide $CO_2$ tax, because of its broader scope also outside the ETS, which in turn has a larger impact on all fossil fuels.

Although the overall welfare loss of increasing the ETS target does not change, compensating firms for the increased cost of the ETS by a more generous free allocation and indirect cost compensation (variant 1b) would mitigate the impact of ETS reform on energy-intensive production sectors. This was not further investigated in our model simulations, but these results do indicate that a directed recycling of auction revenues can be directed to unwanted distributional effects as well as competiveness (see also Bovenberg and Vollebergh, 2008).

### The role of fuel prices and international climate policies

Our results are based on assumptions of globally increasing fossil-fuel prices as predicted by the WEO-2011. With these fossil-fuel prices, the $CO_2$ prices we found both in our Reference Scenario and reform options would still be too low to cause an immediate impact on decisions to invest in new, efficient power plants or other

Figure 10
**$CO_2$ price level that induced UK power plants to switch from coal to natural gas**




Source: Point Carbon (2013)

low-carbon technologies, such as wind turbines and solar panels (Smekens et al., 2011). For instance, $CO_2$ prices of more than USD 75[2] would be needed to retrofit newly built coal-fired power plants with carbon capture and storage (CCS) (OECD/IEA, 2012). Moreover, power plants are unlikely to switch from coal to gas with emission prices below EUR 20/t$CO_2$ (see Figure 10). With current power plant efficiencies and coal-to-gas price ratios, the required $CO_2$ price level up to and including 2012 should be substantially higher than $CO_2$ prices currently observed.

Investment in low-carbon technologies, however, also depends on the development of fossil-fuel prices. Recently, improved prospects for the commercial production of unconventional gas ('shale gas') have significantly affected fuel prices; particularly increasing the difference between the price for natural gas in the United States and in other parts of the world. Obviously, such changes influence investment decisions of electricity producers and other energy-intensive firms. In particular, a downward pressure on fossil-fuel prices makes the non-fossil fuel substitutes even relatively more expensive.

In our WorldScan simulations, it was not possible to take these regional differences in the development of fuel prices into account. The extent to which these developments would have an impact on our findings was outside the scope of our study. Notwithstanding their relevance for the location decisions of firms and decisions on fuel mix in power production in the model calculations, such developments do not have an impact on the overall functioning of the ETS as an incentive *at the margin* to stimulate low-carbon investments, which has been the focus of our study. Indeed, carbon emissions are an environmental externality that requires proper pricing of the social cost. However, the social costs of the emissions of this uniformly mixing pollutant within the EU also depend on reduction efforts elsewhere in the world. Furthermore, in our study, the context of international policies was kept constant. Changing assumptions on (climate) policies in countries outside the EU would affect the simulation results, as well. For instance, Hof et al. (2012) show that welfare losses associated with EU climate policies increase if the emission reduction targets in the rest of the world become less ambitious or are absent. Assuming more ambitious climate policy targets in the rest of the world would have a mixed effect. On the one hand, it will be more difficult for the EU to pass on part of the costs of their climate policies to other countries. On the other hand, welfare losses for the EU would be smaller with higher reductions in other regions, because companies in the EU are very able to maintain or increase their market share if other regions face higher costs to reduce emissions.

## Procedural and political aspects associated with reform options may differ

Another issue are the potential differences in implementation between the structural reform options. Obviously, all policy options that imply adjustments to current ETS legislation would require a decision by European Parliament and European Council of Ministers. This would require a majority of the parliamentary votes and a qualified majority vote in the Council. For some options, however, this could be more complex and thus more time consuming than for other options. For instance, adjusting the linear reduction factor probably would require a full revision of the ETS directive, because it would affect the entire climate and energy package and have a structural impact on the European economy in both the short and long term (EC, 2012f). Setting aside an amount of allowances might be less complex and could be implemented by using the Comitology Procedure, as long as changes to the ETS directive are not required (Egenhofer et al., 2012). Expansion of the scope of the ETS by including fuels for road transport (or any other sector) would require a renegotiation of the EU ETS, while a possible auction reserve price would be an entirely new mechanism to the ETS. This would probably require a range of decisions and procedures that would determine the price level and the actual implementation at the auction platforms.

The use of a unilateral flexible carbon tax in combination with the ETS, in the Netherlands, would simplify decision-making, considerably. Instead of lengthy and complex European decision-making procedures, a Member State could decide to introduce such a system nationally, as the case of the United Kingdom illustrates. This could possibly lead to a coalition of countries willing to set certain price floors (Grubb, 2012). National policies, however, could impede the further integration of energy markets. Introducing a real European $CO_2$ tax would be much more complicated as this requires unanimity among EU Member States. The current, difficult negotiations on the revision of the Energy Taxation Directive indicate that the introduction of a European $CO_2$ tax may be too ambitious.

An evaluation of the extent to which the different options would require a full revision of the ETS directive, or assessing the potential differences in implementation costs, was outside the scope of our study. If speed of implementation were an important criterion, which seems the case considering the current state of the ETS, the implementation of a permanent set aside seems the most attractive option. However, whether this will materialise is rather uncertain as the decision-making process on the backloading proposal is lengthier than anyone within the EC has probably foreseen.

### Interactions between different policy instruments

If, at some point, the use of a regulatory quantity instrument, such as an emission trading system, would produce disappointing results, policymakers could become tempted to add other instruments. This, however, may create considerable additional complexity and hence regulatory costs; in particular, if these instruments are not very well tailored to each other. Meanwhile, the same result could very well be achieved through some minor adjustments to the regulatory instrument. Obviously, a combination of instruments can be very useful if their effects are complementary and not substitutional. For example, combining an emission trading system with an environmental tax could provide proper marginal incentives across the economy while the combination would save on transaction costs (Vollebergh et al., 1997).

However, tailored policies are far from easy to implement in practice – of which the EU ETS is a clear example. This system is part of the wider package of instruments envisaged to implement the energy and climate package. The policies in this complementary area would also significantly affect the demand for EU ETS allowances. In this study we did not address the full complications involved in the design and evaluation of the energy and climate package of the EU. For instance, we did not evaluate all dynamic implications of the EU ETS and its role in the entire package for the EU Roadmap. Instead, we kept assumptions on other policies constant in our comparison of reform options (see also Section 3.2). Interaction of other policies with the ETS were been addressed explicitly in our sensitivity analysis, because the focus of this study has been to compare the impact of various policy options. For this reason, we kept exogenous parameters, such as other elements of the climate and energy policies, constant in order to better understand their implications. Even without specific model simulations that would have changed these assumptions, more incentives for renewable energy will further reduce the demand for EU ETS allowances, and consequently also reduce emission prices – not only in the Reference Scenario but also all options. However, not many difference are expected *between* the different options, other than the differences discussed in our sensitivity analysis of changing assumptions affecting demand for allowances, such as reducing the demand by international aviation.

Ideally, including road transport into the EU ETS would require adaption of existing (implicit) carbon policies on road transport, such as the Fuel Quality Directive and the existing taxes and levies on fuel consumption. Otherwise such an expansion is likely to induce inefficiencies from interactions between different instruments. However, this point was not considered in our scenario calculations. Moreover, as the inclusion in the EU ETS would enable road transport companies to buy abatement against lower cost, investments in low-carbon technologies within the transport sector may slow down. This may present a conflict with long-term objectives, such as with respect to the transition towards a more efficient and sustainable European transport system, as laid down in the Roadmap 2050.

In fact, interaction between other policies and the ETS is one of the uncertainties around the ETS. In this light, uncertainty and flexibility are main issues to consider in the choice for allowance trading as a policy instrument. These issues are particularly relevant for policy aimed at *long-term* change, as is the case with green growth. Uncertainty is inevitable and plays an important role in policy processes, particularly, in the case of long-term strategies. These policies will need to be adjusted, over time, in response to sudden economic developments, new scientific insights, and the arrival of new technologies, as has been argued before. Thus, there must be some room for discretion to make policy adjustments.

## Notes

1 Note that a stricter cap might indeed be justified if the current price within the EU ETS in combination with the other instruments that implicitly or explicitly price carbon is *below* the social cost of carbon. However, as long as the EU ETS would be a unilateral policy which is more stringent than other regions, such a stricter reduction policy would not be very effective (see Bollen et al., 2012).

2 Roughly corresponding with 60 euros per tonne of $CO_2$.

# Annexes

## Annex I WorldScan methodology & assumptions

### Description of the WorldScan model

The macro-economic consequences of the ETS reform options were assessed using the WorldScan model, which is a multi-region, multi-sector, recursively dynamic computable general equilibrium model with a global scope. A detailed description of the model is given in Lejour et al. (2006). The model has been used for various types of analyses; in particular, with respect to climate change policies. The WorldScan model includes emissions of non-$CO_2$ greenhouse gases and the possibility to invest in emission control by modelling marginal abatement cost curves (MACs) for emissions from each sector. These MACs mainly include 'end-of-pipe' abatement options, removing emissions largely without affecting the emission-producing activity itself (Bollen and Brink, 2012).

WorldScan data for the base year, to a large extent, were taken from the GTAP-7 database (Narayanan and Walmsley, 2008) that provides integrated data on bilateral trade flows and input–output accounts for 57 sectors and 113 countries. The aggregation of regions and sectors can be flexibly adjusted in the WorldScan model. The version used here features 19 regions (8 of which are regions within the EU) and 17 sectors (Table 12). The power sector is divided into 5 technologies: (i) fossil-fuel-fired electricity generation (using coal, oil and natural gas as imperfectly substitutable inputs), (ii) wind (onshore and offshore) and solar energy, (iii) biomass, (iv) nuclear energy, and (v) conventional hydropower (Boeters and Koornneef, 2011).

### The ETS in WorldScan

A relatively disaggregated sector classification is used in this study to come as close as possible to the sectors that are currently subject to the EU ETS. Under this classification, the following six sectors are covered by the EU ETS: Power generation; Base metals; Chemical, rubber, and plastic products; Non-metallic mineral products; Paper, paper products, and publishing; and Food processing, beverages and tobacco. Although it is not a perfect match, the share of total EU greenhouse gas emissions thus attributed to the ETS largely agrees with the share following from reported emissions for 2011. Emissions from fossil-fuel combustion in power generation and the base metals sector can be considered to be fully subject to the EU ETS. For the remaining sectors, this assumption may not hold, as the representation of these sectors in the WorldScan model also comprises activities not covered by the EU ETS (such as publishing as opposed to paper production). Auction revenues from the sale of EU ETS allowances are redistributed in lump sum payments, i.e. without changing the behaviour of firms or households. Free allocation of EU ETS allowances to the manufacturing industry is modelled according to a lump sum allocation to firms. To largely reflect the EU ETS allocation rules based on benchmarks of greenhouse gas emissions performance, the allocation of allowances was based on the emission performance of each sector in 2010. In the WorldScan model, there is one representative firm per sector within a region, so the emission performance of a specific sector does not differ within a region, but there may be differences between regions. As a benchmark for a specific sector, we used the emission performance in the region where in 2010 this sector was the most efficient within the EU.

Firms maximise profits, given the demand for their products and production technologies. Firms that maximise profits will pass on all of the costs of emission allowances to their customers, realising profits at the expense of some loss of market share. A detailed analysis of the economic theory of the EU ETS in relation to passing on the costs can be found in De Bruyn et al. (2010). They show that this is not only the case if allowances are auctioned, but also if allowances are freely allocated. Indeed, profit maximising firms will also pass on the opportunity costs of allowances if they are obtained for free. The main difference between free bulk allocation and an auction or a tax is the effect on firm profits: free allocation corresponds to a wealth transfer, which increases profits compared to an auction. Therefore, free allocation or auction of the allowances do not differ in their effect on competitiveness as long as the allocation is in bulk and companies are assumed to incorporate the opportunity cost of free allowances into their price setting (see also Bollen et al., 2011). If, however, the free allocation is not in bulk but related to the firms' decisions on production, the cost impact of emission

Table 12

**Overview of regions, sectors, technologies and production inputs in the WorldScan model**

| Regions | Sectors[a)] | Inputs |
|---|---|---|
| Germany | Agriculture | |
| France | Mining | Low skilled labour |
| United Kingdom | Oil | Highly skilled labour |
| Italy | Coal | Capital |
| Netherlands | Petroleum and coal products | Land |
| Other EU15 | Natural gas | Natural resources |
| Poland | **Power generation** | |
| Rest of EU27 | **Base metals** | *Non-electricity energy carriers* |
| EFTA countries | **Chemical, rubber, and plastic products** | Coal |
| Russia | **Paper, paper products, and publishing** | Petroleum, coal products |
| United States | **Non-metallic mineral products** | Natural gas |
| Japan | **Food processing, beverages and tobacco** | Modern biomass |
| Australia | Other consumer goods | Biodiesel |
| Brazil | Capital goods and durables | Ethanol |
| Middle East and north Africa | Road and rail transport | |
| China (incl. Hong Kong) | Other transport | *Other intermediates* |
| India | Other services | Agricultural products |
| Other OECD | | Minerals |
| Rest of the World | *Power generation technologies* | Crude oil |
| | Conventional fossil fuel (without CCS) | Electricity |
| | Fossil fuel with CCS | Base metals |
| | Nuclear energy | Chemical, rubber, and plastic products |
| | Wind | Paper, paper products, and publishing |
| | Biomass | Non-metallic mineral products |
| | Hydropower | Food processing, beverages and tobacco |
| | | Other consumer goods |
| | *Conventional biofuel technologies* | Capital goods and durables |
| | Ethanol | Road and rail transport |
| | Biodiesel | Other transport |
| | | Other services |
| | | Ethanol |
| | | Biodiesel |

[a)] *ETS sectors are denoted in bold.*

trading will be reduced because then the allocation will include a subsidy element (see Bovenberg and Vollebergh, 2008).

Environmental policies were simulated in the WorldScan model by the introduction of a carbon price; either directly or by imposing a restriction on emissions. For emissions directly related to the use of a specific input, such as fossil fuels, the carbon price will lead to an increase in the user price of this input. Consequently, the demand for this input will decrease (either by using less energy or by substituting more carbon emitting fuels by less emitting ones), leading to a reduction in emissions. As a result of these changes, production costs will increase. For emissions related to sectoral output levels, the carbon price will cause a rise in the output price of the associated product. The increase in the output price will lead to a decrease in demand for this product (as consumers substitute goods that become more expensive by other goods), which will reduce emissions. Moreover, if emission control options are available, these will be implemented up to the level where the marginal cost of emission control equals the emission price.

To assess welfare effects, the concept of (Hicksian) equivalent variation (EV) was used, providing a cardinal welfare measure. The EV is defined as the amount of money by which household income in the baseline situation B should change to attain the utility level of an alternative situation V in which prices have changed, e.g.

due to policy measures. As not only changing prices but also changes in income will affect the utility level, this welfare measure is related to other indicators that are often used, such as change in GDP, consumption and national income.

# Annex II Supply of allowances

## Supply of allowances and credits in the Reference Scenario

The supply of allowances in the ETS is determined by several factors. The total supply of EU allowances (EUA) was calculated with a pre-determined amount for 2013, combined with a linear reduction factor that reduces the annual supply, linearly. For stationary ETS installations, the level in 2013 will amount to 2.082 billion allowances (EC, 2012a). This amount was derived from the average supply during the 2008–2012 period, plus an estimation for additional supply for new installations. In the Reference Scenario, the linear reduction factor, according to current ETS legislation, was determined at 1.74%. For aviation, the supply of EU allowances is fixed during the entire trading period from 2013 to 2020, at 95% of historical emissions (determined by the EC at 221 million tonnes of $CO_2$). In this study, we assumed the supply for aviation in the 2021–2030 trading period to equal that of the former trading period. In various policy options on ETS reform, adjustments were made to the supply of allowances. These adjustments are described in Section 3.4.

## Allowances sold at auction, handed out for free or kept in a new entrants reserve

From the total amount of EU allowances for stationary installations, 5% is reserved for new entrants and/or substantial enlargements of production capacities of existing installations. The remaining 95% of allowances is distributed to installations either through auction platforms or by handing them out for free based on benchmarks. In our study, we used the figures that where estimated by the EC (2012a) for the 2013–2020 period. We extrapolated the trend in that period to the next trading period, from 2021 to 2030. For Member States in transition (mostly eastern European countries), a transitional arrangement exists for the allocation of free allowances to power producers, up to 2020. This enables Member States with relatively many old, carbon-intensive power installations to hand out allowances for free instead of the principal that power producers should buy all their allowances at auction. This arrangement is not mandatory for Member States to apply and, at the moment of writing this report, the extent to which allowances will be handed out for free instead of being auctioned was uncertain. This study therefore followed the EC's assumption of 2012 (EC, 2012a).

Furthermore, the supply of allowances is affected by the new entrants reserve (NER300) programme and by early auctioning. For the NER300, 300 allowances were deducted from the NER for the 2013–2020 period and auctioned in the years 2012 (200 million) and 2013 (100 million). In our study, we distributed the remaining NER evenly over the 2014–2020 period. The early auctioning of 90 million allowances in 2012 was deducted from the allowances to be auctioned in 2013 and 2014 (the intention was to auction 120 million before 2013; therefore, an additional 30 million allowances will be auctioned in 2013). For international aviation, 3% of the total supply of allowances is part of the aviation NER. This level was also assumed for the 2021–2030 period.

## Allowed use of CDM/JI credits

Beside EUAs, the supply for the ETS is also determined by the allowed supply of credits from CDM and JI projects. The potential use of these credit is based on the assumption that their maximum use, in the 2008–2020 period, by stationary ETS installations will be limited to 1.7 billion allowances (EC, 2012a). Up to 2011, 556 million of these credits were surrendered (EEA, 2012). It is our conservative assumption that 255 million CDM/JI credits were surrendered in 2012 (similar as in 2011), resulting in a total use of 811 million CDM/JI credits in the 2008–2012 period. This means that nearly 889 million credits can be used in the third trading period. We assumed the use to be evenly spread over the 2013–2020 period (111 million credits, annually). For international aviation operators, an additional amount of credits from CDM and JI projects will be allowed. In accordance with the EC, roughly 4 million credits are assumed to be used, annually (EC, 2012a).

Tables 13 and 14 present the detailed data with respect to the supply of allowances in the Reference Scenario.

Table 13

**Supply of EU allowances and CDM/JI credits in the Reference Scenario, 2013–2020**

| *million tonnes of $CO_2$ eq* | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | total 2013-2020 |
|---|---|---|---|---|---|---|---|---|---|
| auctioning (stationary installations) | 1116 | 1104 | 1092 | 1080 | 1067 | 1055 | 1043 | 1031 | 8588 |
| auctioning (aviation) | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 252 |
| | | | | | | | | | |
| transitional arrangement for electricity | -153 | -136 | -120 | -103 | -85 | -65 | -43 | - | -705 |
| | | | | | | | | | |
| total auctioning | 995 | 1000 | 1004 | 1009 | 1014 | 1022 | 1032 | 1063 | 8135 |
| | | | | | | | | | |
| free allocation (stationary installations) | 862 | 837 | 813 | 789 | 765 | 741 | 717 | 693 | 6217 |
| free allocation due to transitional arrangement for electricity | 153 | 136 | 120 | 103 | 85 | 65 | 43 | - | 705 |
| free allocation (aviation) | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 1380 |
| | | | | | | | | | |
| New Entrants Reserve (stationary installations) (Phase III) | 104 | 102 | 100 | 98 | 96 | 95 | 93 | 91 | 779 |
| New Entrants Reserve (aviation) (Phase III) | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 50 |
| | | | | | | | | | |
| total supply (stationary) | 2082 | 2043 | 2005 | 1967 | 1928 | 1891 | 1853 | 1815 | 15584 |
| total supply (aviation) | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 1683 |
| | | | | | | | | | |
| early auctioning Phase III EUAs | -30 | -60 | - | - | - | - | - | - | |
| NER300 | 100 | -43 | -43 | -43 | -43 | -43 | -43 | -43 | - |
| | | | | | | | | | |
| total supply (stationary installations, corrected) | 2152 | 1940 | 1962 | 1924 | 1885 | 1848 | 1810 | 1772 | 15294 |
| - free allocation | 1015 | 973 | 933 | 892 | 850 | 806 | 760 | 693 | 6922 |
| - auctioning | 933 | 908 | 972 | 977 | 982 | 990 | 1000 | 1031 | 7793 |
| - NER | 204 | 59 | 57 | 55 | 53 | 52 | 50 | 48 | 579 |
| total supply (stationary installations + aviation; corrected) | 2362 | 2150 | 2172 | 2134 | 2095 | 2058 | 2020 | 1982 | 16977 |
| | | | | | | | | | |
| total (excluding CDM use) | 2292 | 2253 | 2215 | 2177 | 2138 | 2101 | 2063 | 2025 | 17267 |
| | | | | | | | | | |
| potential CDM use (stationary installations) | 111 | 111 | 111 | 111 | 111 | 111 | 111 | 111 | 889 |
| potential CDM use (aviation) | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 32 |
| | | | | | | | | | |
| total supply (stationary installations) including CDM use | 2263 | 2051 | 2073 | 2035 | 1996 | 1959 | 1921 | 1883 | 16183 |
| total supply (aviation) including CDM use | 214 | 214 | 214 | 214 | 214 | 214 | 214 | 214 | 1715 |
| | | | | | | | | | |
| total including CDM use | 2477 | 2266 | 2288 | 2250 | 2211 | 2174 | 2136 | 2098 | 17898 |

Table 14

**Supply of EU allowances and CDM/JI credits in the Reference Scenario, 2021–2030**

| *million tonnes of $CO_2$ eq* | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | total 2021–2030 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| auctioning (stationary installations) | 1019 | 1007 | 995 | 983 | 971 | 959 | 947 | 935 | 923 | 911 | 9650 |
| auctioning (aviation) | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 316 |
| | | | | | | | | | | | |
| total auctioning | 1051 | 1039 | 1027 | 1015 | 1003 | 991 | 979 | 967 | 955 | 943 | 9966 |
| | | | | | | | | | | | |
| free allocation (stationary installations) | 669 | 645 | 621 | 597 | 573 | 549 | 525 | 501 | 477 | 453 | 5610 |
| | | | | | | | | | | | |
| free allocation (aviation) | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 1725 |
| | | | | | | | | | | | |
| New Entrants Reserve (stationary installations) (Phase III) | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 763 |
| New Entrants Reserve (aviation)(Phase III) | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 63 |
| | | | | | | | | | | | |
| total supply (stationary installations) | 1764 | 1728 | 1692 | 1656 | 1620 | 1584 | 1548 | 1512 | 1476 | 1440 | 16023 |
| total supply (aviation) | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 2103 |
| | | | | | | | | | | | |
| total supply (stationary installations; corrected) | 1764 | 1728 | 1692 | 1656 | 1620 | 1584 | 1548 | 1512 | 1476 | 1440 | 16023 |
| - free allocation | 669 | 645 | 621 | 597 | 573 | 549 | 525 | 501 | 477 | 453 | 5610 |
| - auctioning | 1019 | 1007 | 995 | 983 | 971 | 959 | 947 | 935 | 923 | 911 | 9650 |
| - NER | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 763 |
| total supply (stationary installations + aviation; corrected) | 1975 | 1939 | 1903 | 1867 | 1831 | 1795 | 1759 | 1723 | 1687 | 1651 | 18126 |
| | | | | | | | | | | | |
| total (excluding CDM use) | 1975 | 1939 | 1903 | 1867 | 1831 | 1795 | 1759 | 1723 | 1687 | 1651 | 18126 |
| | | | | | | | | | | | |
| potential CDM use (stationary installations) | - | - | - | - | - | - | - | - | - | - | - |
| potential CDM use (aviation) | - | - | - | - | - | - | - | - | - | - | - |
| | | | | | | | | | | | |
| total supply (stationary installations) including CDM use | 1764 | 1728 | 1692 | 1656 | 1620 | 1584 | 1548 | 1512 | 1476 | 1440 | 16023 |
| total supply (aviation) including CDM use | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 2103 |
| | | | | | | | | | | | |
| total including CDM use | 1975 | 1939 | 1903 | 1867 | 1831 | 1795 | 1759 | 1723 | 1687 | 1651 | 18126 |

# Annex III Demand by international aviation

## International aviation included exogenously

Although international aviation has been covered by the ETS since 2012, this sector was treated exogenously in our model calculations. As international aviation is a significant sector in terms of emissions and allowances (roughly 10% of total ETS supply of allowances), we took into account the net demand for allowances in the ETS. In this way, a complete balance of supply and demand for the ETS could be simulated in our model. However, there was no feedback of the modelled $CO_2$ price on, for example, mitigation efforts, demand for allowances, carbon leakage or air pollutants. Nor was the economic impact of options to reform the ETS on international aviation calculated. Consequently, in the model simulations, demand by aviation is unaffected by the policy options that reform the ETS.

## Estimation of demand for allowances by international aviation

In order to estimate the net demand for allowances by international aviation, we deducted the available allowances and possible use of CDM/JI credits from the emissions by international aviation (gross demand for allowances). We estimated the emissions by using parameters from Kolkman et al. (2012). In their study, growth rates from various studies are mentioned. They took the average of those rates (3.5%) for the annual volume growth and assumed an annual efficiency improvement of 1%. They found that with a carbon price of EUR 10/tonne $CO_2$ the annual volume growth reduced to between 2.6% to 3.3%. Based on this range we assumed an annual volume growth of 3%, which combined with an annual efficiency improvement of 1% resulted in emissions increasing annually by 2%. This resulted in an linear increase in emissions from aviation from 243 million tonnes of $CO_2$ in 2012 to 285 million by 2020 and 347 million by 2030. These levels are based on the assumption that the scope of operators included in the ETS remains constant (i.e. no operators opting out). Supply of allowances and CDM/JI credits was kept constant at 210 million allowances and 4 million credits for the 2013–2020 period, according to current legislation (see Annex II for more details). Tables 15 and 16 present the detailed data that underlie the net demand for allowances by international aviation, as estimated for inclusion in our model simulations.

The inclusion of international aviation in the EU ETS has sparked fierce debate on a global level on whether the EU could indeed force non-EU operators to buy and surrender sufficient allowances and CDM credits to match their emissions. Not only the emissions that end up in EU airspace should be taken into account by those operators, but also the pollutants related to the entire flight that are emitted outside EU airspace. In order to facilitate the ongoing international negotiations in the International Civil Aviation Organization (ICAO) on dealing with climate change, the EC decided to derogate the enforcement of the ETS obligations for non-EU operators for the year 2012 (EC, 2012d). One possibility is that international negotiations will results in a global agreement on $CO_2$ emissions from aviation, such that a level playing field is created for all operators. That could result in non-EU operators opting out of the EU ETS. This discussion adds significant uncertainty to the scope of flights included. To analyse the consequences of this uncertainty for our modelling results, in our sensitivity analysis we assessed the impact of the assumption that only emissions (and corresponding allowances) for flights within the EU ('intra-EU flights') are included (Section 4.3).

Table 15

**Detailed data for estimating the net demand for allowances by international aviation, 2013-2020**

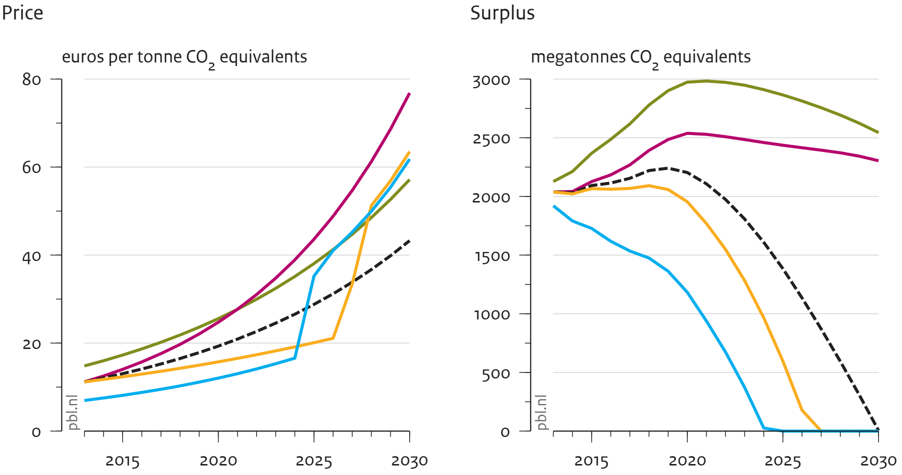
| **Supply of aviation allowances and CDM credits (2013–2020)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **million tonnes of $CO_2$ eq** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** | **total 2013-2020** |
| auctioning | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 252 |
| free allocation | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 1380 |
| NER | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 50 |
| potential CDM use | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 32 |
| total | 214 | 214 | 214 | 214 | 214 | 214 | 214 | 214 | 1715 |
| **Demand for allowances by international aviation (2013-2020)** | | | | | | | | | |
| emissions | 248 | 253 | 258 | 263 | 268 | 274 | 279 | 285 | 2127 |
| *demand for allowances* | *-34* | *-39* | *-44* | *-49* | *-54* | *-59* | *-64* | *-70* | *-412* |

Table 16

**Detailed data for estimating the net demand for allowances by international aviation, 2021–2030**

| **Supply of aviation allowances and CDM credits (2021–2030)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **million tonnes of $CO_2$ eq** | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **total 2021-2030** |
| auctioning | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 316 |
| free allocation | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 1725 |
| NER | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 63 |
| potential CDM use | - | - | - | - | - | - | - | - | - | - | - |
| total | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 2103 |
| **Demand for allowances by international aviation (2021-2030)** | | | | | | | | | | | |
| emissions | 290 | 296 | 302 | 308 | 314 | 321 | 327 | 334 | 340 | 347 | 3180 |
| *demand for allowances* | *-80* | *-86* | *-92* | *-98* | *-104* | *-110* | *-117* | *-123* | *-130* | *-137* | *-1076* |

Figure 11
**Effect of price of EU ETS allowances on surplus**




Starting price, discount rate

- 15 euros, 8%
- 11 euros, 12%
- 11 euros, 8% (Reference Scenario)
- 11 euros, 5%
- 7 euros, 8%

Source: PBL

# Annex IV The value of banked allowances

The WorldScan model explicitly includes the possibility of banking allowances for future use if the market price becomes too low. In our analysis, we assumed that companies will optimally use the total supply of allowances over the time period from 2013 to 2030, with the price of emission allowances having been chosen such that total demand for allowances would equal total supply over the whole period (including the surplus from the previous trading period). Although it is likely that also after 2030 there will be an emission trading system and there might be possibilities to use allowances from the period before 2030 and also beyond 2030, this was not taken into account in our analysis. Given the large uncertainties about climate policies in the long term, it is also not very likely that this possibility will currently affect firms' behaviour.

An important assumption is the level of the emission price below which allowances will be banked and above which allowances banked in earlier years will be used. Overall costs are minimised if the discounted marginal cost is constant, which implies that the optimal price follows a path that increases from year to year according to the interest rate (Chevallier, 2012). Neuhoff et al. (2012) describe how different actors use different discount rates. The discount rate used for future prices in the case of hedging was estimated at about 5%, whereas speculative buyers of allowances carry more risk and as a result they generally require higher rates of return than hedging buyers. For this category of buyers, Neuhoff et al. (2012) derived an annual rate of return that ranged between 10% and 15%.

WorldScan is a recursively dynamic model. This means that agents behave myopically in the sense that they react to current prices only. To take forward looking behaviour of firms into account with respect to banking in our model analyses, we exogenously imposed the emission price to increase annually according to the rate of return on capital. As uncertainty is not modelled in WorldScan, the rate of return on capital is the same for all investments. Hence, we used this rate of return on capital also as the rate at which the carbon price will increase in the optimal path (which is about 8% on average). Next, we assumed that in the Reference Scenario the total supply of allowances over the 2013–2030 period, including the surplus from the previous phase, will be used in full in a cost-efficient way. We found, given the surplus and the supply of allowances in the Reference Scenario, for this to be the case for a price path increasing at about 8% per year, the price must start at EUR 11/t$CO_2$. Figure 11 shows that, with a higher starting price, there will be allowances left in the bank in 2030, while a lower starting price would result in a depletion of the surplus before 2030, and afterwards emission prices would increase at a rate higher than the rate of return on capital. Using a higher or lower discount rate will also result in a different development of the price and the surplus.

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This policy study is a publication by

**PBL Netherlands Environmental Assessment Agency**

Mailing address
PO Box 30314
2500 GH The Hague
The Netherlands

Visiting address
Oranjebuitensingel 6
2511VE The Hague
T +31 (0)70 3288700

www.pbl.nl/en

April 2013