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Valuation of CO2 emissions in CBA: implications of the scenario study Welfare, Prosperity and the Human Environment

Rob Aalbers (CPB)
Gusta Renes (PBL)
Gerbert Romijn (CPB)

Summary

The scenario study Welfare, Prosperity and the Human Environment (WLO[1]) forecasts long-term developments on four topics, climate being one of them. The study's climate scenarios have been constructed taking into account various ways of international collaboration on the climate issue around the world. The WLO climate scenarios are characterised by a CO_2 emission budget for the rest of the century and an associated CO_2 emission reduction target. Under the *High* reference scenario, the world prospers and manages to agree on a low CO_2 emission budget and is able to achieve large CO_2 emission reductions. Under the *Low* reference scenario, far less CO_2 emission reduction is achieved. In addition to these *High* and *Low* scenarios, other WLO scenarios comprise an analysis of what happens to CO_2 emission reduction if the world manages to stay at or below a global temperature increase of two degrees Celsius. The way these scenarios have been constructed has implications for how the benefits of CO_2 emission reductions are addressed and how they can be valued in cost-benefit analysis (CBA).

To achieve the European share of the required CO_2 emission reduction, under each of the WLO climate scenarios, national and European climate policies have to be implemented. Within each scenario, climate policy is assumed to be as efficient as possible; the required emissions reduction is realised at the lowest possible cost to society, in a broad welfare economic sense. This involves a so-called efficient CO_2 price. The assumption is that the implemented national and European climate policies all have a positive CBA balance, given the efficient CO_2 price. The CO_2 price is determined in such a way that the resulting CO_2 emission reduction is exactly what is needed, under the scenario. This implies that, under the *High* reference scenario, more policy measures will be taken than under the *Low* scenario, but fewer than under the *Two degrees* scenario.

The WLO study only presents the prices set in the EU Emissions Trading System (EU ETS), but these do not reflect the price level at which a reduction in CO_2 emissions becomes efficient. In this paper, we further examine the details of efficient CO_2 prices. The information is intended for use in CBAs and may help determine what an efficient climate policy means for decisions taken by the Dutch Government. In this regard, this paper complements the WLO scenarios.

To determine a given measure's CO_2 benefits for use in CBAs, the efficient CO_2 prices, listed in Table S1, provide the relevant valuation. The development of the efficient price shows, for the period between now and 2050, the CO_2 prices required to achieve the cumulative CO_2 reduction in a scenario at the lowest possible cost. When using these WLO scenarios, it is not necessary to take any possible waterbed effects into account, *provided* efficient prices are used.

[1] WLO, CPB and PBL, 2015a

Table S1 **Efficient prices and ETS prices of 1 tonne CO_2 (in euros) used in the High and Low scenarios and in the two-degree scenario.**

		2015	2030	2050
High	Efficient price	48	80	160
	ETS price	5	40	160
Low	Efficient price	12	20	40
	ETS price	5	15	40
2°C	Efficient price	60–300	100–500	200–1000
	ETS price	5	100–500	200–1000

The applicable CO_2 prices and ways of dealing with the waterbed effect are important issues in determining the effects of climate measures. However, the manner in which CBAs for climate and energy policies should be drawn up is beyond the scope of this paper. The guidelines of the General Guidance for cost-benefit analyses (Romijn and Renes, 2013; Ministry of Finance, 2013) need to be worked out in a sector specific handbook for climate and energy policies.

In addition, the WLO climate scenarios have been drawn up on the basis of the current air quality policy, of which further tightening is conceivable.[2] A stricter air quality policy often also reduces CO_2 emissions, therefore leading to lower efficient CO_2 prices. At the same time, this implies higher prices for emissions of NO_x, SO_2 and particulates. As a result, in CBAs for climate or energy policies where air quality is also important, sensitivity analyses need to make clear what the effects are of a stricter air quality policy..[3] This too is beyond the scope of this paper.

[2] On 30 June 2016, the EU Member States reached an agreement on a new directive to lower national emission ceilings for harmful substances.

[3] To determine these prices, it is necessary to expand the WLO scenarios with air quality projections. As in the case of climate change, this involves setting feasible international targets in the context of the issue of international coordination. A thorough analysis is required for this, but is not available at the moment. In addition, determining the significance of the emission reduction targets and the related prices poses a problem similar to that of CO_2 pricing: to what extent do measures attain a social optimum and what roles are played by prevention costs and willingness to pay (see Section 2.3).

1 WLO climate scenarios and CBAs

To assess climate measures with a CBA, it is necessary to specify the exact way in which changes in greenhouse gas emissions should be determined and valued. The 2015 report by the Werkgroep Discontovoet (Discount Rate Task Force) states that this is to be based on the climate scenarios of the Future Exploration of Welfare, Prosperity and the Human Environment (WLO: CPB and PBL, 2015a). These climate scenarios describe the future development of total greenhouse gas emissions in the Netherlands and the price of one tonne of emitted CO_2 in the EU ETS.[4] The two scenarios available for the assessment are the High and Low reference scenarios. The CO_2 prices in these scenarios are consistent with the assumed CO_2 emission reduction within the ETS.[5]

Table 1 CO_2 emission reduction compared to 1990 levels; CO_2 prices applied under EU ETS, in the WLO reference scenarios

	High		Low	
	2030	2050	2030	2050
Emission reduction	40%	65%	30%	45%
CO_2 price (euros/tonne)	40	160	15	40

The two reference scenarios are the background against which the CO_2 prices are determined that are to be used in all CBAs. This means that, in CBAs, a climate measure has to be assessed for *both* reference scenarios. This approach brings not only the efficiency of the measure into focus, but also any future uncertainty surrounding it.

In addition to the reference scenarios, a third scenario was developed in which global temperature increase is limited to 2 °C (i.e. the *Two degrees* scenario). For that to be realised, CO_2 emissions in 2050 need to be 80% below 1990 levels. This requires a CO_2 price of 100–500 euros per tonne for 2030 and 200–1000 euros per tonne for 2050, according to the model calculations made in the WLO study. It is recommended that CBAs dealing with climate measures include an assessment for the *Two degrees* scenario, in addition to the two reference scenarios.[6]

Achieving the emission reductions requires having policies in the Netherlands, in the EU and in all other parts of the world. The assumption within the scenarios is that those policies are as efficient as possible, meaning that climate policy has been formulated in such a way that

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[4] In addition to CO_2, there are several other greenhouse gases such as methane (CH_4), nitrous oxide (N_2O or laughing gas) and halogenated hydrocarbons (a group of gases containing fluorine, chlorine and bromine). These gases produce varying levels of greenhouse effects. For a given concentration, methane has a much stronger greenhouse effect than CO_2. This report applies the CO_2 price to all greenhouse gases, and follows the general convention of converting the emissions of various greenhouse gases to their CO_2 equivalents, based on their greenhouse effect.
[5] In the High scenario, the ETS is set to change into an economy-wide CO_2 emissions trading system after 2030.
[6] The background of the choices that led to the reference scenarios and the additional two-degree scenario analysis are described in CPB and PBL (2015a). The role played by the *High* and *Low* reference scenarios and the *Two degrees* scenario analysis in policy preparation and the role played by CBAs are described in CPB and PBL (2015b).

the emission reductions are achieved at the lowest possible cost to society. A CBA of a climate change measure reveals whether the measure makes an efficient contribution towards achieving the emission reduction under a certain scenario, given the efficient CO_2 price. This will provide an answer to the question of whether the new project is 'better' than others already implicitly included in the scenario.

This paper details how WLO climate scenario results should be used in a CBA when the establishment of a measure's CO_2 emission reductions plays a role.[7] Two issues are important in this regard.

1. Which CO_2 prices are to be used? The problem here is that the WLO scenarios apply EU ETS-based CO_2 prices while there are also policy measures which are implemented outside the ETS. Therefore, the ETS prices for 2015 and 2030 do not reflect the price level for efficient CO_2 emission reduction.

2. Determining the extent to which a measure reduces emissions and the role of the so-called *waterbed effect*. This refers to the effect that any emission reduction resulting from the measure, provides a greater margin for emissions elsewhere within the ETS or at a later point in time, because the ETS emission ceiling follows a predetermined path and allows for banking of emission credits. As a result, the measure produces no net emission reductions. We argue that the characteristics of the scenarios mean that the waterbed effect does not need to be taken into account.

The applicable CO_2 prices and ways of dealing with the waterbed effect are important issues in assessments of climate effects in the context of a CBA. This paper, however, does not cover the way in which CBAs of climate and energy policy, generally, should be conducted. The guidelines of the General Guidance for cost-benefit analyses (Romijn and Renes, 2013; Ministry of Finance, 2013) need to be worked out in a sector-specific handbook for climate and energy policies.

In Section 2, we discuss the question of what proper CO_2 prices are, and in Section 3 we explain why it is not necessary to take the waterbed effect into account, illustrating the assertion with an example of the electricity market.

[7] The approach adopted in this paper can also be used to determine the value of variations in CO_2 emissions brought about by transport infrastructure projects. In actual practice, CBAs for such projects go into far less detail since they apply a fixed amount per vehicle kilometre to assess the external damage caused by CO_2 and air pollutant emissions.

2 CO_2 prices in the WLO study

2.1 The efficient price: definition and calculation

The WLO scenarios envision a period of several decades during which a policy aimed at preventing emissions of CO_2 and other greenhouse gases coexists with subsidies for clean technologies. In the *Low* reference scenario, this continues almost up to 2050. However, in the *High* reference scenario, the support measures are set to be completely abandoned after 2030, leaving only a carbon tax or emissions trading system in operation. These then apply across the whole economy, and will lead to ETS prices that are much higher than they are today. To stimulate the development of low-carbon technologies, the optimal solution, from a social point of view, subsidies should be offered, in addition to carbon taxes or an emissions trading system. This is needed because innovation has a sub-optimal bias towards polluting technology. Subsidies will make sustainable energy technologies become profitable more quickly and eliminate the innovation bias. As a result, over time, subsidising innovation will become unnecessary.

Compared to a policy based exclusively on CO_2 pricing, the two-track policy of CO_2 pricing *and* the promotion of low-carbon technologies prevents a sharp increase in carbon taxes (a strict ETS ceiling) during the first few decades, thus leading to higher levels of prosperity. An example of a more detailed, model-based justification can be found in Acemoglu et al. (2012). This impact is the result of two external effects. In addition to CO_2 issues, deploying clean technologies also produces non-internalisable learning effects and spill-over effects.

To assess measures using a CBA, we apply the scenarios' efficient CO_2 price path. This price path, for each year between now and 2050, represents the CO_2 prices needed to achieve a given scenario's assumed cumulative reduction in CO_2 emissions[8] against the lowest possible costs. The economy-wide efficient price equals the minimum marginal emission-abatement costs. In other words, any deviation from the set CO_2 price path leads to an increase in the cost of achieving the CO_2 emission target. Use of other prices is therefore incompatible with the welfare-economic principles of a CBA, which hold, among other things, that the benefits of an invested euro are to be compared with the most profitable alternative use. Here, this has to do with the *law of one price*, which states that in an efficiently running economy identical goods and services have the same price. This means that concurrent use of ETS prices and differing (implicit) non-ETS prices for CO_2 reduction cannot serve as a starting point for a CBA of climate-related energy measures. Therefore, the efficient CO_2 price path acts as a benchmark for the inspection of new climate-related energy measures and projects in a CBA.

[8] In each scenario, the assumed reduction for 2050 is consistent with the corresponding CO_2 budget for 2100 (see also CPB and PBL, 2015a). It should be noted that in each scenario there are still major differences in the primary energy mix, resulting from the assumptions made about technological development. Even so, they have a negligible impact on the CO_2 price path. Put differently, regardless of the various possible technological developments, the CO_2 price path reflects the relative price of CO_2 emissions needed to achieve the CO_2 emission target.

Market prices and efficient prices

When valuing the effects of measures in a CBA, the use of market prices is generally promoted. If there are no instances of market failure, market prices will achieve a balance between costs in terms of allocation of resources, and benefits in terms of consumer appreciation.

If market failure does occur, this balance becomes disrupted. If it is related to external effects on the production side, not all the production costs have been reflected in the price. For these cases, the General Guidance for Cost-Benefit Analysis recommends identifying the missing markets in which the external effects occur. The data on the effects occurring within these missing markets should be worked into a CBA.

An alternative approach is to refrain from using market prices in the CBA, and work with prices adjusted for the external effects, i.e. the welfare-economics efficient cost price of production. The use of efficient prices is therefore an alternative to an explicit interpretation of the missing market.

Which approach is most useful will vary from one case to another. In assessments of CO_2 markets, the use of efficient prices seems to be the preferred option. This has to do with the fact that, while estimates of efficient prices are available, there is also uncertainty about the level of the social cost of carbon (see Section 2.3).

The WLO study only provides EU ETS prices. A non-ETS price has not been established, in part because no explicit non-ETS price exists. The ETS price is efficient if all economic actors and, thereby, the full volume of greenhouse gas emissions are covered by the Emissions Trading System. In all the WLO scenarios, this is the case for the 2050 projection. The efficient CO_2 price for the period between 2016 and 2050 can be determined by applying the Hotelling rule[9] and marking down the efficient price for 2050 with the appropriate discount rate.

Therefore, there are three efficient price paths: one for the *Low* scenario, one for the *High* scenario and one for the *Two degrees* scenario. The efficient CO_2 prices for 2050 are 160 euros for the *High* scenario, 40 euros for the Low scenario and between 200 and 1000 euros for the *Two degrees* scenario.[10] Applying Hotelling's rule, using a discount rate of 3.5%, results in efficient prices, for 2015, of 48 euros for the *High* reference scenario, 12 euros for *Low* scenario and between 60 and 300 euros for the *Two degrees* scenario. Table 2 shows these ETS prices and the efficient prices.[11] The WLO's ETS prices for 2015 and 2030, therefore, are not efficient prices because, for those years, the Emissions Trading System does not cover all economic operators. The Two degrees scenario forms the exception, as it does cover all actors operating under the scheme in 2030.

[9] Hotelling (1931). The Hotelling rule states that in an optimal situation, the growth rate of the price of a non-renewable resource is equal to the discount rate.

[10] In the *Low* scenario, climate policy is not yet fully efficient by 2050, but is projected to be so, shortly thereafter. Nevertheless, the rounded efficient CO_2 price for 2050, in the *Low* scenario, is the same as the EU ETS price (see Table 3.6 of the background document to the WLO climate scenarios; CPB and PBL, 2016). This is due to the fact that, under the ETS, mitigation costs are almost level across a wide range.

[11] In the past, the ETS price has almost always been lower than the efficient price. Acemoglu et al. (2012) assert that this is logical, given that the efficient price also corrects for complementary policies within the ETS. The complementary policies mainly have to do with innovation promotion, and, whether within or outside the ETS, they must be valued at the efficient CO_2 price, regardless of the ETS price. This does not imply, however, that the historical ETS price up to the present has been optimal or that additional policies have been designed optimally.

Table 2 Efficient prices and ETS prices for 1 tonne of CO_2, according to WLO (in euros)

		2015	2030	2050
High	Efficient price	48	80	160
	ETS price	5	40	160
Low	Efficient price	12	20	40
	ETS price	5	15	40
2^{o} C	Efficient price	60–300	100–500	200–1000
	ETS price	5	100–500	200–1000

These calculations are performed with a discount rate of 3.5%, the average value for Europe. It is somewhat higher than the 3% applicable in the Netherlands (see the Advice drawn up by the Task Force for discount rates, Ministry of Finance, 2015). The reason for this is that eastern and southern Europe are growing a bit faster than north-western Europe and the Netherlands. The Dutch economy is more highly developed than those of southern and eastern Europe, which can benefit from a period of catching up[12]. This makes it appropriate to apply a slightly higher discount rate there than for the Netherlands.[13]

2.2 Assessing measures: determining CO_2 benefits

To calculate benefits, CBAs use the efficient prices shown in Table 2. All measures under study must be assessed using the efficient CO_2 price of both the *High* and *Low* scenarios. Measures that are cost-effective at a CO_2 price below the efficient CO_2 price in either scenario are socially beneficial within that scenario. Measures that only become cost-effective at CO_2 price levels above the efficient CO_2 price in either scenario are not socially beneficial. In evaluations of climate-related energy measures, in addition, a sensitivity analysis is required for the *Two degrees* scenario.

Determining CO_2 benefits on the basis of the ETS price is not the correct approach. We demonstrate this by looking at the relationship between the efficient price on the one hand, and the ETS and non-ETS prices on the other. The relationship is shown in Figure 1. The graph on the left shows how the ETS price is determined by the ceiling established for emissions within the ETS sector. Here, the emission reduction is q_{ETS}. The emission reduction consistent with the long-term objective (under the *Low* and *High* reference scenarios and the *Two degrees* scenario) is determined by the efficient price. If policy measures exist both within and outside the ETS at the same time, an optimal emission reduction arises for both sectors, represented here by q^*_{ETS} and $q^*_{non\text{-}ETS}$.

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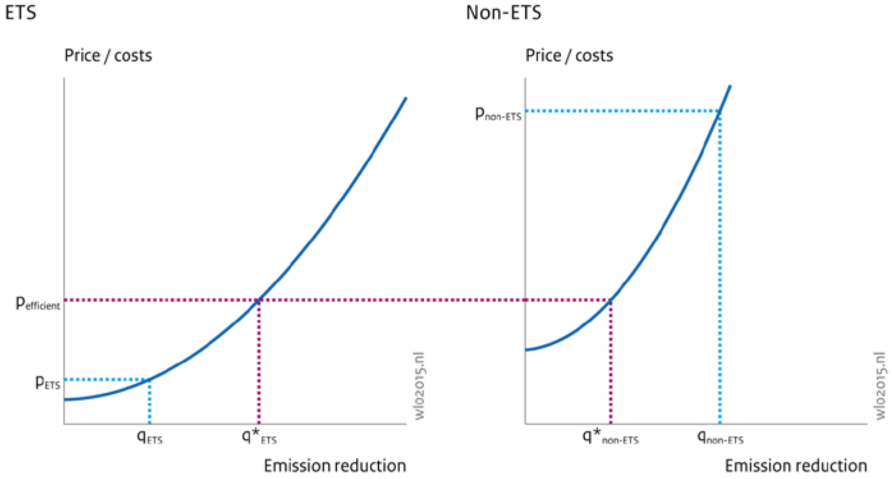
[12] In the long run, the rate of growth in eastern Europe is likely to decrease to the level of western Europe. The discount rate will then decrease accordingly. This will probably only happen after 2050.

[13] In CBAs of Dutch policies, the present value of CO_2 benefits is calculated at a discount rate of 3%, which is lower than the actual 3.5% increase in the efficient CO_2 price. This means that a Dutch policy initiative that was to reduce CO_2 for years on end would have an infinite present value. However, flows of CO_2 benefits brought about by climate policy initiatives are not infinitely long, but last for a limited time. In climate and energy policies the period is often that of the lifespan of the investments made.

Figure 1
ETS, non-ETS and efficient CO_2 pricing



q_{ETS} = Emission reduction within ETS for a given ETS emission ceiling
$q_{non\text{-}ETS}$ = Emission reduction outside ETS for a given ETS emission ceiling
$p_{efficient}$ = CO_2 price consistent with long-term emission reduction

Source: PBL/CPB

In the graph on the left we can see that the low emission reduction below the ETS ceiling and the related low ETS price bring about a reduction in emissions that is smaller than would be efficient. The efficient price is, after all, much higher. This may make it socially beneficial to take additional measures under the ETS, such as offering subsidies or formulating standards. Subsidising measures taken under the ETS is socially beneficial, provided the costs of the measures are lower than the benefits calculated on the basis of the efficient CO_2 price.

Each of the three scenarios has a given cumulative emission budget. As this implies that the total emission reduction is also a given, more needs to be done outside the ETS sector, if no additional measures are taken within the ETS sector. The ceiling for the ETS sector, therefore, entails a limit on emissions in the non-ETS sector. In the figure, this is represented by the equal values of $q^*_{ETS} - q_{ETS}$ and $q_{non\text{-}ETS} - q^*_{non\text{-}ETS}$. The corresponding non-ETS price is determined in the right graph of Figure 1. Consequently, if no additional measures are taken within the ETS, then too much must be done outside the ETS at a much higher price than the efficient CO_2 price.

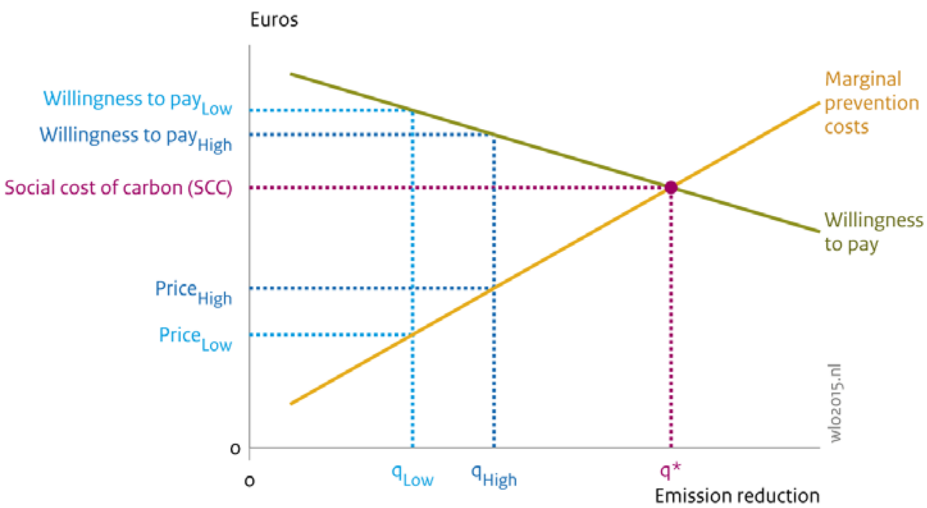
If CBA assessments of measures were to apply the ETS price and the non-ETS price (using an implicit value, since there is no explicit value), this would lead to too few measures being taken under the ETS and too many in the non-ETS sectors. This is avoided by using the efficient CO_2 price and, therefore, there is no need for a distinction between ETS and non-ETS sectors in the assessment of measures.

2.3 Willingness to pay and prevention costs

All CO_2 prices in the WLO study (ETS, the efficient price) are based on prevention costs. The General Guidance for CBAs states that prevention costs are generally not a good measure of willingness to pay. Nevertheless, for the case at hand, we recommend making the calculations using these prevention costs.

This has to do with the way the WLO scenarios are set up with regard to this issue. The figure below shows the global willingness to pay for CO_2 emission reduction. It involves the marginal benefits which are obtained by avoiding damage. The willingness to pay decreases as the reduction in emissions increases. The costs of achieving the CO_2 emission reduction are also shown. These prevention costs increase with the need for greater emission reductions. At the intersection point of the lines for willingness to pay and prevention costs, the marginal costs of additional emission reductions are equal to the marginal willingness to pay. This is where the situation is optimal. The corresponding CO_2 price is called the *social cost of carbon* (SCC).

Relationship between CO_2 prices, willingness to pay and social cost of carbon (SCC)



q* = Emission reduction in the optimal situation

q_{Low} = Emission reduction corresponding to the WLO 'Low' scenario

q_{High} = Emission reduction corresponding to the WLO 'High' scenario

Source: PBL/CPB

Determining the global willingness to pay for CO_2 reduction is a complicated exercise because of the distant time horizon and the considerable uncertainty regarding the effects of climate change (low probability, high impact). Therefore, the scientific literature presents a wide range of values when referring to the social cost of carbon.[14] Moreover, achieving the optimum emission reduction is not something that happens by itself. It requires international cooperation, which is being hampered by a coordination problem. This is because the more emissions are reduced abroad, the less willing a country, or its population, is to pay for domestic emission reductions. The more the rest of the world contributes to CO_2 reduction, the less serious the damage you cause yourself and the less willing you are to adopt expensive measures yourself. Ideally, the rest of the world solves the problem and you do not need to do anything. But, if nobody takes action, a major problem arises. This is known as a *prisoner's dilemma*.

The various WLO climate scenarios are based on the same global willingness to pay and the same prevention costs for the reduction in CO_2 emissions. They differ in the degree of readiness to cooperate internationally. In the High reference scenario, this readiness is high. As a result, it is relatively easy to settle the coordination problem and it is possible to achieve a relatively large reduction of CO_2 emissions. In the Low reference scenario, it is less easy to overcome the coordination problem and lower levels of CO_2 emission reduction are achieved. Although it is not exactly known what the optimal emission reduction is, Figure 2 assumes that the CO_2 emission reductions in both High and Low are below optimal levels.

The figure also shows that this means that in the High reference scenario, the willingness to pay for CO_2 emission reduction is (much) higher than the social cost of carbon identified at the optimal situation. In Low, the willingness to pay is even higher. This implies that if we were to use willingness to pay as a criterion, we would be taking reduction measures which do not pay off in an optimal situation and which would not be considered there. This is the reason we do not use willingness to pay, but rather the (marginal) prevention costs.

In the High reference scenario, the prevention costs are higher than in the Low scenario. Complemented with the sensitivity analysis for the two-degree target, which assumes even more extensive cooperation, this ranking of prices supports the idea that climate policies which are more ambitious are also more expensive. However, as Figure 2 reveals, the prevention costs in the Low and High reference scenarios — and probably also those for the two-degree target — are an underestimation of the willingness to pay in the optimal

[14] Van den Bijgaart et al. (2016) produce an estimate for the (current) social cost of carbon. Their work gives a median estimate of 20 euros per ton and an average estimate of 48 euros per ton. They calculate there is a 10% probability of reaching an SCC of more than 100 euros per ton. These estimates are very sensitive to the combination of applied discount rate and assumptions about the pace at which CO_2 disappears from the atmosphere through natural processes. The coefficients of variation in the study (standard deviation and mean ratio) are between 1.5 and 2. The work therefore shows that, while it is possible to make an estimate, the uncertainty around it has a skewed distribution and covers a wide range. There are also other studies that calculate the cost of carbon-related damage. Tol (2009) has carried out a meta-analysis of a large number of these studies and calculated a median price of 26 euros per ton of CO_2 (converted to 2012 prices) and an average price of 45 euros. The analysis gives a 1% probability of the social cost of carbon going above 500 euros per ton of CO_2. Vollebergh et al. (2014, Section 5.3.1) quote a 2013 publication by the US government that also refers to a price of 26 euros, at 2012 prices, which is based on damage costs. Pindyck (2013) argues that we do not really know anything about the social cost of carbon because the models used to make estimates of the social cost of carbon are based on arbitrary assumptions and are therefore not informative.

situation (the social cost of carbon). Since willingness to pay and social cost of carbon are not known, it is also impossible to establish the magnitude of the underestimation caused by using the marginal prevention costs. It also means that there is no good alternative to the use of marginal prevention costs.

To find out whether a measure makes an efficient contribution to achieving a given objective which is not necessarily economic welfare at equilibrium, prevention costs might be a better approach to evaluation than damage costs (willingness to pay). When determining whether the target is optimal, benefits are to be examined on the basis of willingness to pay.

3 No waterbed effect

Measures to reduce CO_2 emissions under the ETS do not lead to a decrease in CO_2 allowances nor, therefore, to a reduction in the total amount of emitted CO_2. This is because the allowances can be used by other companies operating under the ETS. This is also known as *the waterbed effect*.

The design of the WLO, however, implies that the waterbed effect does not have to be taken into account in CBAs as long as they use efficient prices. First, the global emission reduction and the number of CO_2 credits and their trajectories are given for each WLO scenario. Who owns the allowances is irrelevant. Second, implicit assumptions have been made on international policy measures in the scenarios, consistent with the corresponding required emission reductions.[15] This emission reduction must go hand in hand with an efficient CO_2 price path. Therefore, given the transition up to 2050 for several levels of emission reduction, the WLO scenarios can be used to assess climate measures for efficiency. This means that in CBAs a proposed measure is compared against policies which are already implicitly included in the scenario. This provides an answer to the question of whether the new project is better than the most costly projects implicitly assumed in the scenario. A CBA is therefore used to determine whether a measure makes an efficient contribution to the required CO_2 reduction *within* the scenario. This implies that the calculations must be based on the efficient CO_2 price path that corresponds to the assumed emission reduction.

[15] This implicit policy leads to the freeing up of allowances which are then used by others. That is exactly the objective. Companies for whom the reduction of CO_2 emissions is not profitable at the efficient prices can take advantage of unused allowances.

3.1 The electricity market shows that the waterbed effect is not relevant

What we assess then, is not the emission reduction as such, but rather, the direct effects of the range of investments and measures. A wind turbine generates electricity. A coal-fired power plant (operating without carbon capture and storage technology) produces electricity and CO_2. From a welfare-economic point of view it is beneficial to erect a wind turbine if the revenue from electricity is higher than the costs of generating it. A coal-fired power plant should be closed down if the costs of generation and emissions are higher than revenue from electricity production. Note that neither measure reduces CO_2 emissions within scenarios, because emission levels are set for each scenario. It is, however, possible to assess whether a measure contributes to the assumed emission reduction in a more efficient way.
Suppose that the closure of a coal-fired power plant would have a positive CBA balance. using efficient CO_2 prices. This means that closing down the plant is a good idea. Companies for whom the reduction of CO2 emissions is not profitable at the efficient prices can take over the unused allowances. The waterbed effect is therefore not relevant.

In CBA assessments of measures in the electricity market, it is therefore useful to perform the calculations with efficient electricity prices (see textbox on efficient prices in Section 2.1). These electricity prices are based on the efficient CO_2 prices, assuming the markets to be operating perfectly. Since the emission allowances are relatively expensive compared to production costs, the expectation is that investments in clean technologies will be more sizeable and be made more rapidly in the electricity market than in other sectors. This leads to relatively fast price increases which will also have to be reflected in the efficient electricity prices. In the WLO study these have been calculated with the use of MERGE (see Table 3.4 in the background document). Here, we present the figures in Table 3 below.[16]

Table 3 Efficient prices and wholesale prices of electricity in the WLO study

		2030	2050
High	Efficient price per MWh	110	88
	Wholesale price	67	90
Low	Efficient price per MWh	115	101
	Wholesale price	90	100
2 °C	Efficient price per MWh	113–116	102–104
	Wholesale price	115	105

[16] Since the electricity market may well be decarbonised in the short term, particularly in the High scenario, model calculations will need to incorporate assumptions about the back-up of the electricity system, the level of energy savings, the role of demand side management, and supply security. These assumptions have also been factored in into the figures in Table 3.4 of the background document. The table shows average electricity prices and for specific technologies, such as wind turbines, profile effects must also be taken into account.

3.2 How does this compare to previous analyses?

In previous CBAs of climate policy, the waterbed effect of the current ETS has been highlighted emphatically (see, for example, Verrips et al., 2013). Attention has been drawn especially to the fact that, due to the waterbed effect, additional wind turbine capacity does not deliver any benefits from saved CO_2 emissions. The insights presented in this paper relate to and affect this view. The matter has to do with the fact that the new WLO climate scenarios are structured differently from the older ones.

The old WLO scenarios which formed the basis for earlier analyses did not take into account international climate targets or their feasibility and did not apply any corresponding CO_2 emission reduction targets and CO_2 prices. Instead, it was assumed that there was a more or less trend-based continuation of the EU policy on ETS emission ceilings. They lacked a vision of the extent to which CO_2 was to be reduced, and no CO_2 prices were in place to achieve a reduction. A CBA was then performed to check whether a project would actually save CO_2. In fact, what was examined was whether it would be socially beneficial to move from an existing situation to another with less CO_2 emissions. In such an approach, the properties of the ETS and the static and dynamic waterbed effects *are* relevant. Each ton of CO_2 emission reduction will, therefore, either contribute to protecting the climate, or not, because of the waterbed effect.

The new WLO scenarios are based on our assumption that international climate policy is uncertain and that the European Union and the Netherlands will eventually adapt to this international reality. The uncertainty about international climate policy is expressed through the Low and High scenarios. The Low scenario, for example, assumes that the EU will abandon its CO_2 emission reduction target around 2025. In assessing climate and energy policies, a CBA examines whether a project contributes efficiently to the reductions assumed in the Low and High reference scenarios. It no longer investigates whether it is socially interesting to reduce CO_2 emissions any further. Therefore, the waterbed effect is no longer relevant and efficient prices need to be used.

This does not affect the fact that under the old WLO assumptions too, it was socially optimal to offer innovation subsidies for renewable energy in addition to ETS measures. According to Acemoglu et al. (2012), this is because private initiatives exhibit an innovation bias that is suboptimal from a welfare-economic point of view. By offering subsidies, sustainable energy technologies will become profitable more quickly, a development which also keeps the costs of the ETS low. The previous WLO scenarios probably did not appreciate the full value of these learning effects and therefore it was not taken into account properly. The new WLO scenarios are better equipped for this.

Finally, the former WLO scenarios implicitly assumed a CO_2 price based on the expectations of the time with regard to the ETS. It is now clear that this neither contributes to achieving a climate target, nor generates profit from climate measures. In the new scenarios this is the other way round: a climate target is formulated and a CO_2 price is applied which is consistent with the policy objective in the scenario. The CO_2 price is significantly higher than that considered in the former scenarios. The related efficient electricity price is also significantly higher. This makes erecting wind turbines and closing down coal-fired power plants less unprofitable at the social level. However, wind turbines still do not generate any CO_2 benefits, but for a CBA, the electricity they generate will have to be calculated against efficient electricity prices.

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CPB Netherlands Bureau for Economic Policy Analysis
P.O. Box 80510 | 2508 GM The Hague
T +31 88 984 60 00

info@cpb.nl | www.cpb.nl

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