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## How much does a 30% emission reduction cost?

Macroeconomic effects of post-Kyoto climate policy in 2020

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# Abstract

This study analyses the macroeconomic impacts of a climate policy that aims to reduce emissions of greenhouse gases by industrialised nations to 30% below the 1990 level. Such an effort is consistent with the European Union’s policy target to limit the increase of the average world temperature to 2°C above pre-industrial levels. The economic consequences of such a climate policy may vary widely. In 2020, the economic loss to the Netherlands of such a strategy is assessed as 0.8% of national income, provided that all countries implement the climate policy and that efficient international emissions markets are in place. However, if the developing countries do not join the abatement coalition, and only industrialised nations are engaged in climate policy, the costs to the Netherlands may rise to 4.8% of national income. The costs also depend on economic growth in the underlying scenario. In a scenario with a global abatement coalition and moderate economic growth, these costs will amount to 0.2% of the national income.

# Abstract in Dutch

Deze studie verkent de macro-economische gevolgen van klimaatbeleid, waarbij industrielanden voor 2020 een reductiedoelstelling nastreven die 30% beneden de emissies van 1990 ligt. Een dergelijk regime past bij het uitgangspunt van de Europese Unie, dat de gemiddelde wereldtemperatuur niet meer dan 2 graden Celsius mag stijgen ten opzichte van het preïndustriële niveau. De macro-economische gevolgen kunnen sterk uiteen lopen. Als alle (ontwikkelings-)landen meedoen aan het klimaatbeleid en emissiemarkten efficiënt werken, dan worden de kosten in 2020 voor Nederland in een scenario met hoge groei geraamd op 0,8 procent van het Reëel Nationaal Inkomen. Als ontwikkelingslanden echter niet meedoen aan klimaatbeleid en alleen de industrielanden beleid voeren, dan kunnen de geschatte kosten oplopen tot 4,8 procent van het Nationaal Inkomen. De kosten van klimaatbeleid zijn ook afhankelijk van toekomstige economische ontwikkelingen. Bij een gematigde economische groei zullen bij een mondiale coalitie de kosten 0,2 procent bedragen.

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# Preface

With the ratification of the Kyoto Protocol, a large number of nations will set a first step towards a world with reduced greenhouse gas emissions. According to current insights, a considerable effort to abate the emissions of greenhouse gases is necessary to avoid the impacts of climate change. This asks for more stringent emissions targets for the post-Kyoto period. Emission reduction targets mentioned in this respect allocate a target to industrialised countries in 2020 that lies 30% below their emission levels in 1990. Two members of the Dutch Lower House, De Krom and Spies, asked in a resolution to explore the macroeconomic consequences of such climate objective.

This study assesses the macroeconomic consequences of a post-Kyoto policy, in which industrialised countries in 2020 accept emission targets that lie 30% below their 1990 levels. Hence, this study provides answers to the resolution from the Lower House. This is a joint study by MNP Netherlands Environmental Assessment Agency and CPB Netherlands Bureau for Economic Policy Analysis.

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# Summary

This report analyses the macro-economic consequences of climate policy beyond the first budget period of the Kyoto Protocol (2008-2012). It is assumed that in 2020 industrialised countries accept an emission reduction target that lies 30 percent below their 1990 levels. Such a regime fits with the EU strategy to keep the rise of mean global temperature below 2 degrees Celsius compared to the pre-industrial level.

Policy design strongly influences the costs of the abatement effort. In a cap-and-trade system, costs are mainly driven by the number of countries participating. The efficiency of any climate policy depends on the availability of cheap abatement options. The low cost options are mostly to be found in the developing countries. Hence, the participation of developing countries in an emission trading system is crucial to lower the costs.

If all countries join a global abatement coalition to reduce emissions and if emission markets are competitive, the costs of compliance for the Netherlands in 2020 are estimated to be 0.8 percent of National Income (NI)[1] in a high growth scenario. However, if developing countries do not participate and only industrialised countries (Annex I) abate emissions, then the estimated costs increase up to 4.8 percent of NI. It is to be noted that Australia and the United States are assumed to join this abatement coalition, although these countries opted out of the Kyoto Protocol. In comparison, the compliance costs of the Kyoto Protocol in 2010 in a high economic growth scenario are estimated to be 0.4 percent of Dutch NI. The Kyoto reduction target is only 6 percent below the 1990 level, but the abatement coalition is much smaller. In the longer term the climate goal (of limiting the maximum rise of global temperature to 2 degrees Celsius) requires a substantial stepping-up of emission reduction efforts after 2020. Earlier research, based on the same reference scenario, showed that the costs of compliance rise considerably after 2020.

For both the Netherlands and other industrialised countries, the costs of post-Kyoto policies will mainly stem from the import of emission permits. In the high economic growth scenario with all countries participating in emissions trading, the permit price equals 17 euros per ton $CO_2$. In The Netherlands only 18% of the total reduction effort will be realised by domestic action. The domestic effort will mainly be driven by energy savings and structural shifts from energy-intensive activities to services. This will entail a lower energy-intensity. Only a small fraction of domestic reductions will come from switching to low-carbon fuels (gas and carbon free energy).

[1] Due to the climate policy, the estimated shortfall of Dutch National Income is 0.8% from the income level reached in the reference scenario without any climate policy.

Reallocation of energy-intensive activities to foreign countries will be limited, because competitors all over the world will face an increase in production costs.

The costs of compliance also depend on the growth of emissions in the reference scenario. The above mentioned costs are evaluated against the background of a scenario with high economic growth. However, if a reference scenario with moderate economic and emissions growth is used as a background, then the costs to meet the 30% reduction target will fall accordingly. If in this moderate economic growth scenario both industrialised and developing countries join the abatement coalition and emission trading occurs in a fully competitive market, then the costs to the Netherlands in 2020 can be estimated to be only 0.2 percent of NI, instead of 0.8 percent.

The regional distribution of costs depends on the allocation of emission rights to countries. If this allocation is based on an equal per capita basis, developing countries will receive a surplus of emission rights over their current emission levels. Industrialised countries will get less. Industrialised countries will import emission permits in order to meet the requirement of their emission target. This will lead to income transfers from importing to exporting countries.

Generally, compliance with the climate target is more costly for the Netherlands than for the European Union on average. The reason is that the Netherlands has a relative high energy demand and the assumed allocation of rights on an equal per capita basis yields more stringent targets for the Netherlands. Alternative allocations based on historical emissions (grandfathering) or equal costs (equal burden sharing) will be favourable for the Netherlands. The analyses show that the costs of abatement can then be reduced by 25 percent.

These conclusions are based on a macro-economic analysis of climate policies. The costs are driven by a number of factors: the reduction target, economic growth and the related emissions in the baseline scenario, and the policy design. Given the reduction targets, there are large uncertainties concerning the other elements. To explore this uncertainty, a number of alternative policy variants has been analysed. The analysis is based on simulations with the WorldScan model, which is a global applied general equilibrium model. The macro-economic consequences in 2020 have been investigated against the background of two different growth scenarios. These scenarios closely match the scenarios developed for the so-called "Referentieraming" for the Netherlands. In none of the baseline scenarios used in this study climate policy is assumed. The benchmark policy simulation uses the GLOBAL ECONOMY scenario as a baseline. This scenario is characterised by high economic growth. Accordingly, the policy effort and associated costs to meet the 30 percent reduction of emissions compared to the 1990 level are relatively high. As an alternative, the STRONG EUROPE scenario is chosen, characterised by more moderate economic growth and environmental policies focusing on local problems. In all analyses, cost-reducing options, like carbon sequestration or major break-throughs in carbon free technologies, are not taken into account. It is too early to properly assess the effects of these options. Also the costs of structural adjustments, as well as transaction costs of emissions trading, and monopolistic power of suppliers on the international emissions market are not explicitly covered in this study. Hence, the reported cost estimates should be interpreted with caution.

# 1 Introduction

The Dutch government is currently preparing its position within the EU with regard to negotiating a future climate regime. An important starting point is the EU ambition that the average world temperature should not increase more than 2°C above pre-industrial levels. Climate models indicate that this goal requires greenhouse gas (GHG) concentrations to be kept below 550 ppmv $CO_2$-equivalent (Criqui *et al*., 2003). This assumes an average sensitivity of the climate system to increased GHG concentrations in the atmosphere, such as indicated in studies by the Intergovernmental Panel on Climate Change (IPCC). The concentration ceiling associated with this sensitivity probably prevents important consequences of climate change. Ambitious emission-reduction targets are required in order to prevent these maximum concentrations to be exceeded, and these can only be attempted in a global context. GHG emissions worldwide need to be stabilised within two decades (Criqui *et al*., 2003) and then, around 2035, need to be reduced to current emission levels. Taking into account the emissions growth required in developing countries, the aforementioned emission-reduction targets for industrialised nations appear to amount to around 30% in 2020, compared to 1990 levels. This study assesses – for the Netherlands in particular – the possible macroeconomic consequences of such an objective, thus providing answers to the resolution of two members of the Dutch Lower House, De Krom and Spies (motion 29200 XI, nr. 40).

The macroeconomic consequences of climate policy are largely determined by three factors: the reduction target, the economic development in the underlying scenario without new climate policy, and the design of that policy. Given the reduction target, considerable uncertainty remains regarding the last two elements. In order to explore the macroeconomic consequences of a 30% reduction target, the uncertain factors are varied around a benchmark case.
For the underlying economic development, baselines are taken that closely resemble the scenarios of the “Referentieraming” currently being developed by ECN (Netherlands Energy Research Centre) and MNP (Netherlands Environmental Assessment Agency). This outlook consists of various scenarios for Dutch economic development in the long term and focuses on developments in two worldwide scenarios known as GLOBAL ECONOMY and STRONG EUROPE. These scenarios allow long-term assessments of developments in climate change and energy markets (Bollen, Manders and Mulder, 2004). This analysis primarily uses the reference scenario associated with the GLOBAL ECONOMY scenario, i.e. with a relatively high growth rate in which the costs of a stricter climate policy are also relatively high. The alternative reference scenario STRONG EUROPE (with a lower growth rate) is addressed as a variant. In contrast to the “Referentieraming”, no climate policy is assumed in the scenarios for the underlying economic development used in this study. The background scenarios also exclude current policies to achieve Kyoto Protocol objectives. This approach was chosen in order to provide a clear overview of the consequences of climate policy. Against the background of the GLOBAL

ECONOMY reference scenario, the costs of implementing the Kyoto Protocol in 2010 are compared with those of a post-Kyoto climate policy in 2020.

The macroeconomic consequences of climate policy are assessed using an applied general equilibrium model that is called WorldScan. This model has global coverage and in particular details regions within Europe (see Lejour, 2003, and Bollen, Manders and Mulder, 2004). The model distinguishes various sectors and is sufficiently detailed to monitor the development of energy-related $CO_2$ and other GHG emissions. The emission ceiling defined generates an endogenous shadow price known as 'carbon tax' or 'emission price'. A global ceiling with free emissions trade would result in a single worldwide emission price. The model can be used to analyse the effects of certain policies on economic growth, sector structure and trade patterns. WorldScan is often used for scenario analysis and (climate) policy studies (Bollen *et al*., 2003, De Mooij and Tang, 2003, Lejour, 2003, Bollen, Manders and Mulder, 2004).

In addition to the expected long-term economic developments, there is also uncertainty concerning the design of a climate policy obliging industrialised nations to commit themselves to a 30% reduction in GHG emissions, compared to 1990 levels. As a starting point it is assumed that a global emissions trading system is used to achieve these reduction targets. It is assumed that in 2010 the current Kyoto countries, i.e. the industrialised nations excluding the USA and Australia, will be joined by all other countries to form a global coalition. The current Kyoto countries will depart from their current Kyoto objectives, and the new countries (including Australia and the USA) will be allocated emission quota equal to their emission levels in 2010 in the background scenario. From this point of departure, emission quota will then be modified such that, at some future point, all countries will be granted equal emission levels per capita. This future point is chosen such that in 2020 all industrialised nations (thus including the USA and Australia) receive a joint emission-reduction target equal to a 30% reduction, compared to 1990 levels. This reduction target matches a worldwide convergence towards equal emissions per capita around the year 2025. The consequences of this climate policy are shown in the so-called benchmark case, against the background of the GLOBAL ECONOMY reference scenario. As an alternative, we also show the consequences of this policy against the background scenario known as STRONG EUROPE.

Alternative variants are explored to determine how the macroeconomic consequences of climate policy are affected if other abatement coalitions are formed and if emission rights are allocated differently. In order to analyse the effect of smaller coalitions one variant simulates the situation in which Asia and Africa are not part of the climate-policy coalition, while another variant includes only the Annex I industrialised nations as partners of a joint emission abatement coalition. The consequences of another allocation of emission rights are shown in two separate variants: the first assumes that (from 2010 onwards) worldwide emissions quotas are allocated to countries on the basis of their emissions in 2010, while the second distributes the total EU emission quota over EU countries such that, in 2020, the macroeconomic consequences are the same for all EU Member States.

This report is structured as follows. The following section describes in detail the outcomes of the benchmark case for the post-Kyoto and Kyoto policies. Several factors are highlighted that will increase or decrease the assessments of the costs involved. These factors may be important in practice but are not included in the calculations. Section 3 shows how the economic consequences of climate policy are affected by alternative assumptions with regard to the underlying economic development scenario, climate coalitions and regulations for allocating the emission quota. This section also indicates the sensitivity of the results with respect to changes in model parameters. The last section summarises the most important conclusions resulting from the study.

# 2 The benchmark policy case

## 2.1 Post-Kyoto (2020)

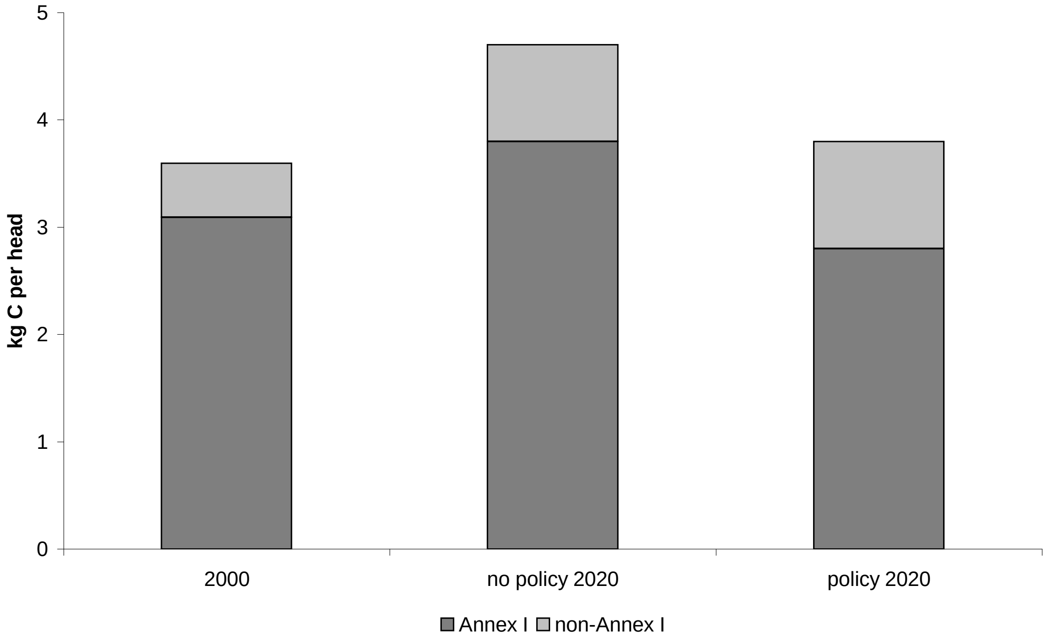
The so-called benchmark case is the main starting point for the analysis. However, this does not mean that this case has a greater probability to materialise in the post-Kyoto period than the alternative variants discussed in the following section. The most important characteristics of the post-Kyoto policy in the benchmark case are the following. The main assumption is a global emissions profile restricting worldwide emissions such that, in the long term, GHG concentrations will be stabilised at 550 ppmv $CO_2$ equivalents. This will probably[2] be sufficient to achieve the EU climate target of limiting an average global temperature increase to at most 2°C above pre-industrial levels. In order to achieve this objective the global *rise* in GHG emissions will need to be converted into a *drop* somewhere around the year 2020. This means that the reductions of GHG emissions by Annex I countries will need to go much further than their current Kyoto commitments. Taking into account the required capacity for emission growth in developing countries, the aforementioned emission-reduction targets for Annex I countries would amount to a reduction of approximately 30% in 2020, compared to 1990 levels. Country-specific emission quotas are derived from a worldwide emissions ceiling. They are not to be exceeded unless emission allocations can be bought from other countries. The quota per country is arrived at on the assumption that in a certain year all countries will be allocated an equal emission quota per capita. This distribution mechanism is known as 'contraction and convergence' (see also Bollen, Manders and Mulder, 2004; Den Elzen, 2001). A final year with equal rights per capita was chosen such that in 2020 the industrialised nations will be allocated an emission quota that is 30% below 1990 levels. This emission-reduction target is the main point of departure of this study. With regard to emission projections for 2020 in the background scenario, this quota means a reduction in GHG emissions of just over 50% for Annex I countries (see Figure 2.1).

It is assumed that, in 2010, the coalition of Kyoto countries (i.e. Annex I countries excluding the USA and Australia) will be joined by all other countries. A global emissions ceiling will be announced for this worldwide abatement coalition and a system of global emissions trading (without restrictions) will be put in place. The calculations concerning emissions trading take no account of transaction costs. In 2010 the Kyoto countries will depart from their Kyoto targets, and the countries that join the coalition will be allocated emission rights equal to their 2010 levels. These rights are then adjusted such that in 2024 all countries have equal rights per capita and the total worldwide rights do not exceed the global emissions ceiling. The allocation process between 2010 and 2024 will begin with wide-ranging rights per capita, and the

[2] There is uncertainty regarding climate sensitivity towards GHG concentrations. An average sensitivity is assumed here, as indicated in various IPCC studies.

differences between countries will be eliminated in equal steps until 2024. This means that convergence of the rights per capita will not be complete in the year 2020 (see Figure 2.1).

**Figure 2.1** **Emission rights per head in Annex I and non-Annex I countries in the benchmark case (kg C per head)**




The convergence year has been chosen such that the point of departure for this study is enforced in 2020, i.e. a joint emission target for the Annex I-countries of a 30% reduction below their actual $CO_2$ emissions in 1990[3].

It is assumed that, with a global emissions trading scheme, countries will not shift part of their quota to consecutive budget periods. In other words, post-Kyoto climate policy would not include the 'banking'[4] of emission rights, as suggested in earlier analyses (see Bollen *et al*., 2003). There will also be no restrictions on the extent to which countries domestically reduce emissions reduction, or the extent of imports on emissions rights. The 50/50[5] setting selected by the Netherlands within the Kyoto framework for domestic efforts / import of permits, does not apply to the benchmark case.

Figure 2.2 shows the emissions indicated in the benchmark. Global emissions will increase up to 2020, regardless of whether or not there is a climate policy. However, without a climate policy, in 2020 global emissions will be almost 11 Tg C. With climate policy this will be reduced to 8.5 Tg C. This is clearly far more than the global emissions of 6.5 Tg C for the year

[3] If a convergence year later than 2024 is selected, emission rights for the Annex I countries will be greater in 2020 and the limitation on their emissions quota will be less than for a 30% reduction, compared to 1990 levels.

[4] Countries may move their emission rights into the following budget period.

[5] During the 'Purple Coalition' period the Dutch government decided that, in achieving its emissions targets, no more than 50% emission rights might be purchased from foreign countries.

2000. The climate policy (with emissions trading) will lead in 2020 to emissions (of both Annex I and non-Annex I countries) well above the 2000 level. The Annex I countries will largely achieve their emission-reduction targets of 30% below 1990 levels by importing emission rights from non-Annex I countries. Nevertheless, emissions by non-Annex I counties will still increase compared to 2000 emission levels.

**Figure 2.2 Emissions in Annex I en non-Annex I in the bench mark case, in Tg C**

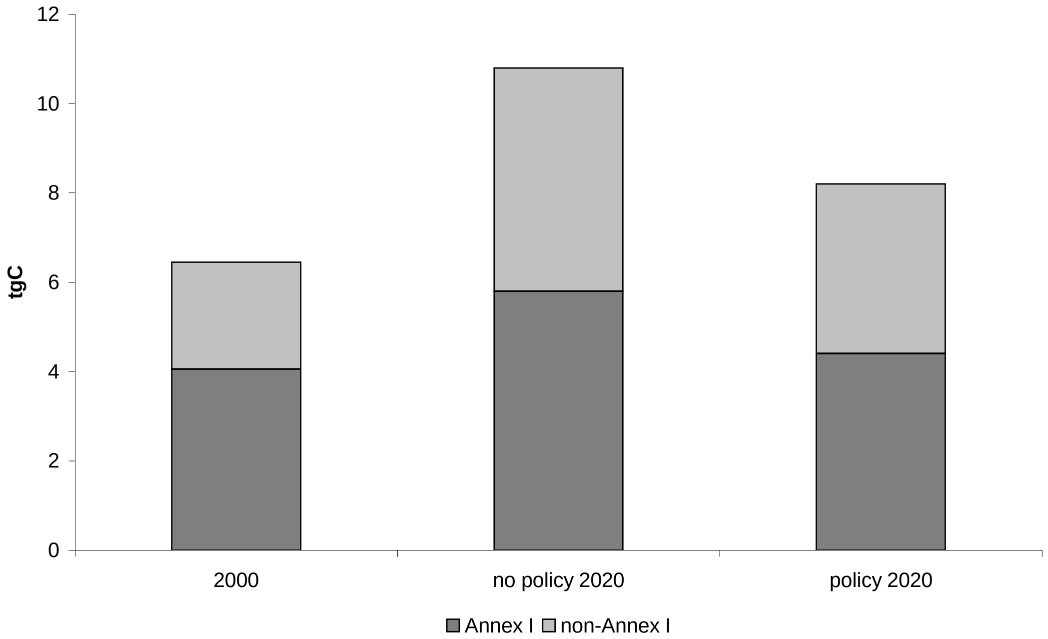



Table 2.1 shows the effects of a post-Kyoto climate policy, such as previously described, as compared to the GLOBAL ECONOMY scenario without any climate policy. In the benchmark case the permit price will be 17 € per tonne $CO_2$ [6]. This price results from unrestricted global emissions trading. The price of emission rights depends on the global emissions ceiling, and is independent from the allocation rule of those rights to countries.

Table 2.1 describes the following for both Annex I and non-Annex I countries. The first three columns of figures provide information on emissions and targets. The first column indicates the size of the reduction target compared to actual 1990 emission levels. For Annex I countries this is 30%. The second column indicates the target compared to the baseline emissions level in 2020 without climate policy. For Annex I countries this means an emissions reduction in 2020 of 53% compared to the baseline without climate policy. The third column shows the percentage change of emissions in 2020 after emissions trading compared to the baseline without any climate policy. For Annex I countries this means an estimated reduction of 18%. This also implies that Annex I countries will only partly achieve their reduction target within

[6] This carbon tax consists of 130% of the price for coal, 34% for gas, and 35% for oil. The oil price has relatively lower tax for climate policy, due to current excise duties on petrol.

their own borders, i.e. for 34% (=18/53). The majority of the reduction will therefore be achieved through the imports of emission rights from non-Annex I countries. The loss of income for industrialised nations mainly comes from payments to non-Annex I countries. The fourth column in the table indicates the extent to which the actual emissions reduction will be realised through a lower energy intensity. This does seem to be the case. Annex I countries can achieve an 83% reduction by changing the sectoral structure and increasing energy efficiency, while the remaining 17% is the result of changing the energy-mix to low-carbon energy carriers. The fifth column describes the macroeconomic consequences of the climate policy in terms of changes of national income. The real national incomes for Annex I countries in 2020 will thus be 0.6% less compared to the baseline without any climate policy. The last column shows the change in the total production volume of energy-intensive sectors plus the trade and transport sector, compared to the baseline without any climate policy. The global emissions market yields an emission price that is felt in all countries. For Annex I countries the effects on production volume are limited, i.e. a drop of 1% compared to the baseline in 2020.

**Table 2.1 Results in 2020 of the benchmark policy case, GLOBAL ECONOMY, global emissions trading with a permit price equal to 17 € / t $CO_2$.**

| | Percentage $CO_2$ reduction | | | Share of energy-intensity changes in emission reduction a) | National Income | Production Energy-intensive and Trade and Transport |
|---|---|---|---|---|---|---|
| | Target compared to emission level in 1990 (%) | Target compared to baseline emission level in 2020 (%) | Emissions compared to baseline emission level in 2020 (%) | % | % change from baseline | % change from baseline |
| Annex I | – 30 | – 53 | – 18 | 83 | – 0.6 | – 1 |
| EU 25 | – 30 | – 53 | – 14 | 82 | – 0.6 | 0 |
| Netherlands | – 41 | – 66 | – 12 | 80 | – 0.8 | 0 |
| Non-Annex I | 238 | 8 | – 27 | 80 | 0.3 | – 4 |
| Global | 49 | – 22 | – 22 | 81 | – 0.3 | – 2 |

[a] The total emission reduction is equal to the reduction of production, the energy-intensity (energy per unit of production), carbon-intensity ($CO_2$ per unit of energy). This column shows the share of the energy-intensity reductions in total emission reduction.

In comparison to Annex I countries, the Netherlands has a relatively heavy reduction target of 41% compared to 1990 levels. This is due to the fact that the Netherlands specialises in energy-intensive sectors and therefore has a relatively high per-capita emission level. Compared to the 2020 emission levels in the baseline, this means a reduction target of 66%. Only a relatively small percentage of this, 18% (=12/66) is achieved domestically, as the emission price at global emission market adopts remains rather modest. This price mirrors the relatively inexpensive emission-reduction options available in the developing countries. The domestic emission reduction will mainly be achieved through reduced energy intensity (80%) and reduced usage of high-carbon intensity energy carriers (20%). The movement towards a lower-carbon energy consumption is accompanied by greater amounts of natural gas and green energy in the energy-supply sector. Due to the relatively large reduction efforts required, the macroeconomic costs for the Netherlands are also relatively high: 0.8% of real national income in 2020, compared to the baseline without climate policy. Compared to the baseline, this policy has almost no consequences in the Netherlands for the collective production volume of energy-intensive sectors and the transport sector.

The costs of post-Kyoto climate policy will be relatively high for the Netherlands because:

- The distribution mechanism, whereby in 2024 all countries will have equal emission rights per capita, results in a relatively large emission reduction for industrialised countries;
- The Netherlands uses relatively large quantities of energy.

The distribution mechanism allocates the global emission rights based on the size of each country's population. Since the Netherlands has a relatively high $CO_2$ emission per capita, this leads to a relatively large drop in the Dutch emissions quota. Table 2.1 shows a 41% drop in the emission-reduction target for the Netherlands, while this is only 30% for the Annex I countries as a whole.

The post-Kyoto policy – as well as global emissions trading – will mean relatively high energy costs for the Netherlands, as it specialises in energy-intensive sectors such as basic chemicals and transport. Nevertheless, these energy-intensive sectors will not lose market share, as the emission price will apply worldwide. The production volume can therefore be kept at the same level as in the baseline without climate policy.

Table 2.2 shows the loss of revenue compared to the baseline without climate policy, and provides insight in two underlying factors: the drop in GDP (gross domestic product) and the costs/revenues of buying/selling emissions rights (both as a percentage of the national income)[7]. For Annex I countries the effect of post-Kyoto policy, with a global coalition and a worldwide emissions trading system, can remain limited in 2020 to 0.6% of national income (NI). Almost half this loss (0.3%) is caused by purchasing emission rights; the production loss (0.1%) is less. These amounts also roughly apply to the European Union as a whole.

[7] These components do not add-up to the drop in national income due to terms of trade effects and changes in the capital return on foreign capital investments.

**Table 2.2** **Results in 2020 of the benchmark policy case, GLOBAL ECONOMY, global emissions trading with a permit price equal to 17 € / t $CO_2$.**

| | Change in National Income (NI) | Change in GDP | Trade in Emission rights |
|---|---|---|---|
| | % change from baseline | % NI | % NI |
| Annex I | – 0.6 | – 0.1 | – 0.3 |
| EU 25 | – 0.6 | – 0.2 | – 0.3 |
| Netherlands | – 0.8 | – 0.3 | – 0.5 |
| Non-Annex I | 0.3 | – 0.6 | 0.8 |
| Global | – 0.3 | – 0.3 | 0.0 |

In 2020, the costs for the Netherlands will amount to 0.8% of the national income, of which 0.3% will be due to a reduced GDP. As shown in Table 2.1, the reduced production is not due to a loss of market share in the energy-intensive sectors. The loss of income is dominated by the costs of buying foreign emission rights in developing countries. This amounts to 0.5% of the national income, which is around the same size as the Dutch budget for development cooperation.

The non-Annex I countries will profit from global emissions trading. They receive most of the emission rights and have an inefficient method of energy consumption, so that they have a lot of emission rights to offer. They can thus earn 0.8% of their national income in emissions trading. The post-Kyoto policy will ensure that, in 2020, national incomes in non-Annex I countries will increase by 0.3% [8].

Emissions reduction in 2020 due to the post-Kyoto policy is an important step towards realising EU climate objectives, although further emission reductions will still be needed in the years following 2020. The costs of a climate policy will also increase after 2020. Bollen, Manders and Mulder (2004) calculate (for the GLOBAL ECONOMY background scenario) a revenue loss for Europe in 2020 of 6.7% of the real national income in a policy environment comparable to the benchmark case of this study (global coalition, a worldwide system of global emission trading without restrictions, the same emission-reduction options). This loss of revenue is due to a necessary 80% emissions reduction for Europe in 2040, compared to emission levels in 2000.

## 2.2 Costs of post-Kyoto (2020) versus Kyoto (2010)

How are the costs of post-Kyoto policy related to the costs of implementing the Kyoto Protocol against the background of the economic development in the GLOBAL ECONOMY scenario? Answers to this question can be found in Table 2.3, which shows that the costs of implementing the Kyoto policy amount to around half of those of the simulated post-Kyoto policy.

The most important characteristics of this simulated implementation of the Kyoto Protocol are as follows. It is assumed that Russia will ratify the Kyoto Protocol and that the Annex I countries (apart from the USA and Australia) will implement the Protocol in accordance with

[8] The changes in global national income as a result of global emissions trading are by definition equal to zero.

the guidelines agreed in Marrakesh (see Den Elzen and De Moor, 2001). It is also assumed that maximum use will be made of both international emissions trade and 'Joint Implementation' (CDM is beyond the scope of this study).

**Table 2.3 Effects of the Kyoto Protocol (international emissions trading at 11 €/ t $CO_2$ in 2010) and post-Kyoto policies (global emissions trading at 17 €/ t $CO_2$ in 2020), GLOBAL ECONOMY.**

| | Percentage $CO_2$ reduction in | | | Share of energy-intensity changes in emission reduction a) | National Income | Production Energy-intensive and Trade and Transport |
|---|---|---|---|---|---|---|
| | Target compared to emission level in 1990 (%) | Target compared to baseline emission level in 2020 (%) | Emissions compared to baseline emission level in 2020 (%) | % | % change from baseline | % change from baseline |
| **Kyoto (2010)** | | | | | | |
| EU 25 | – 6 | – 24 | – 10 | 84 | – 0.3 | – 2 |
| Netherlands | – 6 | – 35[a] | – 9 | 82 | – 0.4 | – 3 |
| **Post-Kyoto (2020)** | | | | | | |
| EU 25 | – 30 | – 53 | – 14 | 82 | – 0.6 | 0 |
| Netherlands | – 41 | – 66 | – 12 | 80 | – 0.8 | 0 |

[a] The policy effort of the target is higher than in Bollen *et al*. (2003) due to higher economic growth in the baseline.

Russia makes use of its power as the sole supplier of emission rights on the emissions market by transferring these to the second budget period, thus maximising its revenues from emissions trade[9]. There are no restrictions regarding the domestic/foreign distribution of the emissions reduction (via the purchase of foreign rights).

A post-Kyoto policy aimed at 30% emissions reduction requires far greater efforts than implementing the Kyoto Protocol with a reduction target of around 6%, and will therefore be far more expensive. Implementation costs of the Kyoto Protocol[10] are actually not dramatically lower, but amount to around half those of the post-Kyoto policy, which make it seem relatively inexpensive. This is due to the fact that this policy allows a worldwide emissions market to be used.

[9] Russia transfers 55% of its rights to the second budget period, thus maximising emission trading revenues. If Russia 'banks' less then the price of emission rights will increase less than the drop in sales volume thus reducing revenues. However, if Russia banks more, then the emission price will drop more than the increase in sales volume.

[10] Bollen *et al.* (2002) shows lower costs. This is because the economic growth in the GLOBAL ECONOMY scenario is higher than in the baseline without climate policy in Bollen *et al*. (2002).

For the first budget period the EU and the Netherlands have agreed to reduce GHG emissions by 8% and 6% respectively, compared to 1990 levels. For post-Kyoto policy – as analysed here – with a convergence towards equal emission rights per capita, the distribution mechanism leads to a collective 30% emission reduction for all Annex I countries in 2020, and to the same reduction percentage for the EU as a whole. At the same time, this distribution mechanism will also result in a stricter regime for the Netherlands – i.e. 41% compared to 1990 levels. This is due to the fact that its emissions level per capita is relatively high compared to other Annex I countries.

If unlimited use can be made of flexible instruments in order to achieve the Kyoto objectives, then the 50/50 rule will be exceeded during the first budget period (only 26% (=9/35) of the domestic reduction target will be achieved). Should Russia and other former Soviet nations utilise less market power than projected during this period, then the larger amounts of emission rights available will put pressure on the price, and the 50/50 rule will be exceeded even further. Ignoring the 50/50 rule will help to limit the costs of climate policy.

The domestic emissions reduction will predominantly be realised by reducing the energy intensity via shifting sector structures and energy conservation (82%). The remainder will be achieved by using more low-carbon fuels. This applies to both Kyoto and post-Kyoto policies. The Netherlands is more vulnerable than the EU to climate policy, due to its relatively high energy intensity. Under Kyoto, shifting activities abroad is encouraged[11], because there is neither a global abatement coalition nor a system of worldwide emissions trading. Countries such as Australia and the USA do not feel the emissions price. Relocating energy-intensive activities outside the country also means moving labour into energy-extensive production. The simulated post-Kyoto policy generally does not include relocating such activities to foreign countries, due to the global emissions trading system. The uniform emissions price ensures penalties on carbon emissions in all countries.

[11] Relocation effects for Kyoto – despite the higher emission price – are less than in Bollen *et al*. (2003) due to new information on the Armington elasticities, which describe the sensitivity of trade with respect to price differences with other countries.

## 2.3 Factors that increase or decrease costs

The calculated macroeconomic consequences need fine-tuning due to factors that, in practice, can be important but which are not included in the model. This subsection therefore discusses several factors that may result in increased or decreased costs.

#### Factors that increase costs

- *Adjustments costs*. The costs of climate policy can be significantly increased due to adjustment costs. The simulations here do not take these into account. Higher energy costs lead to lower real revenue growth and lower real wages. Wage restraints can lead to temporary unemployment and thus to considerably higher temporary costs. Model experiments have shown that rigid wage structures may imply short-term and medium-term costs in an order of magnitude of several percent of GDP (OECD, 1999). There are also costs involved in reallocating production factors. Employees need to be retrained; machines and buildings need to be modified or replaced. Modification costs can be limited if economic agents have sufficient time to anticipate upon the changes required. A timely announcement of the post-Kyoto climate policy may therefore reduce these costs.
- *Distribution effects.* Relatively low macroeconomic costs are generally a balance of costs and benefits. Some economic agents may suffer huge losses, while others benefit. These distribution effects are not included when calculating macroeconomic outcomes. These therefore do not reveal the possibility of considerable local negative effects in specific regions.
- *Transaction costs.* Setting up, monitoring and maintaining a global emissions trading system is costly. The transaction and maintenance costs are extremely difficult to estimate with regard to climate policy, and also depend on the extent to which the policy tools are designed and installed efficiently. A rough estimate of the transaction costs for emissions trading consists of the income effect of an extra surcharge on the emissions price with several percent (see also Broer *et al*., 2000).
- *Market power.* If the number of suppliers remains limited then cartels can push up the price of emissions rights. This increases the climate policy costs for those countries importing emissions rights, and reduces the costs for exporting countries. The simulations for post-Kyoto policy assume that suppliers do not use such powers to influence the market.

#### Factors that decrease costs

- *Carbon storage.* Options for carbon storage, e.g. by planting trees or underground storage, are also not included here, simply because there is insufficient insight into the costs involved in the large-scale use of these reduction methodologies. Should large-scale usage seem attractive, then the costs will be reduced.

The results of the simulated policy experiments need to be fine-tuned due to all factors, whether they increase or decrease the costs, where these are not included in the calculations. It is extremely difficult to give a good quantitative analysis of the collective influence these factors could have on the calculated macroeconomic costs. On balance, these factors could contain an upward, cost-increasing risk.

# 3 Alternative variants

The benchmark policy case sketches a picture in which the macroeconomic effects of climate policy are fairly insignificant. However, this picture changes when a number of factors are modified in the analysis.

### Baseline scenario

The simulation results cannot be separated from the reference scenario. If projections of production growth and energy conservation lead to reduced emissions in the future, the policy effort to achieve the objectives, defined relative to 1990 levels, decreases. One variant takes STRONG EUROPE as the baseline scenario (without any climate policy). Compared to the benchmark policy case, this scenario is primarily characterised by lower economic growth.

### Participation by developing countries

The smaller the abatement coalition, the higher the costs of climate policy. On the one hand this is due to the global objective being realised by a smaller number of countries, while on the other hand fewer opportunities exist to outsource emission reduction to developing countries that have less expensive abatement options. In order to analyse the effects of a smaller abatement coalition, a variant has been simulated in which (in 2020) Asia and Africa still have no climate policy, while another variant simulates the situation where only the industrialised nations (Annex I) carry the burden. Both variants could be interpreted as stages of a multi-stage approach: countries only join the abatement coalition when their per-capita income exceeds a certain income level (see Criqui *et al*., 2003).

### Alternative Allocation rules

The regional and structural distribution of the effects of climate policy depends on the allocation of emission rights of the global emission constraint. The benchmark policy case assumes a convergence towards equal rights per capita in 2025. Alongside this stylised variant we also simulate two alternative allocation schemes. One variant assumes that allocation of emissions rights takes place within the coalition and is based on the projected emissions for 2010. This distribution mechanism is a form of ‘grandfathering’, where rights are distributed according to historic emission levels. A second variant selects an allocation within the EU such that the macroeconomic consequences are equal for all Member States (equal burden-sharing).

Figure 3.1 shows the following variants:

| | |
|---|---|
| BO | benchmark policy case |
| B1 | baseline STRONG EUROPE (without any climate policy) |
| B2 | as B1, but no participation of developing countries in Asia and Africa |
| B3 | as B2, but 'grandfathering' of emissions rights |
| B4 | as B0 but only participation of Annex I countries |
| B5 | global coalition, equal effects within the EU |

**Figure 3.1 Policy variants**

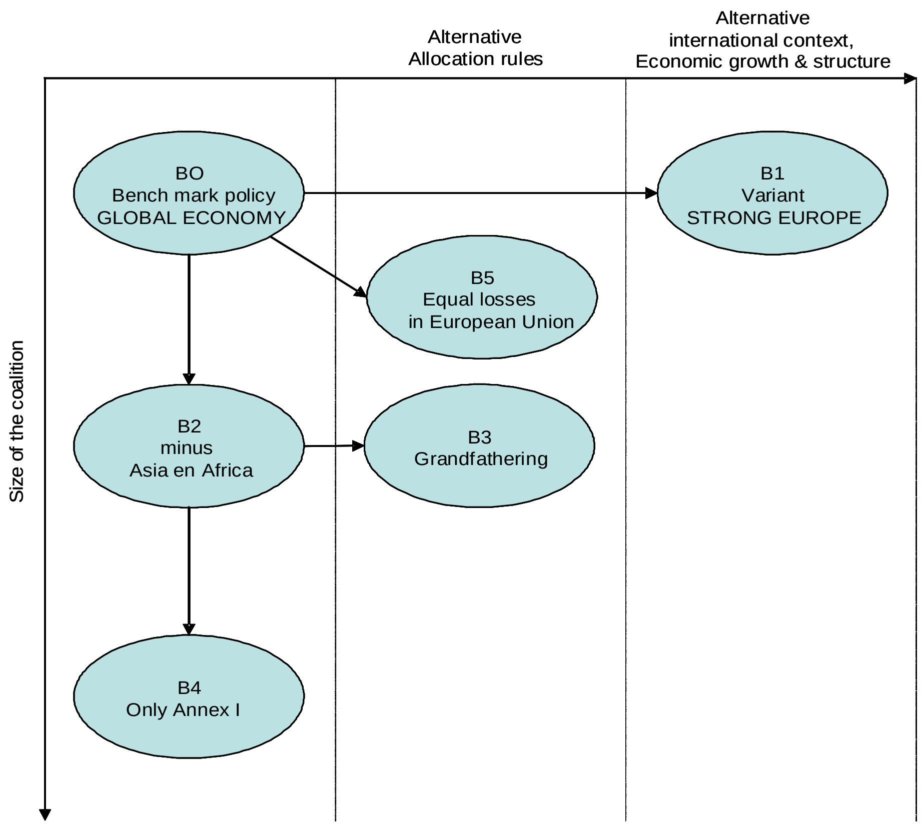



Table 3.1 reports the outcomes for the various variants and highlights three aspects: the income effect, the carbon tax, and the consequences for the energy-intensive sector. The table also shows the reduction targets. The appendix contains more details.

The table clearly shows that the costs of climate policy depend considerably on the policy efforts required to achieve the emissions objective. This policy effort is low in the reference scenario with a small increase in emissions (B1, STRONG EUROPE). This is shown by the low carbon tax of only € 4/t$CO_2$. At such a low price the distribution is less relevant. Even if the Netherlands needs to purchase a large amount of emissions rights, the revenue effects would remain limited. The loss of revenue in this scenario is limited to 0.2% of National Income. Further emission reductions in the years following 2020 will result in increased costs. Bollen, Manders and Mulder (2004) indicate a 2.2% loss of revenue for Europe (of national income) in 2040, for the background scenario STRONG EUROPE. This scenario is a continuation of the B1 variant and has a comparable policy environment (global coalition, worldwide emissions trading system without restrictions, the same emission-reduction options). Income loss is a consequence of the 80% emissions reduction considered necessary for Europe in 2040, compared to 2000 emission levels.

**Table 3.1 Variants, effects for the Netherlands in 2020**

| | | B0 | B1 | B2 | B3 | B4 | B5 |
|---|---|---|---|---|---|---|---|
| | | Bench-mark policy | Low growth | Multi-stage | Multi-stage | Multi-stage | Bench-mark policy |
| Coalition | | global | global | Annex I+ | Annex I+ | Annex I | global |
| Allocation rule a) | | CC | CC | CC | GF | CC | EU equal burden |
| Target | % change to 1990 emission level | – 41 | – 38 | – 41 | – 29 | – 41 | – 10 |
| Target | % change to baseline emissions in 2020 (without climate policy) | – 66 | – 55 | – 66 | – 60 | – 66 | – 49 |
| Emissions | % change to baseline emissions in 2020 (without climate policy) | – 12 | – 8 | – 29 | – 29 | – 45 | – 12 |
| Production Energy-intensive sector | % change to baseline volume in 2020 (without climate policy) | – 1 | 0 | – 6 | – 6 | – 17 | 0 |
| Permit price | € / $tCO_2$ | 17 | 4 | 58 | 57 | 129 | 17 |
| Global Emissions | Tg C | 8.53 | 8.15 | 8.55 | 8.56 | 8.34 | 8.53 |
| Income effect Netherlands | % change to baseline in 2020 (without climate policy) | – 0.8 | – 0.2 | – 2.6 | – 2.3 | – 4.8 | – 0.6 |
| Income effect EU-25 | % change to baseline level in 2020 (without climate policy) | – 0.6 | – 0.1 | – 1.8 | – 1.6 | – 3.1 | – 0.6 |

[a] CC is targets per capita convergence in 2026; GF is ‘grandfathering’ based on emission levels in 2010 for USA, Australia, and all countries in non-Annex I, and 2010 target levels for the Kyoto-countries.

The cost-effectiveness greatly depends on participation by developing countries. The loss of inexpensive reduction opportunities in these countries (B2, B3 and B4) drives the carbon tax up to over the € 57/t$CO_2$. The income effects are also relatively higher. In this case terms of trade effects also play a role. Since the Netherlands can import relatively inexpensive emission rights from non-participating countries, this amounts to positive terms of trade effect, which buffers the drop in real national income. A limited coalition also has certain effects on the sector structure. Energy-intensive sectors have to cope with relatively high costs, due to the competitive disadvantage with respect to non-participating countries. The variant in which only Annex I countries finance these costs (B4) shows that the production in energy-intensive sectors therefore drops by 17%.

Allocating emission rights on the basis of 'grandfathering' (B3) and equal burden-sharing throughout the EU (B5) is more favourable for the Netherlands. In the initial situation the Dutch economy is relatively energy-intensive. Convergence to equal rights per capita means that the Netherlands will also need to ensure considerable policy efforts. Using 'grandfathering' the relatively high emissions in the Netherlands are 'rewarded' in the form of emission rights. If the EU then decides to redistribute these rights, whereby the estimated macroeconomic effects of emission rights are the same for all Member States in a certain year, then the Netherlands will also receive a larger emissions quota than via a convergence scheme based on equal rights per capita.

A certain allocation of rights leads via emissions trading to international income transfers. Incomplete coalitions also need to consider the dynamic effects of using a system where rights are distributed according to the behaviour of new members. Distributions based on convergence to equal emissions per capita encourage the timely joining by developing countries because they can then sell their surplus of rights. 'Grandfathering' lacks this encouragement.

#### Reducing costs through CDM?

For non-global coalitions, the use of the *Clean Development Mechanism (CDM)* can reduce the costs. However, this is not included in the simulations. CDM deals with projects to reduce GHG emissions in non-coalition countries. It is extremely difficult to determine the extent to which these projects could actually contribute to emissions reduction. There is a considerable danger of leakage effects as CDM may result in higher energy consumption in other parts of the economy (Bollen, Gielen, Timmer, 1999).

#### Sensitivity analysis

Uncertainty not only exists with regard to climate policy and the economic background scenario, but also regarding the values of some model parameters. In order to assess this sensitivity, the most important key parameters in WorldScan have been altered. These are the substitution elasticities[12], which indicate the ease with which energy can be substituted in production processes with other inputs, or the ease of 'fuel switching'. Lower substitution elasticities make it more difficult to substitute energy for labour or capital, or to replace carbon-based energy carriers with cleaner alternatives. The costs of climate policy will therefore be higher. The substitute elasticities are halved in a sensitivity analysis. Table 3.2 shows the effects on several outcomes of the benchmark policy case.

**Table 3.2 Effects on the benchmark policy case from lower substitution elasticities**

| | B0 | O1 |
|---|---|---|
| | Benchmark policy variant | Halving substitution elasticities |
| Income effect Netherlands | – 0.8 | – 1.4 |
| Income effect EU25 | – 0.6 | – 1.1 |
| Permit price (€ / $tCO_2$) | 17 | 32 |

Halving the substitution elasticities leads to almost a doubling of the carbon tax and a considerable increase in income losses. The results therefore seem sensitive to the values of these parameters. This is another reason why the calculated outcomes should be interpreted with care.

[12] Other important parameters include: the Armington elasticities, which determine the movements in trade patterns, and the (energy) supply of elasticities, which partly determine the energy price. Sensitivity analyses have shown that changing these parameters produces little effect.

# 4 Conclusions

If industrialised countries reduce their GHG emissions in 2020 to 30% below their 1990 levels, an important step would be set towards achieving the current EU climate goal. According to this objective, the average temperature increase should stay below 2°C above pre-industrial levels. The costs of this climate strategy are uncertain and depend on the underlying economic scenario and the policy design. Coalition size, the use of flexible mechanisms, like an international market for emission permits trading, and the allocation of emission rights all play an important role.

A global coalition and an unrestricted international emissions trading system would yield relatively low macroeconomic costs for the Netherlands, compared to alternative designs of the climate policy. Depending on the underlying scenario for economic development without climate policy, the income losses in 2020 ranges from 0.2% to 0.8% of the National Income. Based on the high-growth scenario (GLOBAL ECONOMY) the costs of implementing the Kyoto Protocol in 2010 would for the Netherlands equal 0.4% of their National Income – only half the costs of the post-Kyoto policy in 2020 (0.8%). The post-Kyoto policy is therefore considered to be relatively inexpensive. But this result hinges on the assumption of an efficient worldwide cap-and-trade system. The post-Kyoto climate policy also assumes that the emission rights will be allocated to countries on an equal per capita base in 2025. Alternative allocation rules have no influence on the price of $CO_2$ emissions, but can affect the macroeconomic costs at the national level. The consequences of an alternative allocation rule within the EU have also been considered. An allocation based on equal burden-sharing within the EU shows that the costs for the Netherlands in 2020 could drop from 0.8% to 0.6% of the National Income, based on an unchanged emission price of € 17/t$CO_2$.

Using a multi-stage approach, the post-Kyoto climate policy will start with a smaller coalition of participating countries, assuming that non-participating countries will join later when a certain income level has been achieved. However, costs could increase substantially using this approach. If only the developing countries in Africa and Asia (including China and India) remain outside the coalition, then in 2020 the income losses for the Netherlands are estimated to rise from 0.8% to 2.6% of National Income (at an emission price of € 58/t$CO_2$). If the coalition is further restricted to just Annex I countries (including Australia and the USA) then the income loss will increase further to 4.8% at an emission price of € 129/t$CO_2$. Smaller coalitions therefore result in significantly increased costs, as there would be no opportunities for using inexpensive emission-reduction options in the non-participating countries.

For the Netherlands, allocation rules based on convergence towards equal emissions rights per capita is a relative disadvantage. Since the Netherlands is specialised in energy-intensive sectors (e.g. chemicals and transport), it has a relatively high energy consumption per capita. Allocation rules based on actual emissions (grandfathering) would lead to lower macroeconomic costs for the Netherlands. In a policy variant, in which developing countries do not join the abatement coalition, the global target is not allocated on the basis of convergence to equal rights per capita, but according to the emission shares in 2010. The income losses in 2020 for the Netherlands would then not be 2.6% of National Income, but 2.3%.

The model-simulated policy variants have a ‘stylized’ character. The calculations do not take account of many factors that could substantially increase or decrease the macro-economic costs. For example, the costs of economic restructuring, distributional effects, transaction, screening and enforcement costs of the climate policy, and monopolistic behaviour by suppliers of emission rights are all excluded from the calculations. On the other hand, cost-reducing factors such as carbon storage and – for incomplete coalitions – the use of CDM, are also excluded from the analyses in this report. The numerical impact of these factors is difficult to assess. The factors excluded from the calculations can result in an upward, cost-increasing risk for the simulated macroeconomic effects. The costs associated with post-Kyoto policies as simulated in this study are therefore still uncertain.

The climate policy that leads to a 30% emissions reduction for the industrialised countries in 2020 can be seen as a necessary step towards achieving the EU’s climate objectives. Under certain conditions the macroeconomic costs of this policy will, in 2020, be fairly small and, for the Netherlands, amount to less than 1% of National Income. These conditions are: that a global climate coalition is formed quickly and that a worldwide emissions trading system (without restrictions) is put in place. If these criteria are not met then the macro-economic costs for the Netherlands will increase sharply.

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# Appendix

**Table A.1 Base-year data (2000)**

| | Population | National Income | Energy | Emissions | E-Intensity | C-Intensity |
|---|---|---|---|---|---|---|
| | (mn) | (bn $) | (toe) | (GtC) | (USA=100) | (USA=100) |
| EU-25 | 543 | 9124 | 167 | 1.21 | 77 | 96 |
| Netherlands | 16 | 381 | 10 | 0.05 | 106 | 72 |
| Germany | 82 | 2175 | 33 | 0.25 | 63 | 100 |
| France | 60 | 1478 | 18 | 0.11 | 52 | 79 |
| United Kingdom | 59 | 1418 | 23 | 0.16 | 68 | 95 |
| United States | 283 | 9091 | 215 | 1.63 | 100 | 100 |
| Russia | 292 | 601 | 85 | 0.58 | 595 | 90 |
| Annex I | 1310 | 24807 | 552 | 4.05 | 94 | 97 |
| Non-Annex I | 4746 | 6959 | 300 | 2.40 | 182 | 106 |
| Latin America | 514 | 2086 | 52 | 0.36 | 106 | 90 |
| Middle East | 315 | 805 | 48 | 0.35 | 253 | 95 |
| Rest non-Annex I | 3917 | 4066 | 199 | 1.70 | 207 | 112 |
| Global | 6056 | 31765 | 852 | 6.45 | 113 | 100 |

**Table A.2 Baseline characteristics, annual growth in 2000-2020 in GLOBAL ECONOMY and targets in the benchmark policy case (convergence of per capita targets in 2024)**

| | Population | National Income | Energy | Emissions | Target | Target |
|---|---|---|---|---|---|---|
| | % per year | % per year | % per year | % per year | % change compared to emissions in 1990 | % change compared to emissions in 2020 without any climate policy |
| EU-25 | 0.4 | 2.8 | 2.0 | 1.9 | – 30 | – 53 |
| Netherlands | 0.7 | 3.0 | 2.4 | 2.4 | – 41 | – 66 |
| Germany | 0.5 | 2.5 | 1.4 | 1.3 | – 47 | – 54 |
| France | 0.5 | 2.7 | 1.6 | 1.8 | – 21 | – 48 |
| United Kingdom | 0.4 | 2.7 | 1.9 | 1.7 | – 42 | – 58 |
| United States | 0.8 | 2.9 | 1.2 | 1.2 | – 39 | – 60 |
| Russia | 0.1 | 4.6 | 1.7 | 1.6 | – 45 | – 34 |
| Annex I | 0.4 | 2.7 | 1.5 | 1.5 | – 30 | – 53 |
| Non-Annex I | 1.3 | 5.5 | 4.4 | 4.3 | 238 | 8 |
| Latin America | 1.1 | 3.9 | 4.5 | 4.6 | 145 | – 22 |
| Middle East | 2.0 | 4.1 | 3.5 | 3.5 | 121 | – 23 |
| Rest non-Annex I | 1.2 | 6.4 | 4.5 | 4.3 | 282 | 20 |
| Global | 1.1 | 3.5 | 2.7 | 2.7 | 49 | – 22 |

**Table A.3 Baseline characteristics, annual growth in 2000-2020 in STRONG EUROPE and targets in the benchmark policy case (convergence of per capita targets in 2024)**

| | Population | National Income | Energy | Emissions | Target | Target |
|---|---|---|---|---|---|---|
| | % per year | % per year | % per year | % per year | % change compared to emissions in 1990 | % change compared to emissions in 2020 without any climate policy |
| EU-25 | 0.4 | 1.9 | 0.9 | 0.7 | – 27 | – 36 |
| Netherlands | 0.4 | 1.9 | 0.9 | 0.7 | – 38 | – 55 |
| Germany | 0.5 | 1.7 | 0.2 | – 0.1 | – 33 | – 32 |
| France | 0.5 | 1.7 | 0.6 | 0.4 | – 26 | – 32 |
| United Kingdom | 0.4 | 1.8 | 0.7 | 0.4 | – 34 | – 40 |
| United States | 0.8 | 2.2 | 0.5 | 0.2 | – 42 | – 45 |
| Russia | 0.1 | 4.3 | 0.9 | 0.7 | 41 | – 11 |
| Annex I | 0.4 | 2.0 | 0.6 | 0.4 | – 30 | – 35 |
| Non-Annex I | 1.3 | 4.9 | 3.5 | 3.2 | 124 | 18 |
| Latin America | 1.1 | 3.7 | 3.8 | 3.8 | 79 | – 15 |
| Middle East | 2.0 | 4.2 | 3.0 | 2.9 | 46 | – 17 |
| Rest non-Annex I | 1.2 | 5.5 | 3.5 | 3.2 | 149 | 33 |
| Global | 1.1 | 2.7 | 1.8 | 1.6 | 27 | – 8 |

**Table A.4 Effects in 2020, benchmark B0, global emissions trading at permit price equal to 17 € / $tCO_2$**

| | $CO_2$ emission targets compared to 1990 | $CO_2$ emission targets compared to 2020 | $CO_2$ emissions compared to 2020 | Income | Production E-int. and Trade & Transport |
|---|---|---|---|---|---|
| | (%) | (%) | (%) | (% change comp. to baseline level) | (% change comp. to baseline level |
| EU-25 | – 30 | – 53 | – 14 | – 0.6 | 0 |
| Netherlands | – 41 | – 66 | – 12 | – 0.8 | 0 |
| Germany | – 47 | – 54 | – 11 | – 0.6 | 0 |
| France | – 21 | – 48 | – 8 | – 0.3 | 2 |
| United Kingdom | – 42 | – 58 | – 12 | – 0.5 | 2 |
| United States | – 39 | – 60 | – 19 | – 0.5 | – 1 |
| Russia | – 45 | – 34 | – 26 | – 1.4 | – 10 |
| Annex I | – 30 | – 53 | – 18 | – 0.6 | – 1 |
| Non-Annex I | 238 | 8 | – 27 | 0.3 | – 4 |
| Latin America | 145 | – 22 | – 13 | – 0.7 | – 2 |
| Middle East | 121 | – 23 | – 15 | – 1.3 | – 5 |
| Rest non-Annex I | 282 | 20 | – 32 | 0.8 | – 5 |
| Global | 49 | – 22 | – 22 | – 0.3 | – 2 |

**Table A.5** **Effects in 2020, variant B1, STRONG EUROPE, global emissions trading at permit price of 4 € / t $CO_2$**

| | $CO_2$ emission targets compared to 1990 | $CO_2$ emission targets compared to 2020 | $CO_2$ emissions compared to 2020 | Income | Production E-int. and Trade & Transport |
|---|---|---|---|---|---|
| | (%) | (%) | (%) | (% change comp. to baseline level) | (% change comp. to baseline level |
| EU-25 | – 27 | – 36 | – 4 | – 0.1 | 0 |
| Netherlands | – 38 | – 55 | – 8 | – 0.2 | 0 |
| Germany | – 33 | – 32 | – 3 | – 0.1 | 0 |
| France | – 26 | – 32 | – 2 | – 0.1 | 0 |
| United Kingdom | – 34 | – 40 | – 4 | – 0.1 | 0 |
| United States | – 42 | – 45 | – 6 | – 0.1 | 0 |
| Russia | 41 | – 11 | – 7 | – 0.2 | – 1 |
| Annex I | – 30 | – 35 | – 5 | – 0.1 | 0 |
| Non-Annex I | 124 | 18 | – 10 | 0.1 | – 1 |
| Latin America | 79 | – 15 | – 4 | – 0.1 | 0 |
| Middle East | 46 | – 17 | – 4 | – 0.2 | – 1 |
| Rest non-Annex I | 149 | 33 | – 13 | 0.2 | – 1 |
| Global | 27 | – 8 | – 8 | 0.0 | 0 |

**Table A.6** **Effects in 2020, variant B2, multi-stage, emissions trading without rest non-Annex I, permit prices at 58 € / t $CO_2$**

| | $CO_2$ emission targets compared to 1990 | $CO_2$ emission targets compared to 2020 | $CO_2$ emissions compared to 2020 | Income | Production E-int. and Trade & Transport |
|---|---|---|---|---|---|
| | (%) | (%) | (%) | (% change comp. to baseline level) | (% change comp. to baseline level |
| EU-25 | – 30 | – 53 | – 31 | – 1.8 | – 4 |
| Netherlands | – 41 | – 66 | – 29 | – 2.6 | – 6 |
| Germany | – 47 | – 54 | – 26 | – 1.8 | – 5 |
| France | – 21 | – 48 | – 20 | – 1.1 | 0 |
| United Kingdom | – 42 | – 58 | – 28 | – 1.6 | 1 |
| United States | – 39 | – 60 | – 40 | – 1.3 | – 6 |
| Russia | – 45 | – 34 | – 51 | – 1.8 | – 32 |
| Annex I | – 30 | – 53 | – 37 | – 1.5 | – 6 |
| Non-Annex I | | | – 7 | 0.8 | 2 |
| Latin America | 145 | – 22 | – 31 | 0.7 | – 10 |
| Middle East | 121 | – 23 | – 35 | 5.7 | – 24 |
| Rest non-Annex I | | | 3 | 0.2 | 6 |
| Global | | | – 22 | – 0.8 | – 3 |

**Table A.7 Effects in 2020, variant B3, multi-stage, emissions trading without rest non-Annex I, grandfathering at permit price equal to 57 € / t $CO_2$**

| | $CO_2$ emission targets compared to 1990 | $CO_2$ emission targets compared to 2020 | $CO_2$ emissions compared to 2020 | Income | Production E-int. and Trade & Transport |
|---|---|---|---|---|---|
| | (%) | (%) | (%) | (% change comp. to baseline level) | (% change comp. to baseline level |
| EU-25 | – 21 | – 46 | – 30 | – 1.6 | – 4 |
| Netherlands | – 29 | – 60 | – 29 | – 2.3 | – 6 |
| Germany | – 29 | – 38 | – 26 | – 1.3 | – 5 |
| France | – 30 | – 54 | – 20 | – 1.2 | 1 |
| United Kingdom | – 29 | – 48 | – 28 | – 1.3 | 1 |
| United States | 4 | – 31 | – 39 | – 0.4 | – 7 |
| Russia | – 22 | – 8 | – 51 | 1.5 | – 34 |
| Annex I | 0 | – 33 | – 37 | – 0.8 | – 7 |
| Non-Annex I | | | – 7 | – 0.8 | 2 |
| Latin America | 58 | – 50 | – 32 | – 2.9 | – 9 |
| Middle East | 52 | – 47 | – 36 | – 4.3 | – 21 |
| Rest non-Annex I | | | 3 | 0.2 | 6 |
| Global | | | – 22 | – 0.8 | – 3 |

**Table A.8 Effects in 2020, variant B4, multi-stage, emissions trading within Annex I, at a permit price equal to 129 € / t $CO_2$**

| | $CO_2$ emission targets compared to 1990 | $CO_2$ emission targets compared to 2020 | $CO_2$ emissions compared to 2020 | Income | Production E-int. and Trade & Transport |
|---|---|---|---|---|---|
| | (%) | (%) | (%) | (% change comp. to baseline level) | (% change comp. to baseline level |
| EU-25 | – 30 | – 53 | – 46 | – 3.1 | – 12 |
| Netherlands | – 41 | – 66 | – 45 | – 4.8 | – 17 |
| Germany | – 47 | – 54 | – 42 | – 3.0 | – 13 |
| France | – 21 | – 48 | – 33 | – 2.2 | – 3 |
| United Kingdom | – 42 | – 58 | – 43 | – 2.8 | – 2 |
| United States | – 39 | – 60 | – 56 | – 1.9 | – 15 |
| Russia | – 45 | – 34 | – 68 | 1.5 | – 54 |
| Annex I | – 30 | – 53 | – 53 | – 2.2 | – 15 |
| Non-Annex I | | | 4 | 0.1 | 9 |
| Latin America | | | 5 | – 0.1 | 10 |
| Middle East | | | 4 | – 0.8 | 16 |
| Rest non-Annex I | | | 4 | 0.3 | 9 |
| Global | | | – 24 | – 1.5 | – 5 |

**Table A.9 Effects in 2020, variant B5, global emissions trading, alternative allocation within EU, at permit price equal to 17 € / t $CO_2$**

| | $CO_2$ emission targets compared to 1990 | $CO_2$ emission targets compared to 2020 | $CO_2$ emissions compared to 2020 | Income | Production E-int. and Trade & Transport |
|---|---|---|---|---|---|
| | (%) | (%) | (%) | (% change comp. to baseline level) | (% change comp. to baseline level |
| EU-25 | – 30 | – 53 | – 14 | – 0.6 | 0 |
| Netherlands | – 10 | – 49 | – 12 | – 0.6 | 0 |
| Germany | – 55 | – 61 | – 11 | – 0.6 | 0 |
| France | – 108 | – 105 | – 8 | – 0.6 | 2 |
| United Kingdom | – 62 | – 72 | – 12 | – 0.6 | 2 |
| United States | – 39 | – 60 | – 19 | – 0.5 | – 1 |
| Russia | – 45 | – 34 | – 26 | – 1.4 | – 10 |
| Annex I | – 30 | – 53 | – 18 | – 0.6 | – 1 |
| Non-Annex I | 238 | 8 | – 27 | 0.3 | – 4 |
| Latin America | 145 | – 22 | – 13 | – 0.7 | – 2 |
| Middle East | 121 | – 23 | – 15 | – 1.3 | – 5 |
| Rest non-Annex I | 282 | 20 | – 32 | 0.8 | – 5 |
| Global | 49 | – 22 | – 22 | – 0.3 | – 2 |