PBL Netherlands Environmental Assessment Agency

WHAT ARE JUST AND FEASIBLE CLIMATE TARGETS FOR THE NETHERLANDS?

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Content

Findings

By signing the Paris Agreement in 2015, the Netherlands committed to the goal of limiting global warming to well below 2 °C and pursuing efforts to stay below 1.5 °C. Following this agreement, both the European Union and the Netherlands expressed the ambition to be climate neutral by 2050, and, as an intermediate target, to reduce greenhouse gases by 55% by 2030 compared to 1990. The European Union and the Netherlands have also stated that they aim for net negative emissions after 2050.

The question of which emission reduction targets for the Netherlands would comply with the Paris Agreement, especially for 2040, is relevant for two reasons. First, early 2024, the European Commission proposed a new intermediate target of reducing emissions by 90% by 2040. In addition, the Global Stocktake of current climate policies of all countries worldwide recently showed that the expected impacts are still insufficient. When setting national reduction targets, the concepts of *global distributive justice* and *national feasibility* play a central role. In other words, how could global reduction efforts be distributed fairly across all countries?

Setting national emission reduction targets consistent with the Paris Agreement is not only a technical question; political and normative choices play an important role, too. The translation of the Paris Agreement into emission reduction targets for individual countries can be based on 1) how much greenhouse gas could still be emitted globally to meet the Paris Agreement's temperature targets and 2) the distribution of this emission budget across the various countries. Clearly, such distribution implies political and normative choices. These choices are related to the interpretation of the global climate target, to what would be considered a globally just distribution and to what would be feasible for the individual countries.

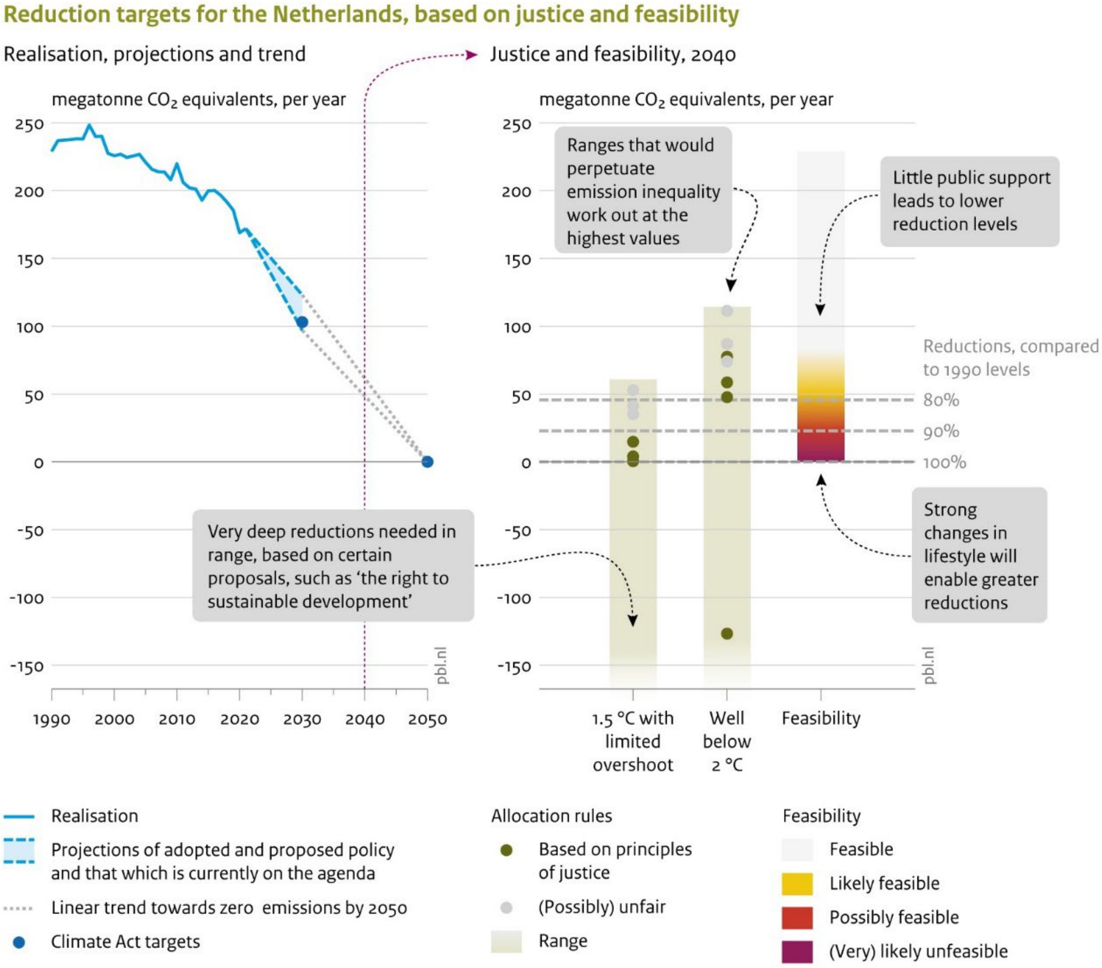
Determining what constitutes just reduction targets from an international perspective is neither straightforward nor unambiguous. There are various principles that come into play when assessing what would be a just distribution of emission reduction target. These principles are related to normative choices and can lead to different reduction targets. In general, principles such as responsibility, equality, emission reduction ability, and the right to sustainable development are seen as consistent with international environmental law (see Chapter 3 for further elaboration of these principles). Calculations based on rules consistent with these principles can help to gain insights into the possible range of just reduction targets consistent with the Paris Agreement. This report looks at seven calculation rules and their associated uncertainty.

For the target of a maximum increase of 1.5 °C with limited overshoot, the range of reduction targets for the Netherlands consistent with principles of international environmental law runs from about 90% to well over 100% by 2040, relative to 1990 emission levels. Some of the calculation rules do not directly lead to outcomes consistent with the principles of international environmental law and, for example, keep current emissions disparities intact. The wide range of possible reduction targets for the Netherlands that could be consistent with the Paris Agreement and with the principles of international environmental law starts at around 90% greenhouse gas reduction by 2040 (compared to 1990) for the 1.5 °C target (with limited overshoot) but continues well beyond 100%. For well below 2 °C, the associated 2040 reductions are about 20 percentage points lower. Ultimately, governments must decide what distribution they consider just. For a specific temperature target, choosing less stringent emission reduction targets for one country would automatically mean that others have to do more. The interpretation of the global temperature target itself also has a justice dimension, not only given the relationship with the reduction effort, but also because of the unevenly distributed impacts of climate change.

Based on current estimates, a reduction to 90% by 2040 is likely geophysically and technically feasible. When setting Dutch emission reduction targets, feasibility is also important. National feasibility is determined by estimating what would be geophysically, technically, economically, institutionally and socially possible. Based on current estimates of the geophysical and technical potential, reductions in the order of 80%–90% by 2040 seem feasible; for larger reductions, the limits of feasibility come into view. To date, little research has been done on the economic, institutional and social feasibility of ambitious national reduction targets for 2040. If society were to make major lifestyle changes, reductions of around 90% or more could be possible. However, if the support base in society is only small — for instance, due to an uneven distribution of costs and benefits — the reduction potential may also be much smaller (also see Figure B1). After all, emission reduction measures impact the physical environment, economy and citizens, and the various consequences and interests need to be weighed against each other. All-in-all, this means that deep reductions that are based on international justice are often at the outer limit (or even far beyond) of what is domestically feasible. Therefore, when setting emission reduction targets, further more detailed analysis of the various dimensions of feasibility is needed, starting from a wide range of reduction options and visions for a future design of the Netherlands.

The Netherlands can do more than its share on a domestic level by also investing in emission reductions abroad. Based on some international justice principles, the Netherlands should do more than is considered likely feasible within its national borders. It is important to note that it is possible to contribute to reductions outside the Netherlands. Through the mechanisms mentioned in Article 6 of the Paris Agreement, it is also possible to gain formal recognition for reductions funded outside the Netherlands.

Figure B1



Source: Emissieregistratie, KEV-raming 2023, PBL

Reductions of more than 100% by 2040 have not been assessed separately but are very unlikely to be feasible

1 Introduction

By signing the Paris Agreement, the Netherlands has committed itself to the objective of limiting global warming to well below 2 °C above pre-industrial levels and pursuing efforts to limit it to 1.5 °C. The latest IPCC report again showed the underlying rationale: only by limiting the rise in global temperature can severe impacts and risks of climate change be mitigated (IPCC, 2023). Signatory countries are expected to formulate and implement policies that contribute to the global goal. In the European Union, it was subsequently agreed to reduce greenhouse gas emissions to net zero by 2050, and to achieve 55% emission reduction by 2030, compared to 1990 levels. After 2050, Europe aims for net negative emissions[1]. In line with this EU policy, the Netherlands has set similar targets, namely 55% reduction by 2030 (and to aim for 60%) and a 100% reduction in 2050.

To test whether the collective contribution by all countries would be sufficient, the Paris Agreement devised what is known as The Global Stocktake. This is a process to evaluate whether the collective effect of plans and policies is in line with the global target. The first Global Stocktake, completed in 2023, showed that current plans and policies are insufficient. All countries have therefore been asked to consider whether their current contribution could be increased.

In discussions around setting national reduction targets, principles of *global distributive justice* and *national feasibility* are crucial. Distributive justice is important, amongst other things, because of the differences in the contribution by individual countries to climate change. For example, would it be fair to expect a large contribution from countries that have played a small role in the cause of climate change, or from those countries that have little financial capacity to reduce emission levels. Moreover, there are large differences between the individual countries' vulnerability to climate change. Justice has also become an increasingly important factor in international negotiations. But of course, target levels must also be feasible. The Paris Agreement indicates that targets should be based on the highest possible ambition level.

In 2023, the *European Scientific Advisory Board on Climate Change* advised on possible emission reduction targets for Europe for 2040 (European Scientific Advisory Board on Climate Change 2023). Their advice also addressed considerations of justice and feasibility. The board recommended a domestic 90%–95% reduction by 2040 as a target for Europe. Based on this advice, the European Commission formulated a proposal to reduce emissions by 90% by 2040 (European Commission, 2024). It is up to the next Commission (after the European elections) to set the 2040 target in a legislative proposal. In 2023, the Dutch Scientific Climate Council (WKR, 2023) and the Adviesraad Internationale Vraagstukken (AIV) (AIV, 2023) also declared to endorse the recommendations by the *European Scientific Advisory Board* for the Netherlands.

The question, therefore, is what the Dutch reduction targets should be for the coming years, and specifically for 2040. At the request of the Dutch Ministry of Economic Affairs and Climate Policy, this report discusses the question of what the considerations of global distributive justice and national feasibility can mean for the Dutch emission targets. In doing so, it addresses

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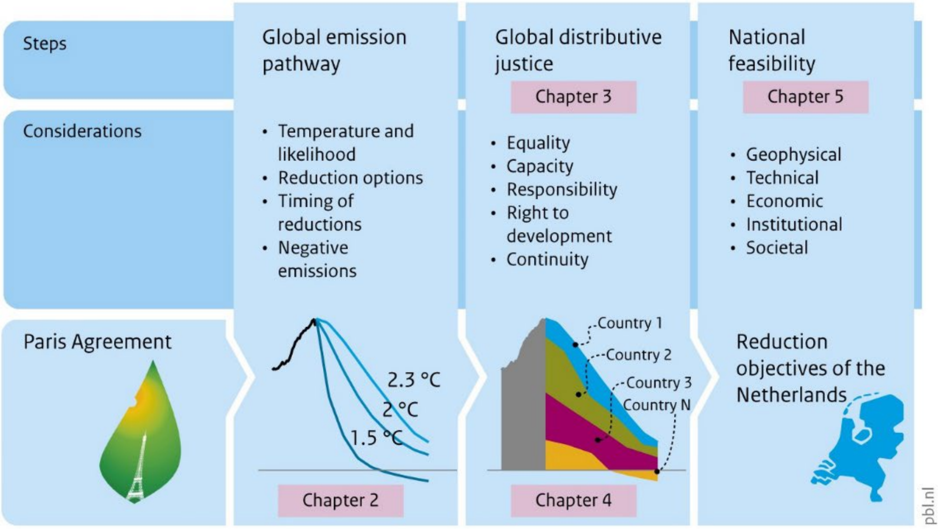
[1] The word net refers to the total sum of emission sources and sinks of greenhouse gases from the atmosphere (e.g. through reforestation).

considerations at the global level as well as the normative choices and interpretations that are required to formulate targets at the national level. The report does not explicitly consider how the EU target could be distributed across EU Member States. The purpose of the report is not to come up with a concrete proposal, but to show how various choices and assessments play a role in providing a final answer.

The structure of the report is as follows: Chapter 2 first addresses the question of what the global challenge is. Chapter 3 discusses the various aspects of global distributive justice. On this basis, Chapter 4 subsequently illustrates the possible consequences of quantitative targets for the Netherlands, followed by Chapter 5 which discusses how national feasibility also plays a role in Dutch reduction targets.

Figure 1.1

Considerations around Dutch reduction objectives related to the Paris Agreement



Source: PBL

Box 1.1: The Carbon Budget Explorer

The 'Carbon Budget Explorer' (www.carbonbudgetexplorer.eu) was developed by PBL in collaboration with the Netherlands eScience Center. It is an open-source web tool that can be used by all countries around the world to derive national emission reduction targets as a function of choices around global climate targets and allocation rules related to the concept of distributive justice. The tool can also compare the outcomes against emission projections based on current policies and with the pledges made by countries under the Paris Agreement (i.e. the nationally determined contributions (NDCs) and net-zero emission pledges). This therefore also makes it possible to evaluate current policies in light of the countries' potential fulfilment of the Paris Agreement targets. Policymakers, researchers and other stakeholders can also use the tool to look at the effects of their various policy choices, in an interactive way. The tool allows easy access to policy-relevant data. The calculations in Chapters 2 and 4 are based on this tool.

2 Emission reductions on a global scale

2.1 The global carbon budget

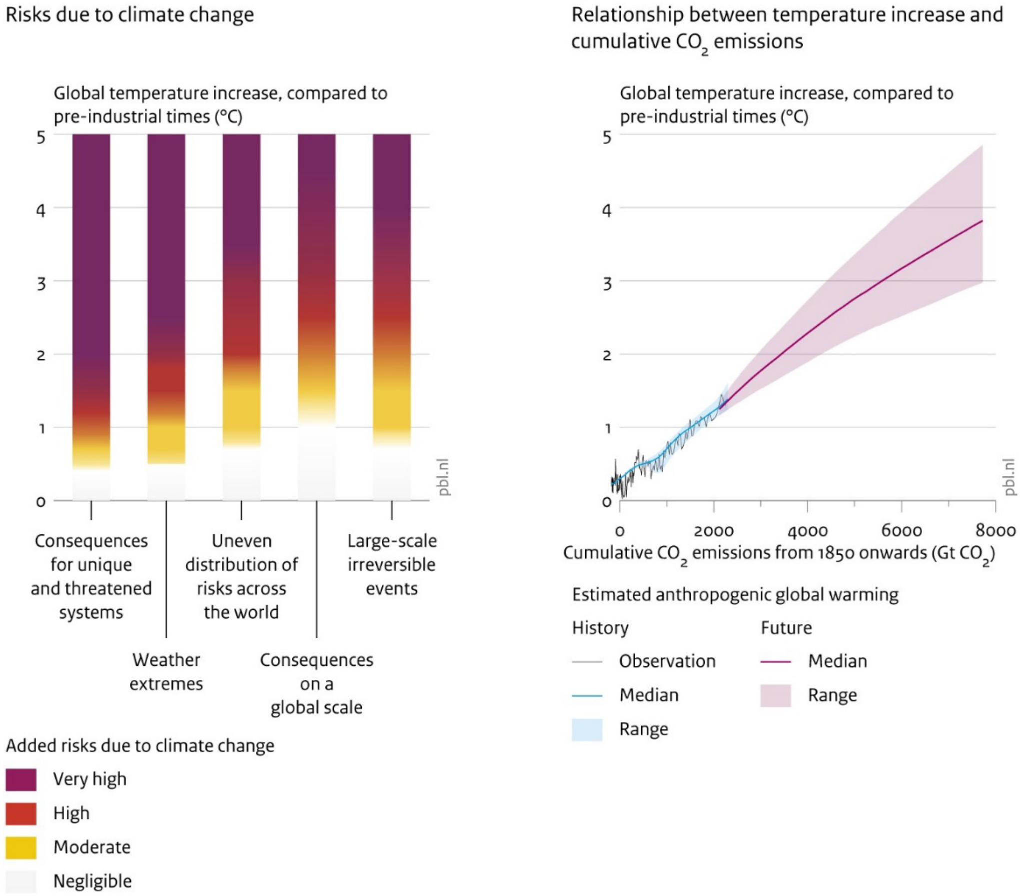
The global mean temperature has risen sharply since the pre-industrial period, due to greenhouse gas emissions. In 2023, temperatures were already about 1.45 °C higher than pre-industrial levels (WMO, 2024) (the long-term average temperature is still expected to show a slightly lower increase, with 2023 as a relatively warm year). Scientific studies show that climate change is likely to have major consequences, ranging from the loss of species to large-scale disruption of the climate system (IPCC, 2023). IPCC reports summarise the risks of climate change as a function of global mean temperature increase (Figure 2.1).

The current level of increase is already showing the impacts. For example, climate change is already impacting nature, sea level rise and changes in weather extremes (IPCC, 2023). If temperatures rise any further, the consequences and risks are expected to increase (Figure 2.1, left). Under a global mean temperature rise of 4 °C, sea levels could rise by 1.5 metres, by the end of this century — and by more than 15 metres by 2300 (IPCC, 2023). Agriculture is also expected to be impacted in several parts of the world, for example, due to longer periods of extreme drought. Climate change is also expected to lead to a sharp increase in extreme weather, worldwide. There is also the risk of positive feedback and tipping points. One example of a positive feedback is that global warming could cause the thawing of permafrost. This would release carbon dioxide (CO_2) and methane (CH_4), which in turn contributes to further warming. The Royal Netherlands Meteorological Institute (KNMI) has used a set of scenarios to explore the risks of climate change for the Netherlands and draws conclusions similar to those in the IPCC report (KNMI 2023). In this recent IPCC report, researchers stress that the risks can only be mitigated by far-reaching reductions in greenhouse gas emissions (IPCC, 2023).

Climate change is caused by various greenhouse gases (see Box 2.1). In the long term, cumulative emissions of CO_2 have the greatest impact, due to their total volume and relatively long lifetime. There is a clear relationship between cumulative CO_2 emissions and the changes in temperature of the past and those projected for the future (IPCC, 2023; Meinshausen et al., 2009) (see also Figure 2.1, right). The red coloured area in Figure 2.1 (right) represents the various outcomes of a large number of climate models and is thus an indication of uncertainty. This means that the amount of greenhouse gas that could still be emitted depends not only on the temperature target, but also on the degree of certainty with which we aim to achieve this target — do we take the estimates of the most sensitive models (the upper part of the coloured area) or do we take more risk and believe the estimates of the least sensitive models (the lower part of the area) (risking that we would pass the target if climate turns out to be more sensitive)?

Figure 2.1

Relationship between climate risks and cumulative CO_2 emissions



Source: IPCC; adaptation by PBL

Left graph: effects of climate change under various increases in global temperature.
Right graph: the relationship between the increase in global mean temperature and cumulative CO_2 emissions.

Based on Figure 2.1, it is possible to deduce the amount of CO_2 that could still be emitted, globally, before a certain temperature target will be exceeded. This amount is also known as the ‘carbon budget’. A point on the median line in Figure 2.1 corresponds to a carbon budget (x-axis) at which there is about a 50% chance of staying below the temperature value (y-axis). Points above or below this line, therefore, have a higher or lower probability of staying below the temperature level. This means that the carbon budget depends not only on a given temperature target, but also on the level of risk that countries are willing to take of possibly exceeding this target.

The Paris Agreement agreed to limit the rise in global mean temperature to ‘well below 2 °C and pursue efforts to limit the increase to 1.5 °C’. These targets, therefore, have implications for the amount of CO_2 that could still be emitted. However, to answer how much some further choices need necessary.

- Firstly, there is the target itself. The Paris Agreement mentions not one, but two temperature levels in defining its goal. There is debate about how to interpret the text. For example, whether a temporary exceedance of the goal is permissible (see also Box 2.2). In recent years, many EU Member States have committed to the 1.5 °C target, including the European Union and the Netherlands. The 2021 UN Climate Change Conference held in Glasgow also showed the intention of parties to limit the increase in global temperature to 1.5 °C.

- Secondly, there is the degree of certainty with which these global temperature targets should be achieved. This is in view of the uncertainty about the relationship between CO_2 emissions and warming (see Figure 2.1, right). Currently, both a 50% and 67% achievement probability are often used in determining the necessary reductions (e.g. by IPCC).
- Thirdly, even after a temperature target has been set as well as the degree of certainty with which this must be achieved, it is still difficult to determine the amount of CO_2 emissions allowed. This is because non-CO_2 greenhouse gases also play a role — notably methane (CH_4), nitrous oxide (N_2O) and aerosols. Emission pathways of non-CO_2 gases have been assumed in the calculations underlying Figure 2.1. However, there is considerable uncertainty about those pathways and, therefore, also about the allowed CO_2 emissions (see Box 2.1).

Estimates of the carbon budget have been regularly adjusted, in recent years. Nevertheless, it is clear that the remaining carbon budget for achieving the Paris Agreement targets is very small compared to current emission levels (emissions of just above 40 Gt CO_2 per year (Friedlingstein et al., 2023).

Table 2.1
Carbon budgets from January 2020, in gigatonnes, based on IPCC AR6 reports

Temperature target	Carbon budget 67%–33% (50%)	
	IPCC AR6 WGI (Gt CO_2)	Forster et al. (2023), consistent with IPCC AR6 WGIII (Gt CO_2)
1.5 °C	400–650 (500)	300–500 (400)
1.7 °C	700–1050 (850)	600–950 (750)
2.0 °C	1150–1700 (1350)	1100–1650 (1300)

Note: Budgets carry probabilities of between 33% and 67% of achieving the temperature target (in brackets the median value representing 50% probability). Numbers are rounded to 50 Gt CO_2. About 150 Gt CO_2 has already been emitted since 2020.

For the budgets in this report, we based our calculations on the latest figures from the IPCC AR6 WGI report (IPCC, 2021) and the more recent update in the WGIII report (IPCC, 2022; Forster et al., 2023)). The WGIII report update contains lower values for the carbon budgets due to higher estimated emission levels from non-CO_2 (based on the scenario database used for the IPCC WGIII report) (see also Foster et al., 2023). The carbon budget to limit the temperature rise to 2 °C, compared to pre-industrial levels, with a 67% probability is thus in the order of 1100 Gt CO_2 starting from early 2020 (this budget leads to a temperature rise of between 1.7 and 1.8 °C with a 50% probability, and could thus be consistent with 'well below 2 °C'). The carbon budget for the 1.5 °C target (50% probability) is around 400 Gt CO_2 (Table 2.1). The budget from early 2024 can be derived from this number by subtracting the cumulative emissions between 2020 and 2023, i.e. over 150 Gt CO_2. This means that, for a maximum temperature increase of 1.5 °C and the emission level remaining constant, the carbon budget would already be exceeded before 2030; and the budget with which to meet the 2 °C target would be exhausted in about 20 years.

Box 2.1: Greenhouse gas emissions

The emissions of other gases besides CO_2 are also contributing to climate change, most notably methane (CH_4), nitrous oxide (N_2O), halogenated hydrocarbons and aerosols. It is not easy to directly compare the individual contribution of each of these substances because of differing atmospheric properties and lifetimes. Nevertheless, this is often done anyway, in what is called CO_2 equivalent emissions. To do so, however, a choice has to be made about period covered by the evaluation. Based on the most commonly chosen period of a 100 years, the current contribution of CO_2 is about 70% of total emissions. CH_4 constitutes the second gas in terms of contribution, based on the 100-year global warming potential, but has an atmospheric lifetime of about 12 years. The short lifetime means that for CH_4, and thus for the sum of all greenhouse gases, a budget approach (as used for CO_2) makes little sense, because most of the CH_4 will be removed again from the atmosphere within a few decades. Therefore, emission reductions are usually determined on an annual basis. In the short term, reducing non-CO_2 greenhouse gas emissions is often relatively cheap, whereas in the long term, it is not yet possible to reduce CH_4 and N_2O emissions to zero with technical measures alone. A large part of the non-CO_2 emissions is inextricably linked to agricultural activities, and deeper reductions would thus require a change in agricultural production itself (in particular regarding livestock numbers).

2.2 Global emission pathways

The carbon budget is about cumulative emissions — the amount of CO_2 that can be emitted in total until the net zero year. However, for emission reduction targets, it is relevant to know what the world can emit in specific years — for example, 2030 and 2040. In theory, a large number of pathways could be consistent with a specific carbon budget from Table 2.1; for instance, one of easy reductions versus one with later but deeper reductions. The shape of an emission pathway may also depend on other things, such as the extent to which emissions could be reduced and expectations around technological development. By creating various scenarios that meet the Paris Agreement targets, researchers can help to understand what those global emission pathways could look like.

As mentioned, the objectives of the Paris Agreement generate debate in the scientific literature because of their somewhat open-ended wording ('limit global temperature rise to well below 2 °C and make efforts to keep the rise within 1.5 °C'). As mentioned in Section 2.1, there are some important considerations on how to interpret this objective in relation to the carbon budget, namely when it comes to the temperature target, the likelihood of achieving it and assumptions regarding non-CO_2 emissions. In the step from carbon budget to global emission pathway, some additional considerations come into play. First, the timing of mitigation policies is important: if strong emission reductions are not achieved at the global level before 2030, the emission pathway with the same temperature target will be shaped very differently (first less steep, then much steeper downwards), compared to a pathway with immediate implementation. For global emission levels in 2030 and 2040, this trade-off matters a lot.

Box 2.2: Global emission pathways and Paris Agreement targets
The literature contains a wide range of scenarios, reflecting the uncertainties and the many choices that can be made regarding emission pathways. An important question is that of which scenarios would be consistent with achieving the Paris Agreement targets. This concerns the temperature targets themselves and how to deal with any temporary overshoot.

Temporary overshoot
The wording of the Paris Agreement does not explicitly mention when the targets should be achieved. Since it is possible to reduce greenhouse gas concentrations in the atmosphere, and thus also global temperature increase, via so-called negative emissions (see also main text), the scientific literature distinguishes between peak temperature (highest value at any point in time) and the long-term temperature (such as the expected temperature in 2100). The question arises as to whether it would be permissible to achieve the temperature targets including a temporary exceedance. The most common interpretation is to assume that such an overshoot might not be intended for the 'well below 2 °C' target. For the 1.5 °C target, however, such overshoot would possibly be allowed — partly because it seems impossible to meet this target without a limited overshoot. Of course, a temporary exceedance also leads to additional climate risks, for the short term, but possibly also for the long term in case irreversible processes or so-called *tipping points* are triggered.

Interpreting 'well below 2 °C' and '1.5 °C'
Although further definition of the climate targets in the Paris Agreement is up to policymakers, the IPCC's assessments need to address the issue of what is needed to meet the Paris Agreement targets. This requires some interpretation of the current text. One starting point here is the information presented by scientists in the so-called *structural dialogue* in the process leading up to the Paris Agreement (in particular, the so-called RCP2.6 scenario and later the SSP1-2.6 and SSP1-1.9 scenarios). In its AR6 report, the IPCC defined three categories of scenarios that could be consistent with the Paris Agreement targets:
C1: Scenarios that have a 50% probability of remaining below 1.5 °C increase in global temperature with no or limited exceedance (limited exceedance refers to an exceedance of 0.1 °C).
C2: Scenarios that have a 50% probability of remaining below 1.5 °C, following a temporary overshoot.
C3: Scenarios that remain below 2 °C with a 66% probability (and thus result in around 1.7–1.8 °C with a 50% probability.

In principle, all these scenarios can be seen as possible interpretations of the Paris Agreement. In light of the debate in the literature, more stringent interpretations such as that by Schleusner et al. (2022) should mainly be seen as policy choices. The current report presents results according to the IPCC interpretation. This means that, for the 1.5 °C temperature target, we applied scenarios such as '1.5 °C with limited exceedance' according to the definition of C1 and, for 'well below 2 °C', we applied the interpretation of C3.

A second consideration in determining global emission pathways concerns technologies or processes that could actively remove CO_2 from the atmosphere (i.e. carbon dioxide removal (CDR)) or negative emissions. As some of these technologies are still under strong development, this is particularly relevant for global emissions in the second half of this century. This means that the impact of 'negative emissions' is linked to the extent to which the temperature target can and may be temporarily exceeded. After all, after an exceedance of a temperature target, these technologies offer the possibility to bring the temperature down again (see Box 2.2 on how the IPCC deals with this).

Carbon dioxide removal options include reforestation and afforestation, the combination of bioenergy and capture and storage of CO_2, so-called *direct air capture* (capturing CO_2 from the air) plus storage, accelerated weathering (sequestering CO_2 through additional mineral weathering) and CO_2 sequestration in agricultural soils. When the amount of CO_2 that is removed from the atmosphere, via these actions, is greater than the remaining amount of emissions, this is referred to as 'net negative emissions'. Virtually all scenarios in the literature that achieve the Paris Agreement targets assume some amount of net negative emissions in the future. For the 1.5 °C target, it is virtually impossible to achieve the target without net negative emissions (IPCC, 2022). The goal of net zero greenhouse gas emissions — the EU and Dutch climate policy objective — can only be achieved by removing carbon dioxide from the atmosphere (as non-CO_2 emissions can most likely not be reduced to zero).

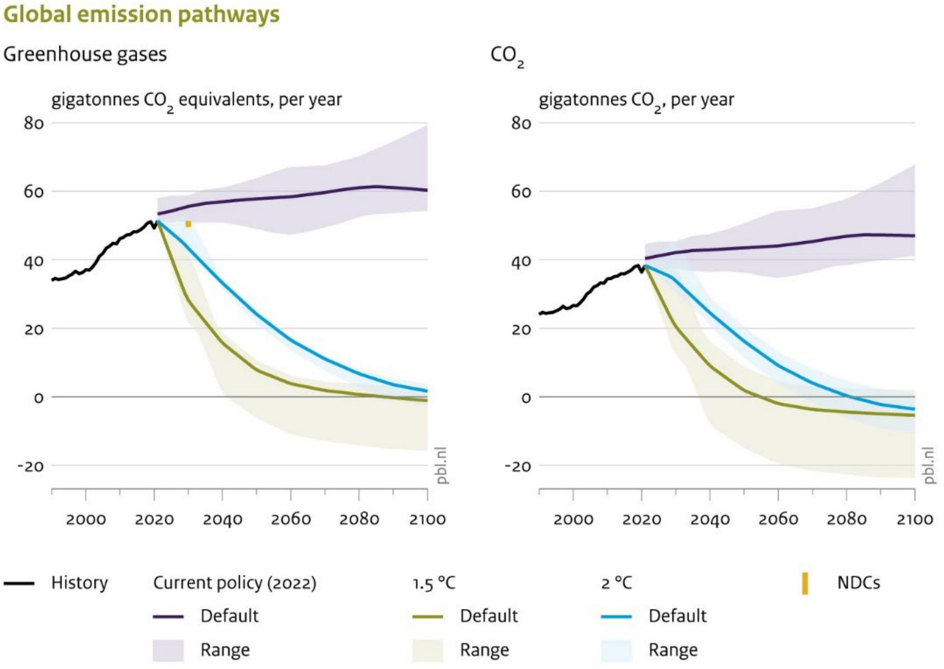
However, carbon dioxide removal cannot be used indefinitely. The techniques and processes described above, often, are not yet widely applied, are sometimes expensive and often lead to increased energy use. Bioenergy with CCS and reforestation/afforestation is also land-intensive, and thus may have negative impacts on food supply and biodiversity (Smith et al., 2016). Finally, the storage capacity of CO_2 is also limited. Therefore, there is debate in the literature about the degree to which climate policy chould rely on negative emissions (Van Vuuren et al., 2017). Nevertheless, it is virtually certain that negative emissions are required to achieve the most ambitious temperature targets. The amount of net negative emissions in the scenarios assessed by IPCC in the C1/C3 category range between 0 and 350 Gt CO_2 in the second half of the 21st century (IPCC, 2022). It should be noted that even with this contribution of negative emissions, the most extensive task is to reduce 'positive' emissions to zero as soon as possible, as without more stringent policies, positive emissions could easily be in the order of 3000 Gt CO_2 or more in hte remainder of the century.

To conclude, not only the carbon budget (Section 2.1), but also the shape of the global pathway contains many uncertainties and choices. For this report, we selected two emission pathways to focus on, in line with the IPCC's interpretation (see Box 2.2):

- '*1.5 °C with limited exceedance*' in line with the IPCC definition of C1. The calculations assume an average peak temperature of 1.56 °C (in line with the IPCC category);
- '*Well below* 2 °C' pathway — here we followed the IPCC's definition of C3 (>67% chance of achieving the 2 °C target).

It should be noted that both the European Union and the Netherlands have indicated that they interpret the Paris Agreement target as aiming to stay below 1.5 °C. Within the pathways described above, we varied other parameters, including the timing of reductions, so that we arrived at a range of global emission pathways for each temperature target. Figure 2.2 shows that both the 1.5 °C target and the well below 2 °C target imply rapid and far-reaching global reductions, in the short term. CO_2 emissions in the 1.5 °C pathways need to be zero by around 2050 to 2060, after which emissions may become negative. For the well below 2 °C pathways, this is later, namely between 2070 and 2080. For CO_2 , the reductions are larger than for greenhouse gases as a group, given the more limited reduction potential for other greenhouse gases. Chapter 4 also briefly discusses what the effect would be of allowing a larger overshoot of the 1.5 °C target.

Figure 2.2



Source: PBL

Global emission pathways under current policies, 1.5 °C and well below 2 °C (based on the IPCC database as used in the PBL Carbon Budget Explorer www.carbonbudgetexplorer.eu)). This figure also shows model results of current policies (purple) and the Nationally Determined Contributions (NDCs) (orange dot).

2.3 Comparison with current policies

As part of the Paris Agreement, countries submitted Nationally Determined Contributions (NDCs). In their NDCs, countries have indicated how they intend to mitigate greenhouse gases over the next 10 to 15 years. Together with the NewClimate Institute, PBL tracks the actual policies implemented by various countries to achieve their NDCs, in a public database (Dafnomilis et al., 2022; Roelfsema et al., 2020). In Figure 2.2. the emission trajectories according to the NDCs of all countries (orange dot) and the expected outcome of current policies worldwide are shown for the period up to 2030. The current policy scenarios are extended beyond 2030 by continuing a similar effort. The figure shows that both the implementation of the NDCs (orange dot) and the continuation of those policies (purple line and range) are absolutely insufficient to meet the Paris Agreement targets (Dafnomilis et al., 2024). It is therefore necessary to tighten both NDCs and current policies, globally.

3 Emission reduction targets based on distributive justice

3.1 Introduction

Justice plays a major role in the distributional questions surrounding emission reductions and the impacts of climate change — given the current situation characterised by high inequality (see also WRR, 2023; AIV, 2023). The Paris Agreement therefore pays ample attention to justice (or equivalent terms); it demands that policies are implemented that take this concept into account (UNFCCC, 2015) (see Box 3.1).

Box 3.1: Articles in the Paris Agreement connected to justice (UNFCCC, 2015)
Various articles in the Paris Agreement do directly refer to justice. We provide some examples.

Article 2.2: "This Agreement will be implemented **to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances**."

Article 4: **Developed countries** should **continue to take the lead** by undertaking absolute economy-wide reduction targets, while **developing countries should continue enhancing their mitigation efforts**, and are encouraged to move toward economy-wide targets over time in the light of different national circumstances.

Article 4.1: "Parties aim to reach global peaking of GHG as soon as possible, **recognizing that peaking will take longer for developing country Parties**, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHG in the second half of this century, **on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty**".

Article 4.3: "Each Party's successive nationally determined contribution will represent a progression beyond the Party's then current nationally determined contribution and **reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances**."

Much of the literature uses the terms *justice*, *equity* and *fairness* almost synonymously. This report mainly uses only the term justice, not only in relation to the international distribution of emission reductions and their associated costs, but also to the uneven distribution of the impacts of climate change (certain countries are disproportionately affected, in part because adaptive capacity differs per country). Moreover, justice concerns not only the outcomes of the efforts of tackling climate change, but also the process itself. For example, it is important that all relevant parties are meaningfully involved in the decision-making related to climate action. The scientific literature attempts to make the concept more concrete, based on ethical, legal and efficacy considerations, as described in more detail in Section 3.2.

One way of operationalising justice principles in the context of mitigation is through allocation rules, also known as burden sharing rules. Such approaches include a wide range of proposals on how best to share the burden of mitigation or distribute the remaining carbon budget. While there is no consensus on what constitutes a just distribution, calculating potential outcomes on the basis of various justice principles can be a way of evaluating current efforts, which can ultimately strengthen the ambition of policy and international cooperation.

3.2 An overview of justice principles

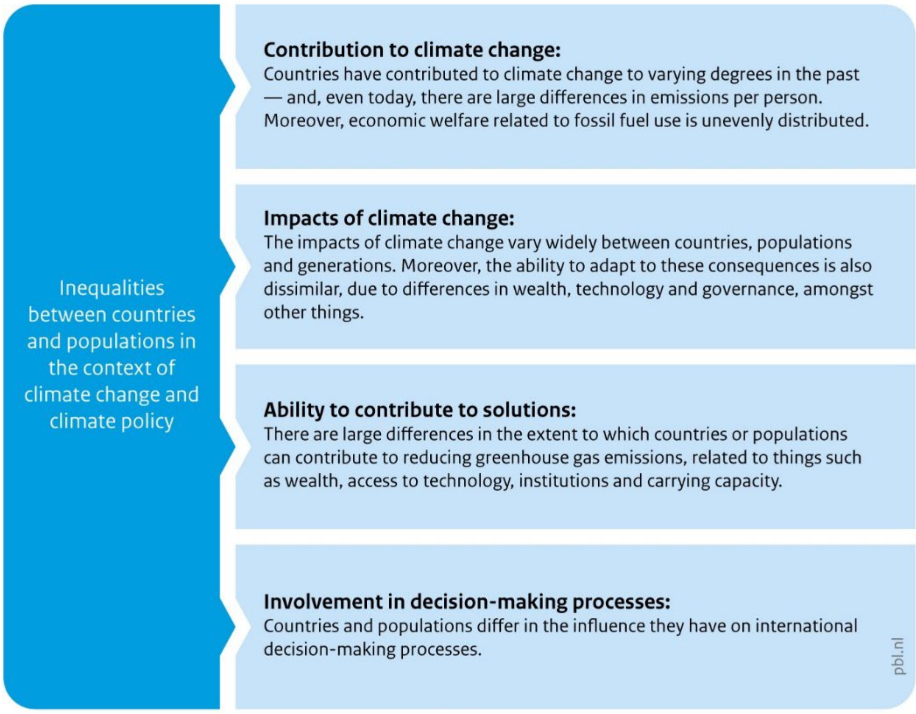
The subject of this report concerns national targets and global distributive justice between countries. However, justice also plays a role in climate policy in other ways — for example, as concerns the distribution of climate-related burdens between population groups, sectors and even individual people. Justice also plays an important role in the relationship between generations (intergenerational justice), meaning the timing of emission reductions is as relevant as the overall target.

Justice is especially significant considering the large regional and national differences in contribution to climate change; predicted climate change impacts and relative vulnerability to these impacts; capacity to contribute to the solution; and involvement in decision-making processes (Figure 3.1). Thus, both distributive and procedural elements are linked to the debate on justice.

A large body of scientific literature has examined the relevance of various justice principles in setting emission reduction targets (AIV, 2023; O'Neill et al., 2020; Pozo et al., 2020; Robiou Du Pont et al., 2017, Scientific Council for Government Policy, 2023; Höhne et al., 2014). A number of common principles feature regularly (see also Table 3.1). The principles emphasise different distributional considerations, though there is also overlap and they can strongly complement each other. Four of the five approaches outlined below are embedded in principles of international environmental law (Rajamani et al., 2021). They can be traced to the 1992 Rio Convention, where agreements were made regarding the importance of protecting the environment for present and future generations (intergenerational justice), the special situation and needs of developing countries, the polluter pays principle, the precautionary principle, and the urgency of poverty reduction. The legal status of these principles varies and they are not equally binding. The United Nations Framework Convention on Climate Change itself (also from 1992) establishes the principle of 'common but differentiated responsibilities', indicating that a greater contribution is expected from some countries based on their responsibility and capability. This also means that not all the principles listed in Table 3.1 are supported in a similar way in international agreements or can be applied universally.

Figure 3.1

Inequalities between countries and populations in the context of climate change and climate policy



Source: based on Fleurbaey et al. 2014; adaptation by PBL

While capability, responsibility, right to development, and equality can be related to principles of international environmental law, this is not the case for the principle of continuity (Rajamani et al., 2021). The large differences between countries worldwide in terms of current emissions per capita, historical contribution to climate change and the capacity to reduce emissions, this principle is not considered to be just and is mainly mentioned in the context of a transition towards a more equitable situation (Knight, 2013). Consequently, it is frequently excluded from many overviews of justice principles.

Table 3.1
Principles cited in relation to distributive justice

Principle	**Equality**	**Capability**	**Responsibility**	**Right to development**	**Continuity**
Meaning	Everyone has equal rights under equal conditions	Those with more opportunities should do more	Those responsible for the problem should solve it	Everyone has the right to a meaningful life	Anyone can assume a given situation
Interpretation	Equal opportunity	Strong shoulders first	The polluter pays	Everyone has a right to exist	Acquired rights

Source: based on Dooley et al. (2021), Van den Berg et al. (2020), Höhne et al. (2014)

3.3 Calculations on a just distribution of mitigation action

The various justice principles and how these can be interpreted mean that a multitude of allocation methods have also been developed in climate policy (Lahn and Sundqvist, 2017; Skeie et al., 2017). A distinction can be made between approaches aimed at sharing either a resource (e.g. the carbon budget) or an effort (Fleurbaey et al., 2014); and between setting the reduction target and equally sharing the consequences (Caney, 2014). It is also possible to link justice considerations directly to the broader international goals of poverty reduction and sustainable development (Roy et al., 2018).

There are several categories of allocation approaches, including those based on: 1) allocating certain economic outcomes; 2) allocating timing of net-zero targets; and 3) allocating emissions (see Table 3.2). Approaches can be further divided into allocations based on an emission reduction target or in terms of a long-term carbon budget. The allocation based on economic outcomes allows to set reductions directly with justice principles in mind (e.g. equal costs per unit of GDP). Other approaches often attempt to achieve such results indirectly. Outcome-based allocations can be based only on climate damage costs or mitigation costs, but also at the sum of both (De Cian et al., 2016). The disadvantage of such approaches is that they rely heavily on model calculations and model assumptions. Justice also plays a role in determining the year in which net zero emissions are to be achieved. The IPCC has shown that pathways consistent with achievement of the 1.5 °C target reach net zero emissions around 2050 for CO_2 and around 2070 for all greenhouse gases combined. The choice of a target of net zero by 2050 for all greenhouse gases combined, thus, means that the European Union has chosen to use on a more stringent target. In general, other high-income countries have also chosen to achieve net zero emissions by 2050, while the LMICs have chosen a later year (Dafnomilis et al., 2024; Lang et al., 2024). A third method uses allocation rules to translate justice principles into concrete reduction proposals. This method is the most common in the literature and is discussed in more detail below.

Distribution of emission allocations based on allocation rules

In Table 3.2, we present some allocation rules and the possible controversies. There is a range of possible rules (and their interpretation) that comply with the various principles of justice. As with the justice principles, different allocation rules may benefit different countries in different ways, depending on not only the allocation rule itself, but also on the choice of parameters (see below). Any allocation is therefore intrinsically a normative choice (Dooley et al., 2021). Chapter 4 considers seven allocation rules in more detail for the Netherlands. The cost-optimal and multistage methods are not presented here, since the former does not sufficiently satisfy justice principles (see Box 3.2) and the latter often consists of a combination of other rules.

Table 3.2
An overview of some common allocation rules and their relationship, based on the principles in Table 3.1

Allocation rule	Related principle	Description
Equal relative reductions (grandfathering) (*)	Continuity	Equal relative reduction targets for all countries
Per capita, immediate(*)	Equality	Immediate population-based allocation of emissions
Per capita, budget (*)	Equality	CO_2 budget based on current population that is used up via a linear emission trend to net zero.
Per capita convergence (*)	Equality and continuity	Equal shift in allocation from current conditions to per capita allocation
Historical-cumulative per capita (*)	Responsibility and equality	Allocation of allowances taking into account historical emissions
Ability to pay (*)	Capability	Stricter emission reduction targets for higher income countries
Greenhouse Development Rights (*)	Responsibility and capability	Emission reduction targets of a reference pathway are calculated based on a responsibility/capability index that includes income and income distribution
Cost-optimised	Cost effectiveness	Allocation is done on the basis of mitigation potential. Emission reductions are determined by equal marginal cost for all countries
Multi-stage approaches	Miscellaneous	These approaches divide countries into various stages (usually income-based), each with their own allocation rules

The allocation rules marked with an asterisk (*) are considered in more detail in Chapter 4 of this report.
Source: Clarke et al. (2014), Robiou Du Pont et al. (2017), Van den Berg et al. (2020), Höhne et al. (2014)

A brief discussion of allocation methods:

1. A first allocation method, based on the continuity principle, is *equal relative reductions* (also called *grandfathering*). In this method, all countries receive the same reduction rate as the global average. As previously reported, the continuity principle is not necessarily equitable in the case of climate policy (Caney, 2014; Dooley et al., 2021), although the *equal relative reduction method is* often used as a reference (Pelz et al., 2023; Robiou Du Pont et al., 2017; van den Berg et al., 2020; Vrontisi et al., 2019). Equal reduction rates ignore the large differences between countries in terms of responsibility, ability to reduce, expected growth and inequality in emissions (see also Box 3.2 for more discussion around existing criticisms of this method).
2. The allocation rule *equal distribution per capita* is a method based on the view that every human being has equal rights and thus an equal claim to emission allowances (Dooley et al., 2021; Robiou Du Pont et al., 2017; van den Berg et al., 2020). There are several ways to translate this into a concrete rule. The aforementioned elaborations, however, exclude other factors such as income, technology, differences in climate and economic structure.

a. *Immediate per capita allocation*. One possibility is to multiply the global emission pathway by a country's population share and let the outcome take effect immediately. The latter leads to a discontinuity between the historical emission trend and the allocation (with the possibility of countries paying for this difference).
b. *Per capita via budget*. Alternatively, the carbon budget could be distributed immediately based on current shares of the world population and distributed, country by country, over time (e.g. linear towards net zero).

3. The next approach is *per-capita convergence*. This approach slowly moves from *grandfathering* to a per-capita allocation (Meyer, 2000; Berk and den Elzen, 2001), providing a transition period for countries to reduce their emissions, but also ensuring that developing countries receive an equivalent carbon budget in the longer term (Böhringer and Welsch, 2006). Since, for the initial period, this approach is similar to *equal relative reduction*, the same critical observations apply (Dooley et al., 2021).
4. For *historical-cumulative per capita*, the allocation includes historical emissions. This is an interpretation of *historical responsibility*. This rule naturally leads to stronger reductions for rich countries, which generally have higher historical emission levels. It is argued that this should also take into account historical relationships, such as colonies (e.g. Carbon Brief, 2023). This approach therefore takes previously emitted emissions into account when allocating emissions. An important question concerns the year from which the historical emissions should be counted. This leads to the question from what year countries could have had sufficient knowledge of the climate problem and who benefited from these emissions. A starting point, for instance, could be 1990 — the publication of the first IPCC report which already indicated that greenhouse gas emissions were probably responsible for the rise in global temperatures. Going further back in time, emissions are usually given less weight (partly because of the natural removal of CO_2 from the atmosphere) (Den Elzen et al., 2013).
5. The principle around *ability to pay* is about the ability of countries to reduce emissions (Jacoby et al., 2008). Globally, income is often used as a factor in the interpretation, but there are various ways of calculating this ability. The approach could be combined with an income level below which a country does not need to reduce its emissions (Baer, 2013).
6. The allocation rule *Greenhouse Development Rights* distributes the reduction target on the basis of justice principles of responsibility and capability (Baer et al., 2009). The countries that face the greatest burden are mostly those with a history of producing large amounts of per capita emissions and high per capita income. This approach enables countries to reach a decent level of sustainable development, especially those that have not yet reached that level (BASIC experts, 2011; Robiou Du Pont et al., 2017; Van den Berg et al., 2020; Winkler et al., 2013). This is also partly in line with the *polluter pays principle*. The down side of this approach is that there are complex rules in weighing capacity and responsibility (Baer, 2013). The implementation of this principle requires making many normative choices (see Box 3.2).
7. There are also approaches that relate to various justice principles in stages, the so-called *multi-stage approaches*. An example of such an approach is one in which the poorest countries are not assigned any targets, a middle group of countries are assigned targets that will limit their emission growth and the richest countries are assigned absolute reduction targets (Den Elzen et al., 2006).
8. Table 3.1 also includes *cost-optimal* reduction as an allocation rule, which is indeed used as a reference in the literature. However, it should be noted that, because emission reductions

are cheaper in some developing countries, the cost-optimal reduction rule often leads to outcomes where costs in developing countries turn out higher than the global average (see Box 3.2).

Box 3.2: Discussion on allocation rules

All allocation rules are related to normative justice principles - and thus all have advantages and disadvantages. The rules — some more than others — are subject to debate. This may mean that they are less applicable for the Dutch reduction targets.

Equal relative emissions reduction (grandfathering)
One of the most controversial allocation approaches is that of equal relative emissions reduction (*grandfathering*). Several publications argue that this rule should not be included as a justice principle, in the absence of a clear moral rationale (Caney, 2014; Dooley et al., 2021; Rajamani, 2021; Kartha et al., 2018), while others do consider this principle and mention it mainly as a reference or in the context of feasibility (Pelz et al., 2023; Robiou Du Pont et al., 2017; Vrontisi et al., 2019). Knight (2013) indicates that this method may be applied as a temporary transition towards a long-term allocation that is based on other justice principles (Knight, 2013). As developing countries tend to have faster population and economic growth than most developed countries, an equal relative reduction would likely lead to a bigger task for these countries. Moreover, the Paris Agreement already stipulates that rich countries should do more (*common but differentiated responsibility*). In this sense, it is clear that, for practical reasons, this principle cannot be considered equitable. It would therefore be effective to set a certain lower limit for the reduction levels that need to be achieved by richer countries.

Cost-optimal allocation
Global cost-optimal allocation leads to cost savings and relates to the principle of a good cost–benefit ratio, as described in Article 2 of the 1992 Climate Convention. However, it can also result to inequitable outcomes (Dooley et al., 2021). Because many developing countries have more mitigation options and a more carbon-intensive economy, such allocation often causes them to be faced with higher costs. This shows that the relevance of this approach lies more in implementation than in determining an equitable allocation (Rajamani et al., 2021).

Greenhouse development rights
This approach was developed by NGOs, such as the Climate Action Network (CAN), on the basis of the right to sustainable development for all countries. Unlike other allocation approaches, it is not easy to reproduce because of a large number of specific assumptions. The underlying Responsibility/Capability *index* published by CERP only runs to the year 2030. The factors within this approach may vary rather widely. The default choices of this approach lead to rather extreme outcomes for rich countries.

3.3 Broader considerations

The different allocation rules reflect various perspectives on distributive justice — and thus complement each other to some extent. It is important to note that not all justice considerations can be translated into quantifiable rules and, moreover, the underlying assumptions about what is equitable are normative for all rules (Rajamani et al., 2021). The degree to which the various rules are consistent with the principles outlined in national and international law varies. The concept of *climate justice*, in fact, captures a wider range of issues. s about an equitable distribution of the burdens and benefits of climate policies based on differential contribution to, vulnerability to, and capacity to act upon climate change, with a specific focus on vulnerable groups within society.

Besides translating justice into emission reduction targets, financial transfers could also be considered as a way to operationalise climate justice where they fund reductions elsewhere and thereby compensate for the potential damage of climate change (see also Chapter 6). Such transfers could both contribute to domestic emission reduction targets and enable stronger reductions in developing countries (Taconet et al., 2020), as long as any negative impacts of emission reduction projects are being mitigated (e.g. those related to local livelihoods, biodiversity, food and water security, and the rights of certain groups, especially indigenous peoples).

Climate negotiations have also decreed that high-income countries should couple ambitious domestic emission reductions with financial support for mitigation and adaptation activities in lower- and middle-income countries (LMICs) (Oxfam International, 2023). At COP16 in 2010, high-income countries made a joint commitment to provide an annual USD 100 billion for adaptation and mitigation efforts in LMICs through 2020. This target was reiterated in the Paris Agreement and extended to 2025. High-income countries have not yet provided the agreed amount. Moreover, the USD 100 billion was intended to be 'new and additional', but in the absence of a clear definition, it is possible that existing funds earmarked for development cooperation (ODA) could also be reassigned as climate funding (Pauw et al., 2022). The Netherlands, to date, is one of a handful of countries calculated to have provided its fair share of the USD 100 billion commitment (Colenbrander et al., 2022); it provided EUR 1.4 billion in 2022 with the ambition to increase this to EUR 1.8 billion by 2025 (Adviesraad Internationale Vraagstukken, 2023). There is also the possibility of funding under Article 6 of the Paris Agreement.

There is an extensive body of literature on how countries could calculate their fair share of mitigation action, yet there is no consensus on how this should be worked into international climate policy, nor on what this range of calculations would mean for setting of emission reduction targets in practice. Differing interpretations of justice and the associated vested interests also play an important role in difficult climate negotiations. Delaying action could lead to severe climate change impacts with related consequences around justice, yet very stringent reductions based on international justice considerations may make it more difficult to achieve just implementation on a national level for all populations and sectors. Exploring the consequences of various allocation rules could increase understanding amongst policymakers about the different choices and make them more explicit.

4 Reduction targets for the Netherlands from the perspective of justice

4.1 Introduction

Where Chapters 2 and 3 deal with climate goals and distributive justice principles from a global perspective, this chapter applies them to the Netherlands. The current targets for the Netherlands are a 55% reduction in greenhouse gas by 2030 (with an additional aim to increase this to 60%) and of 100% reduction by 2050. Since, in many sectors, reducing non-CO_2 emissions (e.g. methane and nitrous oxide) to zero is more difficult than reducing CO_2 emissions, the 2050 target implies that CO_2 emissions should be negative by 2050. The Dutch target for 2050 is based on the European Climate Act, which stipulates that the European Union as a whole should be climate neutral by 2050.

In the coming period, new targets for the years after 2030 will have to be set. Again, this will have to include considerations of distributive justice and feasibility. In the past year, a number of advisory bodies already commented on targets. Based on the advice by the European Scientific Advisory Board on Climate Change (90%–95% reduction by 2040 as a maximum feasible reduction target on European soil and minimum equitable reduction; ESABCC, 2023), the Dutch Scientific Climate Council has indicated that it also endorses this target for the Netherlands (Wetenschappelijke Klimaatraad, WKR, 2023). The Dutch Advisory Council on International Affairs (Adviesraad Internationale Vraagstukken, AIV) indicated in 2023 that considerations around the Dutch climate target should also include the credibility of the country's position in climate negotiations, again leading to a possible endorsement of the proposed EU target of 90% (AIV, 2023). The Expertteam Energiesysteem 2050 also discusses Dutch targets for the longer term and indicates that the Netherlands should be CO_2 -neutral around 2040 to 2045 (Expertteam Energiesysteem 2050, 2023).

All kinds of considerations play a role in deriving Dutch reduction targets from global climate targets, including the Netherlands' vulnerability to climate change, historical responsibility, as well as societal and economic opportunities to reduce emissions. This chapter illustrates how a range of reduction targets for the Netherlands can be derived from the global targets (Chapter 2) and the distributive justice principles (Chapter 3).

4.2 Reduction targets for the Netherlands

In calculating a ‘just’ target for the Netherlands, we took the global emissions pathway (Chapter 2) as a starting point. After all, if a large amount can still be emitted globally, then there is a lot to distribute and this also affects the Dutch target. As discussed in Chapter 2, important factors and choices within this global trajectory include the temperature target as well as the probability of achieving it, assumptions on non-CO_2, negative emissions, and the timing of policies. Based on allocation rules (Chapter 3), these global emission pathways can be distributed amongst countries around the world, including the Netherlands. We followed the descriptions of climate targets in the Paris Agreement yielding global pathways that limit temperature rise to 1.5 °C with limited overshoot, and those that stay well below 2 °C (see also Box 2.2 and Figure 2.2). As mentioned in Chapter 2, these pathways are calibrated to models that are globally cost-effective. This chapter also shows the results for other temperature targets and associated global emission pathways. In the calculations, we looked at the Netherlands from a global perspective rather than focusing on the distribution of the European target amongst EU Member States.

All calculations always include CO_2 emissions from fossil fuels, land use and land-use change as well as non-CO_2 emissions. All these emission sources contribute to climate change (Box 2.1). However, it is important to realise that many studies on national reduction targets based on allocation rules include only some of these sources. Considerations that may play a role when comparing our results to those from other studies include data quality (land-use emissions are more uncertain), differences in the capability to reduce emissions from different sources and, finally, considerations around consistency with justice principles across sources.

The spectrum of just reduction targets

For the distribution of global emissions across countries, we followed the framework as described in Table 3.1. The qualitative, more abstract justice principles — equality, capability and responsibility, with continuity included as a reference — are expressed in quantitative equations to show what they imply for reduction targets. We call these quantification methods 'allocation rules' (Table 3.2). The results of the allocation rules for both the 1.5 °C and well below 2.0 °C global emission pathways are shown in Table 4.1 and Figure 4.1. Regarding the uncertainties in the global emission pathway that trickle down to Dutch reduction targets, we only included the uncertainties around negative emissions and timing of mitigation policies up to 2030. In this exercise we did not vary pathways of non-CO_2 reductions and the likelihood of achieving peak temperature. The timing of mitigation policies up to 2030 is a large factor for the 2030 reduction targets, but plays a smaller role in those for 2040, where uncertainties per allocation rule strongly dominate.

Before commenting on the results, it is important to be aware of the large spread in this table and figure. Within each allocation rule there is dispersion because the global emission pathway is uncertain (Chapter 2), and because choices are made in how they are allocated (see the last column of Table 4.1). This is one reason why these values can differ between sources. The uncertainties are not all of the same nature. Some of them relate to political and normative choices, while others refer to physical or economic circumstances. To account for both objective and normative uncertainties, this report includes the widest possible range of potential values of these values (taken from the literature) in the distribution.

Table 4.1
Greenhouse gas reduction targets for 2030 and 2040, for the Netherlands, as a percentage of 1990 emissions, according to the seven allocation rules

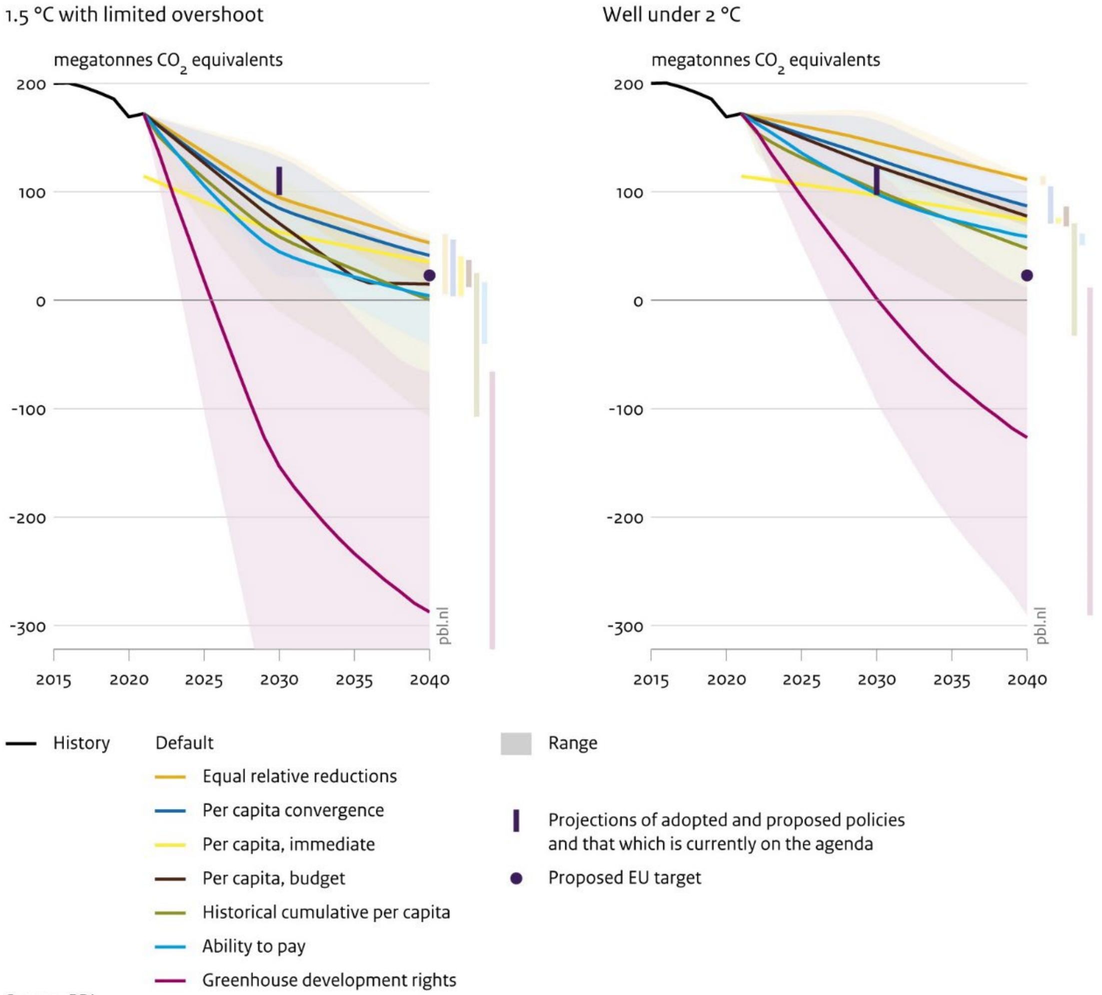
	2030 (%)		2040* (%)		Main uncertainties and choices besides those in the global pathway (also see Sections 2.1, 2.2 and 4.4)
Adopted and planned policies	46–57		-		
EU targets	55		90 (proposed)		
Reduction targets per allocation rule	**1.5 °C**	**2.0 °C**	**1.5 °C**	**2.0 °C**	
Equal relative reduction	40–68	25–38	73–98	50–54	
Per capita convergence	42–73	28–48	76–98	54–69	Population growth (SSP1–5, *SSP2*) Convergence year (2040–2100, *2050*)
Per capita, immediate	60–79	50–59	82–98	67–69	Population growth (SSP1-5, *SSP2*)
Per capita, budget	57–90	45–47	84–95	62–70	Population growth (SSP1-5, *SSP2*) Form CO_2 pathway (*linear to net zero*) Form non-CO_2 pathway (*analogous to per capita convergence*) Non-CO convergence year$_2$ (*2040*)
Historical cumulative per capita	51–104	38–81	89–147	69–114	Population growth (SSP1-5, *SSP2*) Starting year historical emissions (1850, 1950, *1990*) Emission discounting (*0%*, 1.6%, 2.0%, 2.8%) Method to match budget (*square-root functional form*)
Ability to pay	61–90	45–59	93–118	73–78	Economic growth (SSP1-5, *SSP2*) Population growth (SSP1-5, *SSP2*) Mitigation costs (*stylistically exponential MAC, regionally identical*) Reference pathway emissions (SSP1-5, *SSP2; IMAGE model*) Scale-down methodology (from global to national)
Greenhouse development rights	72–276	48–141	129–406	94–227	Economic growth (SSP1-5, *SSP2*) Population growth (SSP1-5, *SSP2*) Weighting and indexing responsibility and capability (*RCI*) Income limit for development before mitigation (None, *USD 7500/cap*, USD 7500/cap with additional conditions) Baseline emissions (SSP1-5, *SSP2; IMAGE model*) Scale-down methodology Post-2030 methodology (*convergence to 'Ability to pay' in 2100*)

Values rounded to integer percentages. Minimum and maximum values are reported, obtained from the uncertainty range due to the aspects in the last column (the values used in the spread are between brackets, the default values in italics). Targets are calculated for global pathways (Chapter 2) that limit temperature rise to 1.5 °C and well below 2.0 °C.

**Note that reduction targets for 2040 are always in the context of those for 2030. If the 2030 targets are not achieved, the 2040 reductions will have to be larger to achieve the same climate targets.*

Figure 4.1

Greenhouse gas emissions for the Netherlands, per allocation rule



Source: PBL

Emission allocations were calculated using the seven allocation rules in Table 4.1: a selection ('default'; based on default values in Table 4.1) of the choices in these rules is shown in thick lines. The spread shows the choices and uncertainties included (see Table 4.1, last column). Left: emission allocations for the Netherlands belonging to a global pathway consistent with 1.5 °C temperature rise with limited overshoot. Right: similar for well below 2.0 °C. The pathway for currently adopted, proposed and scheduled policies for 2030 (source: KEV, 2023) and the European Commission's announced target of 90% reduction by 2040 are indicated. Also see Table 4.2. Bars on the right-hand side of the figures show the spread in 2040.

As seen in Table 4.1 and Figure 4.1, the results for certain rules entail a large spread. For example, the allocation rule based on *Historical Cumulative Per Capita* (green in Figure 4.1 and based on the responsibility principle) partly quantifies the amount of historical emissions of, in this case, the Netherlands. If countries have already emitted large amounts in the past, this rule decreases future emissions allocations for them. For this rule, it matters whether the reference year is 1990 or, say, 1950 or 1850, when less was known about climate change in the public domain. In fact, some of the emissions are no longer present in the atmosphere. Hence, we used a discounting factor to attach less weight to emissions from the distant past; the choice of the exact value is at least partly normative and therefore should be varied in this exercise. Van den Berg et al. (2020) suggest an annual 1.6%, 2.0% or 2.8%, based on the literature (0%–2.0%, according to BASICS experts (2011) and Den Elzen et al. (2013)) and add 0.8% for the CO_2 that is removed naturally from the air. We also added 0% to the spread for comparison, without this correction. For a more detailed account of uncertainties and dispersion in these calculations, see Chapter 2 and Section 4.4.

Both Table 4.1 and Figure 4.1 show an ordering of the allocation rules in terms of reduction targets. A range is thus indicated for all rules. In the short term (2030), this range is highly dependent on the timing of climate policies (i.e. ambition at the global level). The lowest 2030 reduction targets for each regime imply very stringent 2040 reduction targets. This is due to global pathways in which reductions are delayed in the short term, but are stepped up thereafter in order to achieve the same global target. In other words, the 2030 and 2040 reduction targets cannot be regarded in isolation.

As could be expected, the principle of continuity leads to less stringent reduction targets for the Netherlands. The *Equal relative reduction* rule (orange), is a direct reflection of continuity and considers emission reductions relative to the current emission distribution – this is also referred to as *Grandfathering*. This rule always shows the least reduction for the Netherlands, for any temperature target. The rule boils down to a target of 40% to 68% reduction by 2030 to stay below 1.5 °C, a reduction that is reasonably in line with current Dutch adopted, proposed and scheduled policies (KEV, 2023) and between 73% and 98% reduction by 2040, which is around the recently proposed 90% by the European Commission. As indicated in Chapter 3, this conflicts with a variety of justice principles, including historical responsibility and the ability to reduce. However, it can be useful to use a certain transition period starting with this rule — which is done for several other allocation rules. Still, if mitigation policies fail and these calculations would be redone in the future with a later starting year, this principle will effectively be weighted more strongly in all of the results. The controversy of this principle is discussed in more detail in Box 3.2. It is important to note that, if global climate policy is not tightened before 2030, even this allocation rule would lead to more than 95% reduction by 2040, for the Netherlands.

The principle of continuity also plays a role in the *Per capita convergence* allocation rule (Figure 4.1, dark blue line), which starts with the current emission level and works towards an equal per capita distribution. As the Netherlands, on average, emits more per capita than the global average, this line decreases by more than the orange line, and arrives at 42% to 73% by 2030 and 76% to 98% by 2040. This line slowly converges with the yellow line, which reflects an *Per capita immediate* allocation and relies entirely on the equality principle (i.e. for every person on earth the same amount of emissions). This line is discontinuous — that is, the yellow line does not match the historical emissions (black) in 2021 (i.e., the starting year of this analysis). The reason for this mismatch is that it can be considered fair to apply a principle (in this case, 'equality') immediately, and thus discontinuously. Although such discontinuous reductions may lead to extreme reduction targets within a short time frame, the literature suggests that this could be achieved through reducing emissions abroad (e.g. through Article 6 of the Paris Agreement). On the other hand, a transition period may actually be considered more equitable (as under the *Per capita convergence* rule). Robiou du Pont (2023) note that the choice of a transition period should be explicated, which means that it is also essentially normative and it matters quite a bit for the outcomes of short-term allocations (Kartha et al., 2018; Knight, 2013). For 2040, *Per capita immediate* is not the most stringent rule for the Netherlands (82%–98% reduction by 2040 at 1.5 °C), which may seem unintuitive. However, this is due to very substantial reductions in the short term (55% by 2025).

Without an emissions leap, allocating emissions according to the principle of equality is often done through a budget. The global CO_2 budget is divided according to population size and then spread over time from current emissions in a linear trend towards CO_2 neutrality for each individual country. The Netherlands would then achieve CO_2 neutrality between 2030 and 2035 (depending on assumptions around non-CO_2, which strongly influences the CO_2 budget). This is in line with Fekete et al. (2022), although they use a slightly more stringent global temperature target (1.5 °C, with 67% probability), which makes their reduction targets for the Netherlands slightly more stringent. If we were to add non-CO_2 emissions to this linear trend (according to a *Per capita convergence* method), this would result in the *Per capita via budget* allocation rule (brown line in Figure 4.1), with 57% to 90% reduction by 2030 and 84% to 95% reduction by 2040 (for 1.5 °C).

Looking at allocation rules based on the principles of historical responsibility and ability to reduce, reduction targets become more stringent, especially those for 2040. The allocation rule *Ability to pay* (light blue line) is largely based on gross national product per capita, that is countries that are wealthier should reduce more. In 2030, the differences between reductions according to *Ability to pay* and *Per capita immediate* (yellow line) are still relatively small but, especially for the 1.5 °C climate target, these differences in wealth between countries start to weigh more heavily for the Netherlands with 93% to 118% reduction by 2040, i.e. around or well past net zero.

An allocation rule that combines the distributive justice principles of responsibility and equality is that of *Historical cumulative per capita* (green line), which quantifies historical and future shares of global emissions by looking at cumulative population and how much the individual countries have already emitted in the past. For some countries, this is a negative number, which means that those countries have already consumed the amount they would be entitled to under this rule. Again, we see a steeply declining graph, leading to 89%–147% reduction by 2040. This bandwidth is rather wide because of the aforementioned choices on including historical emissions.

A final allocation rule is called *Greenhouse development rights* and is an outlier in this analysis, leading to deeply negative emissions (>100% emission reductions) by as early as 2030. The rule is based on the *Responsibility-Capability Index (RCI)*, published by EcoEquity and the Stockholm Environment Institute, which, as the name suggests, combines historical responsibility and capability to mitigate — two principles that significantly tighten reduction targets.

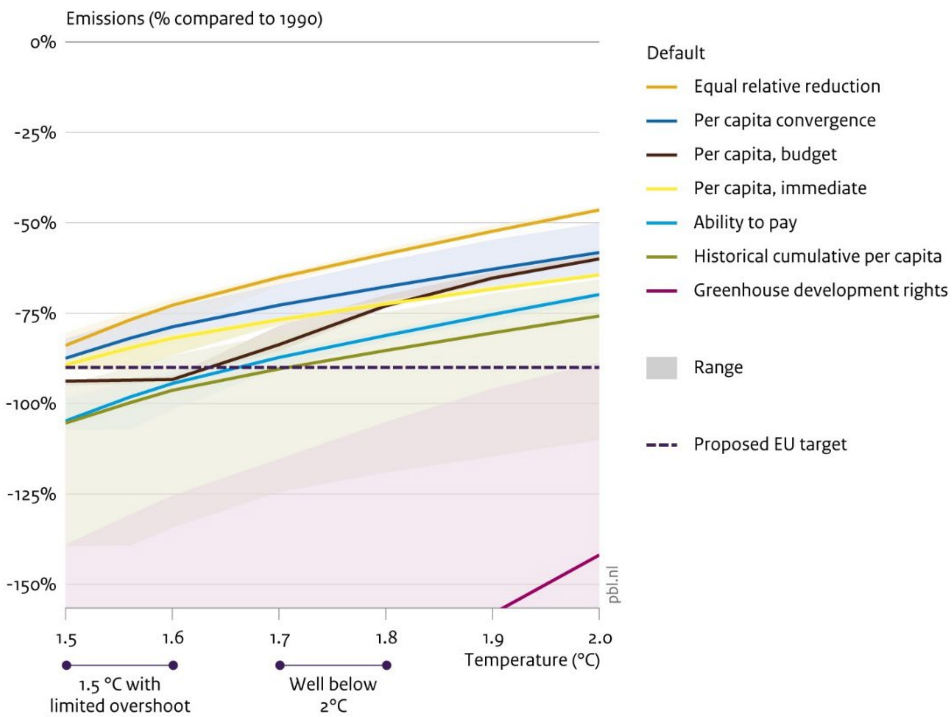
In conclusion, there is no single just reduction target for the Netherlands. When quantified, the justice principles (Chapter 3) lead to a broad spectrum of reduction targets with associated uncertainties. Primarily, this depends on what is considered 'just', but the interpretation of the Paris Agreement targets for the global emission trend is also important. It can be argued that deeper emission reductions mean that more and more justice principles can be adhered to. For the 1.5 °C target specifically, allocation rules leading to less than 90% emissions reduction are seen as violating justice principles. This is certainly true for the *Equal relative reductions*, but possibly also in the case of the *Per capita immediate* rule. An additional condition is that, in the short term, there would need to be investment in large amounts of emission reductions abroad and, e.g., in the case of the *Per capita convergence* rule, some rules initially maintain present-day emissions inequality which is considered not just.

Comparison between allocations and current targets

Figure 4.1 already shows that the outcomes of the allocation rules also depend on the global ambition of climate policies. Figure 4.2 summarises this and shows how the reduction targets from the allocation rules depend on global temperature choices (for various targets between 1.5 °C and 2.0° C). The general trend is intuitive; the more stringent the global temperature target (horizontally to the left), the deeper the reductions needed for the Netherlands by 2040 (vertically downwards). To illustrate this point, the dotted line represents the 2040 EU reduction target of 90%.

Figure 4.2

Change in greenhouse gas emissions in the Netherlands, for various climate targets, 2040



Source: PBL

Greenhouse gas reduction targets for 2040 for the Netherlands, calculated according to the seven allocation rules. Default values and uncertainty margins as in Figure 4.1. Reductions are shown for various peak temperature targets (each with 50% risk of exceedance) on the horizontal axis; a higher temperature target implies less deep reductions under the allocation rules. For illustrative purposes, 90% emission reduction for the Netherlands is marked as a 'translation' of the European proposed target. The global pathways applied in many cases in this report, using targets of '1.5 °C with limited overshoot' and 'well below 2.0 °C', are marked on the horizontal axis.

Each allocation rule for the Netherlands becomes less stringent as the global climate target moves towards 2.0 °C. While for some allocation rules a 90% reduction in the Netherlands (dotted line) is sufficient, for most other rules more than that is needed for achieving the lowest temperature targets (far left). Note that the *Per capita via budget* line is almost horizontal around 1.5 °C–1.6 °C, because the CO_2 emission level is already neutral by that time, and no negative CO_2 emissions are allocated under this rule (leaving only a positive non-CO_2 part). The *Greenhouse development rights* rule leads to very deep emission reductions for the Netherlands.

4.3 Comparison with other countries

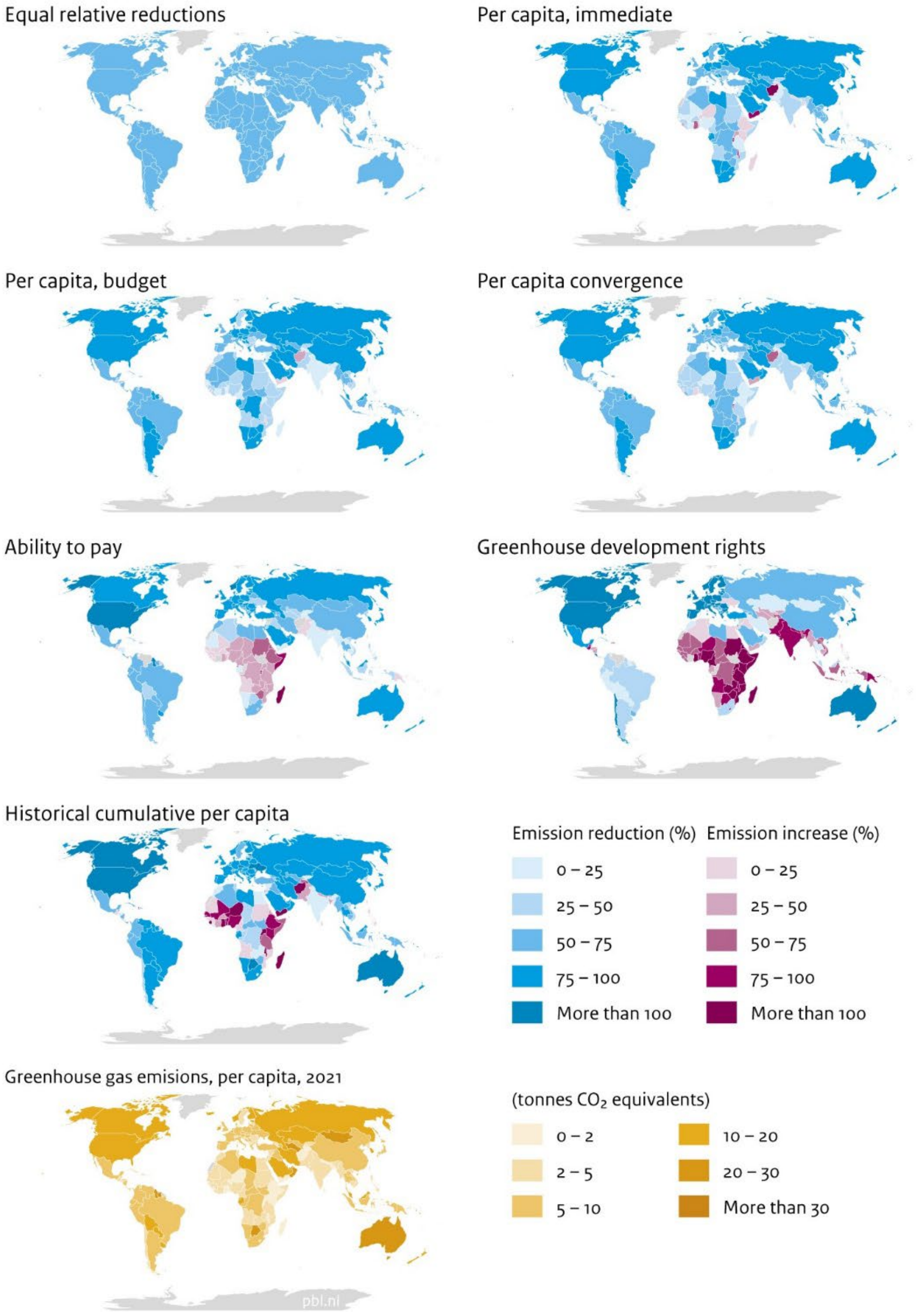
By definition, allocation rules have a global context. Not only because they depend on targets that work out at the global level (see Figure 4.2), but also because they reason from a distributional perspective; if the Netherlands reduces less, other countries have to do more (for a given temperature target). The implications of each rule in other countries is therefore something to consider when thinking about the Dutch reduction target. Although Chapter 5 only focuses on the feasibility question for the Netherlands, the international context also plays a role; very deep reductions in the Netherlands may cross the feasible domestic reduction potential, but limited reductions in rich countries such as the Netherlands, may create feasibility problems in poor countries.

The global implications of the allocation rules for reduction targets for 2040 are shown in Figure 4.3 (as change from 2021 emissions). Although the temperature dependence of the reduction targets is universal (Figure 4.2) — that is, for each country, reduction targets become more stringent with a more ambitious interpretation of the Paris Agreement — the ordering of the allocation roles (e.g. most favourable) is not. For the Netherlands, allocation rules belonging to the principle of continuity set a relatively mild reduction target, while those on responsibility and capability imply much deeper reductions. Allocation rules based on equality are in between these two. This is roughly mirrored for many countries in Africa, while India particularly benefits from rules on a per capita basis due to India's large population. Note that, for certain countries, Figure 4.3 includes allocations of emission increases rather than reductions (towards 2040). It also shows that, up to 2040, countries in Europe and North America cannot increase their emissions under any of the allocation rules.

It is important to note that different countries benefit from different allocation rules. In international negotiations, justice is a crucial issue in setting national ambitions. This played a large role in previous attempts to agree on binding targets, and it still does in national contributions to the Paris Agreement. Therefore, while the Paris Agreement states that countries can determine their own contribution, the agreement also expects countries to contribute to the global goal and take justice into account. Discussions on a just distribution are crucial, particularly now that collective emission reductions remain insufficient. Capability (or prosperity) and responsibility are internationally accepted concepts that may provide direction in this context. But there is no consensus on the details — such as on the allocation rules that should be applied and the interpretation of associated choices and uncertainties (also see Section 4.4 on how various methodologies could be applied for the same justice principles). Because countries will have opposing preferences for allocation principles, a compromise may be necessary, such as to reduce more than only on the basis of their first preference.

Figure 4.3

Change in greenhouse gas emissions, per allocation rule, for 1.5 °C with limited overshoot, 2021–2040



Source: PRIMAP database, PBL

The map shows the global implications of the allocation rules for 2040: purple indicates an emission increase between 2021 and 2040; blue represents an emission reduction. All figures are for the default 1.5 °C pathway (Chapter 2) and the default allocation rule options (Table 4.1).

4.4 Uncertainties and comparisons with other publications

This report includes a wide range of choices, uncertainties, allocation rules and global emission pathways, in order to illustrate the range within which the discussion on just reduction targets can be held. In doing so, we tried to make as few 'own' choices as possible, although certain choices in methodology were unavoidable. The consequence of applying such a wide range is that the calculations presented in other reports and scientific publications on the same subject usually fall within the ranges described in this report. This broad palette also means that the spread is sometimes large (Figure 4.1), but this is illustrative of the diversity of perspectives (both normative and physical/economic) in the context of reduction targets and justice. There are also several methodological reasons explaining why studies on emission targets for the Netherlands and Europe differ. This section discusses the three main methodological differences with regard to this topic and in relation to several well-known publications in this field.

Global emission pathways

The first factor that leads to methodological differences is that of the construction of the global emissions pathway. This greatly affects Dutch reduction targets. After all, the more the world has to reduce, the more the Netherlands has to do so (as also described in Chapter 2). We chose to include not only CO_2, but also non-CO_2 emissions (as is also done in the Dutch Climate and Energy Outlook), including those from land use. The choice to also include non-CO_2 emissions made the analysis more complete, but also more complex: global emission pathways for these gases had to be constructed, which are a lot more uncertain, especially if land use is added. Also, for a country like the Netherlands, where non-CO_2 emissions are of great importance to the total, a reduction purely in CO_2 emissions is of a different order of magnitude than if non-CO_2 emissions would also be included. Note also that, in any case, non-CO_2 emissions should always be part of the consideration; if non-CO_2 emissions were to remain high over the coming decades, the carbon (CO_2) budget would shrink sharply. We included this variation, but other studies are not always explicit about their assumptions around non-CO_2 emissions or they make different choices in this regard, thus leading to a different carbon budget.

In addition to the choice of gases to consider, there is the precise implementation of the Paris Agreement targets. Chapter 2 explains the differences between calculations of carbon budgets. Exactly which budgets are used may differ from one study to another. For this report, we followed the IPCC WGIII report, terms of both non-CO_2 and CO_2 budgets. But even given the same budget, different pathways over time would still be possible. For example, some studies draw a linear line downwards from current emissions to the net zero CO_2 year, with cumulative emissions totalling the available carbon budget. The NewClimate institute's 2021 report (Fekete et al., 2022) on the Netherlands is such an example, and it then adds a static non-CO_2 pathway. We applied this for the *Per capita via budget* rule. However, under other allocation rules, as well as in the recent ESABCC report (2023) and scientific literature (Robiou du Pont et al., 2017; Holz et al., 2018; Pan et al., 2017; Van den Berg et al., 2020), existing pathways are used based on mitigation scenarios from IPCC AR6 WGIII, which does not go down in a straight line but is curved, due to mitigation measures becoming more expensive when the system approaches net-zero emissions. The shape of this curve is often based on cost-optimal socio-economic models. This choice also affects the 2030 and 2040 targets.

Another aspect of why global emission pathways may differ is the point in time from which just allocation of emissions would start. Some studies refer to the Paris Agreement (2015) as the starting point from which such calculations should take place (European Scientific Advisory Board on Climate Change). Other studies use an earlier starting year (e.g. 2010 in Van den Berg et al. (2020)). Others start even earlier, from 1990, the year of the first IPCC report (FAR, 1990). This is therefore partly a normative choice, but an earlier starting point generally does yield more stringent reduction targets for the Netherlands. We chose 2021 for this report, which is the most recent year possible given the availability of the necessary data sources. Related to this is whether allocations should start at current emission levels, or whether a 'jump' in emissions would be possible — as illustrated in the case of the *Per capita immediate* rule and discussed in Robiou du Pont et al. (2023).

Finally, there is a strong dependence on temperature for all of these calculations (also see Figure 4.2); the exact interpretation of the climate target does matter. Studies also deal with this differently. We allowed for a limited overshoot in our 1.5 °C emission pathway — not because we recommend this, but to remain consistent with the emission pathway that is used by IPCC — resulting in a peak temperature of 1.56 °C (average of IPCC AR6 WGIII category C1 scenarios). Other studies, such as Fekete et al. (2022) and Van den Berg et al. (2020), do not do so and use lower carbon budgets (1.5 °C at 67% probability), which makes reduction targets more stringent for 2030 and 2040 (if all else was kept similar). The ESABCC determines the global pathway based on a selection of IPCC WGIII scenarios, which is close to or slightly more stringent than what we did for this report.

Box 4.1: Impact of choices about the timing of global emission reductions
In the analysis, we looked at two emission pathways: one corresponding to a peak temperature of 1.5 °C with small temporary overshoot, and one staying well below 2 °C. The national targets are directly related to the global target, as shown in Figure 4.2. Current global policies are not consistent with these targets, and — without an urgently needed scale-up of policies — these targets will be exceeded. In brief, the implications of accepting a delay in near-term global climate policy for just targets in the Netherlands would be as follow. If the current climate policy for 2030 remains similar or is only slightly scaled up and the target would remain ‘1.5 °C-with a small temporary overshoot’, the period after 2030 (e.g., in 2040) would require much deeper reductions than if such a delay would not happen. In such a case, even under the *equal relative reductions* rule, the emissions reduction target would be over 95%. If a larger overshoot would be allowed (Chapter 2), the reduction by 2040 would be less and the just reduction range for the Netherlands would also shift to slightly less deep reductions (around 15%, globally). However, this would require considerably more negative emissions in the long term — and the climate impacts would be more severe.

Allocation rules

Of course, one of the main differences between studies is that of the choice of allocation rules. Table 4.2 gives an overview of the allocation rules that were applied in the various studies. We included a broad variety of allocation rules and followed Van den Berg et al. in selecting them (except for some extensions and updates), but not all publications make the same choices. Note that we also chose to calculate *Equal relative reduction* and, annotated with the context about its controversy, put it alongside the other allocation rules. Other studies often do not include this rule for the reasons mentioned in Box 3.2. Rajamani et al. (2021) starts with a review of the full literature spectrum, and then makes an assessment of what part of this spectrum is consistent with principles of international environmental law and the Paris Agreement, which discards some of the literature, such as those including rules based on continuity. The ESABCC distinguishes 'Equality', 'Polluter pays' and 'Ability to pay', which are similar to some of our methods in the principles they apply, but differ in how they determine them. The 2022 NewClimate report on the Netherlands reiterates Rajamani's findings (their so-called 'full fair share' method), and also adds its own method from a per-capita perspective, analogous to how ESABCC calculates it.

Table 4.2: Allocation rules included in a selection of studies, compared against those applied in this report

Allocation rule	This report	Van den Berg et al. (2020)	ESABCC (2023)	Rajamani et al. (2021)	Fekete et al. (2022); NewClimate
Per capita, immediate	X	X		X*	
Per capita, budget	X		X*	X*	X
Per capita convergence	X	X			
Equal relative reduction	X	X			
Ability to pay	X	X	X*	X*	
Historical cumulative per capita	X	X	X*	X*	
Greenhouse development rights	X	X		X*	

Cells with an asterisk (*) mark allocation rules that were applied in a different manner but with the same principles. The selection of studies here is not exhaustive.

Default values and other uncertainties

Even if two studies use the same allocation rules, large differences may arise due to a variation in data sources. For example, for several allocation rules, it matters precisely which socio-economic scenarios are used for population projections and future baseline emissions. For this report, we varied along all Shared-Socioeconomic Pathways (SSPs), but in Van den Berg et al. (2020), for example, only SSP2 is considered. Even estimates of historical emissions can vary. For example, we harmonised historical emissions for the Netherlands with those in the Climate and Energy Outlook (KEV, 2023), but there were notable differences with internationally used emission databases, such as the PRIMAPhist data set (used here for other countries, and e.g. also used by Rajamani et al. (2022)). Default values within allocation rules, also sometimes normative, are also a source of the differences between studies (e.g. start year for historical responsibility). There are more examples of differences between such ‘default values’ under allocation rules.

5 Discussion: the feasibility of deep emission reductions

5.1 Methods to assess feasibility

The targets of the Paris Agreement require substantial emission reductions. For rich countries, considerations on justice may even lead to reduction targets of more than 100%. Achieving such targets on a national level would mean the net removal of CO_2 from the atmosphere, for example through increased forestation or permanent storage of atmospheric CO_2 underground. An alternative interpretation is the funding of emission reductions in other countries (Chapter 6). This leads to the question about the extent to which such deep emission reductions on Dutch territory would be feasible within the timeframe of the coming decades. Scientists have attempted to assess this systematically. This includes the question of whether reductions are *technically* feasible. For example, whether there already is a technology to make this reduction possible, or if one is likely to be developed in the foreseeable future. This would also involve, for example, whether sufficient bioenergy would be available or the specific metals and minerals that would be needed for renewable technologies (the *geophysical* dimension). There are also *economic* limits to feasibility, for example, when reduction costs become too high. Furthermore, there are questions around the extent to which society is able to implement change processes (*institutional* dimension) and whether there is sufficient social support (*societal* dimension). Whether a particular emission reduction target is feasible, therefore, depends on a range of factors.

Table 5.1
Dimensions of feasibility

Dimension	Definition
Geophysical	The geophysical dimension includes the availability of resources for the required transformations. These include, for example, land and sea surface area, elevation and availability of raw materials such as metals.
Technical	The technical dimension indicates whether there are sufficient technical capabilities to meet the transformation objective, e.g. whether the necessary technology has already been developed.
Economic	The economic dimension reflects whether economic conditions support or constrain social change. This includes mitigation costs and investment needs, as well as the labour market.
Institutional	The institutional dimension reflects a society's capacity to shape transformation administratively.
Societal	The societal dimension (also called social or socio-cultural dimension) reflects the extent to which there is public support. This is often closely related to the perception of the justice of measures. If certain reductions are seen as unfair or infeasible, support will quickly decrease.

Based on IPCC (2018), Brutschin et al. (2021) and Steg et al. (2022).

The following section presents some considerations related to the above feasibility dimensions, specifically for emission reductions in the Netherlands.

5.2 Considerations regarding geophysical and technical feasibility

This section compares reduction pathways that are in line with current policy ambitions to apply pathways for more rapid reductions. It subsequently discusses the feasibility of such more rapid reductions. First are the technical and geophysical dimensions of feasibility.

In our analysis we assumed that transition in the Netherlands should not come at the expense of transitions in other countries. This means that the Netherlands contributes proportionately to global emission reductions without placing a disproportionate burden on the international supply of, for example, biofuels, hydrogen or labour. At the same time, we assumed that Europe — and to a lesser extent the rest of the world — follows a reduction pathway similar to that of the Netherlands. In particular, the economic, institutional and societal dimensions of feasibility are strongly influenced by interactions with neighbouring countries.

Climate targets for 2030 and 2050 seem geophysically and technically feasible

The Rutte-IV Government's 2030 target (now set in the Dutch Climate Act as at least 55% emission reduction by 2030, compared to 1990 levels) was previously qualified by PBL as approaching the maximum of what is practically feasible. This assumes more or less constant economic structure (PBL, 2021). Although, in principle, there are sufficient policy plans to achieve the 55% reduction by 2030, a significant part of these plans still needs to be worked out in detail. Moreover, a wide variety of uncertain factors must be worked out to such a degree that they lead to maximum emission reductions (PBL, 2023).

New PBL research, published in April 2024, concludes that a linear reduction pathway of 55% emission reduction by 2030 (compared to 1990) to climate neutrality by 2050, under a number of key preconditions, is likely to be geophysically and technically feasible, even including the Dutch share of international aviation and shipping (PBL, 2024). Behavioural and consumption patterns can remain largely unchanged in the process and the impact on national income is expected to be limited. However, the implementation task is very large, for example when it comes to CO_2-free electricity generation, energy infrastructure and the built environment. Also, this linear reduction pathway requires substantial increases in CO_2 storage capacity and in the production of biofuels and green hydrogen.

These findings are generally consistent with the results from previous scenario studies on the Dutch energy system in 2050, which describe a CO_2-neutral or climate-neutral energy system in 2050 (TNO, 2022; NBNL, 2023; Expert Team Energy System, 2022). These widely differing studies, which each consist of multiple scenarios, show that there are several routes that would lead to climate neutrality.

Box 5.1: Feasibility of climate neutrality based on studies from other countries

More than 100 countries, including most EU Member States, have committed to achieve climate neutrality — often by or around the year 2050. Scenario studies have also been conducted in several countries to investigate how climate neutrality could be achieved. Collectively, these studies provide a glimpse into the feasibility of climate neutrality in 2050 or even earlier. These studies consider geophysical and technical feasibility, in particular.

It is notable that assumptions on, amongst other things, energy demand, installed renewable or CO_2-free energy production capacity and resource availability, vary widely. Nevertheless, under all these conditions, a pathway to climate neutrality appears to be possible. Which route is ultimately followed has consequences for citizens, the economy and the physical environment. 'Pathways with constraints on consumer behaviour, land use, biomass use and technological choices (e.g. no nuclear power) would achieve the target, but at higher costs,' Williams et al. (2021) conclude in a scenario study for the United States. A French study notes that the pressure on natural resources varies significantly per scenario (ADEME 2022). Furthermore, there are several studies on climate neutrality by 2050 for the European Union (European Commission, 2018; European Commission, 2020; European Commission, 2024). In Germany, there are studies on climate neutrality towards 2045 (Prognos, Öko-Institut, Wuppertal Institut, 2021; Fraunhofer, ISE 2021; Forschungszentrum Jülich, 2023) including a broader meta-analysis of various scenarios (Wiese et al., 2021). Finally, the United Kingdom also has an important study on climate neutrality by 2050 (CCC, 2020).

The particular situation of the Netherlands has advantages and disadvantages compared to these countries. The disadvantages are that it is a densely populated country (unfavourable for the ratio of renewable energy to energy demand), has little forest cover and substantial non-CO_2 emissions related to the large agricultural sector. But there are also advantages over other countries, as it has a large area of shallow sea and access to a large volume of depleted gas fields. For the purpose of our study, we assumed that the Netherlands is not in a distinctly favourable or unfavourable position compared to other countries. From the multitude of studies, we inferred that the Netherlands may have many pathways to climate neutrality around 2050 that are likely to be technically and geophysically possible.

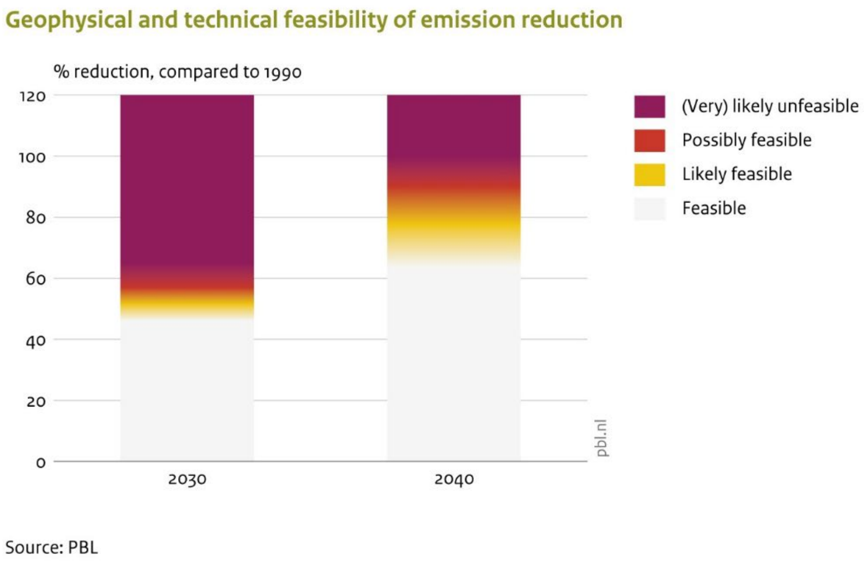
Geophysical and technical limits of feasibility come into view

PBL has not yet done a focused scenario study on the further acceleration of Dutch emission reduction efforts, from the linear pathway of 55% reduction by 2030 to climate neutrality by 2050. Possible policy tightening would lead to limited additional reductions by 2030, but risks of *carbon leakage* would increase (PBL, 2023a). Preliminary modelling results after 2030 suggest that, with an accelerated reduction pathway, 90% emission reduction[2] could be achieved by 2040. However, such a pathway approaches the technical and geophysical limits in the Netherlands, in almost all respects. Figure 5.1 provides an indication of the technical and geophysical feasibility of further

[2] 90% emission reduction by 2040, compared to 1990 levels, corresponds to a residual emission of 23 Mt CO_2 equivalents in 2040.

emission reductions than the linear pathway of 55% reduction by 2030 to climate neutrality by 2050. This is based on PBL (2022; 2023) and PBL (2023a; 2024). Determining the feasibility of the target for 2030 is easier than for 2040. Figure 5.1 shows this difference in uncertainty for a substantially larger range of emission reductions that are 'expected to be feasible' or 'potentially feasible' by 2040, compared to 2030. We emphasise that this concerns the geophysical and technical feasibility of reductions, but without considering the economic, institutional and societal dimensions.

Figure 5.1



Indicative representation of geophysical and technical feasibility of emission reductions by 2030 and 2040.

Box 5.2: Feasibility of climate neutrality Germany by 2045

Germany has changed its climate neutrality target year from 2050 to 2045. Studies have analysed the consequences of such an acceleration for the transition (Fraunhofer-ISE, 2021; Prognos, Öko-Institut, Wuppertal Institut, 2021; Forschungszentrum Jülich, 2023). Although, according to these studies, the new target is feasible for Germany, the limits of this feasibility appear to be in sight there, too. The dependence on various preconditions is becoming even greater with the acceleration (Fraunhofer-ISE, 2021), meaning 'everything has to fall into place'. One of such prerequisites is that of sufficient public support (Forschungszentrum Jülich, 2023).

"Climate-Neutral Germany 2045" shows that an accelerated and comprehensive deployment of climate-friendly technologies in combination with a strong climate policy will ensure that Germany can achieve a climate-neutral economy as early as 2045 and contribute to international climate action through net negative emissions starting in 2045. To make this a reality, it is not necessary to adjust the technology paths for zero emissions by 2050. Rather, the transformation of the energy system must occur faster.In particular, it will be necessary to accelerate the timetable for replacing certain machines and plants. (Prognos, Öko-Institut, Wuppertal Institut. 2021).

Based on our review of the calculations performed for the 2050 study, additional emission reductions in the areas of agriculture and waste will be nearly impossible. Furthermore, in the transport and building sectors, only 5 million tons of additional reductions appear feasible in each. By contrast, we believe that it is possible to attain larger additional savings in the industry and energy sectors – 17 and 77 Mt *CO_2e, respectively* (Prognos, Öko-Institut, Wuppertal Institut, 2021).

'The transformation of the German energy system towards greenhouse gas neutrality by 2045 is technically and systemically feasible. However, it requires speed at all levels and henceforth almost exclusively investments in target-compatible technologies. Model-based calculations of the German energy system also show that the federal government's adjusted climate targets are feasible. According to these targets, 24 years remain to achieve greenhouse gas neutrality. The various calculations show that the path to greenhouse gas neutrality is even more influenced by favourable or restrictive framework conditions, due to shorter timeframes to transform the energy system' (Fraunhofer-ISE 2021).

A fundamental restructuring of the German energy supply across all sectors is required to meet the more stringent greenhouse gas reduction targets and to achieve greenhouse gas neutrality. Provided that there is a willingness to take action and an acceptance among all stakeholders, the required transformation process can be considered viable from a technical and an economic standpoint' (Jülich, 2023).

It should be noted, however, that the situation in Germany cannot be readily compared to that of the Netherlands. Germany, for example, has already achieved stronger greenhouse gas emission reductions with over 40% from 1990 levels, compared to the Netherlands with over 30% (European Commission, 2023). However, nuclear power and CCS are very sensitive issues in Germany, so in Germany's future scenarios they play no role and only a small role, respectively. In scenarios for the Netherlands, a larger role can be foreseen for nuclear power and CCS.

Accelerating emission reductions requires abandoning conventional assumptions

The observation that 90% emission reduction by 2040 in the Netherlands seems possible based purely on technical measures but that the limits of feasibility are coming into view, means that any further acceleration will call for other types of measures. We looked at two options for such an acceleration, both of which will contribute to increasing the geophysical and technical feasibility of deep reductions: 1) changing consumption patterns and 2) scaling up national and European emission reduction technologies even faster and further.

Changing consumption patterns

Different consumer behaviour and/or a different level of consumption, particularly by affluent citizens[3] in both the Netherlands and abroad, could contribute to accelerated emission reductions (e.g. PBL, 2023; LIFE scenario in European Commission, 2024). For example through:

- Faster transition from animal- to plant-based food. This leads to lower emissions from agriculture and more space for forestry and biofeedstock production.
- Consumers buying far fewer new products and/or use products for much longer, in line with circular economy policies. This reduces energy and raw material demand from industry and transport, in particular.
- A faster shift to other forms of transport, using public transport and cycling instead of passenger vehicles and short-haul flights, and less transport, especially fewer long-haul flights.
- More efficient use of space in buildings. This reduces the demand for raw materials and energy for heating.

National emission targets can also be achieved by reducing production, although this comes with economic and social consequences. However, reducing production in itself will not have an effect on climate, as this share of production will then be taken over by factories abroad. Although this will reduce the Dutch emission reduction task, it simultaneously increases the task for other countries. While different behaviour or consumption levels will have an impact on global emissions, this will not necessarily be the case in the Netherlands (PBL, 2022).

Faster and further scaling up of national and European emission reduction technologies

There is a need for a more rapid and greater scale up of national and European energy production and emission reduction technologies than is currently being planned. This would include, for instance, offshore and onshore wind energy, nuclear energy, energy storage, biofuels, biofeedstocks, heating networks, electrolysers and CCS (including negative emissions). This is likely to lead to higher costs as more expensive options would have to be deployed. It may also lead to faster cost reductions due to technological development (European Commission, 2024).
Furthermore, the acceleration leads to greater demands on implementation capacity, with respect to policymakers, official and legal procedures, as well as the labour market, spatial choices and the economy. In short, this would require a large-scale reallocation of public resources. It may also mean that objection and appeal procedures for permits will have to be significantly shortened and that the government will need to take far more control over these procedures. This also brings other dimensions of feasibility into view beyond the technical and geophysical.
Emission reductions may be accelerated through technical developments and cost reductions currently unforeseen. This has happened in the past for solar panels, wind power and batteries, amongst others things (e.g. Way et al., 2022). Breakthroughs can be stimulated by policies that allow innovative technology to displace conventional technology. Substantial investments can also be made in several promising technologies, although without guarantees that they will always pay off.

An accelerated emission reduction pathway will also have positive side effects. Accelerating

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[3] These have by far the largest CO_2 footprint, e.g. see Ecorys (2022).

electrification and the changes in behaviour and consumption mentioned above have strong positive effects, including on air quality and nature quality. The various options lead to an accelerated decrease in the dependence on fossil-fuel-rich countries. To a certain extent, this will involve more imports of energy technology and raw materials. Acceleration may also lead to technological learning effects and cost reductions. Finally, Dutch investments in new emission reduction technology may also increase national earning capacity if Dutch companies can benefit from these investments.

As indicated, in early 2024, the European Commission proposed an accelerated emission reduction of 90% by 2040, compared to 1990 levels (European Commission, 2024). The accompanying *impact assessment* describes a scenario that would result in 92% emission reduction by 2040. Table 5.2 lists the impact of such an acceleration, per sector. These impacts are indicative for the Netherlands.

Table 5.2
Indicative description of an EU scenario towards 92% emission reduction by 2040, compared to 1990 levels, set against a 78% emission reduction scenario (linear trajectory between the existing 2030 and 2050 targets) (European Commission, 2024a).

Sector	Description
Electricity	Electricity generation completely emission-free by 2040; largely renewable
Industry	Larger scale deployment of CCS, e.g. in chemicals; greater deployment of electricity and green hydrogen
Mobility	Increase in passenger and freight transport is mainly by train; from 2035 only emission-free new passenger vehicles and light road transport, from 2040 only emission-free new heavy-duty transport
Aviation and shipping	Greater share of renewable fuels
Built environment	Large-scale deployment of heat pumps, acceleration of renovation rate to 2040
Agriculture	Full deployment of technical measures to reduce emissions
Land use	More forest, wetland and arable farming, less grassland

Non-technological impacts of accelerating emission reductions are highly relevant
Based on the literature, there seems to be some room within the technical and geophysical limits for further acceleration of emission reductions, relative to a linear pathway between 55% reduction by 2030 and 100% reduction by 2050. This does require making certain choices that generally become increasingly radical as the rate of reduction increases. On this subject, the Expert Team Energy System 2050 (2022) notes that quantitative scenarios mainly describe technical options, 'which are not necessarily compatible with a socially feasible transition pathway'.

5.3 Consideration regarding economic, institutional and social feasibility

The feasibility discussion above concerns only the geophysical and technological dimensions of feasibility. If the economic dimension, social acceptance and institutional capacity are also included, the maximum achievable reduction is likely to be lower (e.g. ESABCC, 2023). Although extensive scenario studies have been conducted on the technical and geophysical implications of deep emission reductions and achieving a climate-neutral society, there is a striking lack of supporting scientific literature on non-technological aspects of the transition to climate neutrality (Ulpiani and Vetters, 2023).

Economic dimension of feasibility
Although investment costs are higher in the short term, choosing an accelerated abatement pathway has little direct impact on private consumption or national income in the period from 2031 to 2050 (European Commission, 2024). This does not include indirect effects, such as global acceleration of emission reductions and associated climate change mitigation. Most studies expect an impact on national income that, excluding the avoided costs of climate change, is neutral or slightly positive (EPRS, 2022). From an economic perspective, the energy transition is a huge upfront investment that will pay off by reducing fossil dependence. Accelerating the transition increases the benefits through avoided fossil fuel imports and the benefits of technological learning effects (Way et al., 2022). In the short term, however, acceleration leads to a greater impact on investment, employment and inflation, a situation reminiscent of a war economy, according to Jacques et al. (2023).
Many EU climate policies lack ex-ante assessments of potential socio-economic impacts. However, it can be said that many climate policy instruments, both regulatory (e.g. standards) and pricing (e.g. CO_2 taxes), risk disadvantaging lower-income households and vulnerable groups (ESABCC, 2024; SCP, 2021).

Institutional dimension of feasibility
The institutional dimension of feasibility concerns support and consensus in politics and amongst policymakers. But it also involves capacity and expertise of policymakers, the legislator and executive agencies. The creation and implementation of climate policy requires mutual coordination between governments, the market and society, between sectors, between government departments at the national level and between national and local government. In addition, climate policy must always remain adaptive and responsive; as the problem 'shifts', so must the policy. The required transformative capacity is limited in Dutch climate policy, despite the clear long-term objective, because policy implementation and governance are characterised by sectoral work processes, a short-term orientation and a strong separation between policy and

society. Cooperation between sectors and between policy and society needs to be improved. Policy can and should be regarded with a long-term orientation on the system changes that are needed (PBL, 2023d).

Accelerating the construction of energy production and energy infrastructure already encounters several institutional hurdles, including labour market shortages (Weterings et al., 2023), lengthy procedures and laborious process of issuing permits (e.g. SER, 2024). Limited progress in reducing nitrogen emissions also complicates the acceleration of the energy transition. The 2022 energy crisis showed that substantial acceleration of the energy transition calls for accelerated permit procedures, with renewable energy projects identified as overriding public interests. Such prioritisation of climate measures may be necessary for acceleration, but also carries the risk of diminishing support.

Social dimension of feasibility

The risk of an accelerated transition pathway is that the measures to be taken could undermine public support. There is support for climate measures in the Netherlands, provided it does not make life unnecessarily expensive or less comfortable (Milieu Centraal, 2023). According to TNO (2023), literature research shows that citizens find policy acceptable when they 1) see it as effective in tackling problems, 2) consider it to be fair for everybody, and 3) when it has only limited negative impact on their lives. At the same time, over a quarter of people say they are angry, to some extent, about ‘all the attention that is focused on climate, when there are more important problems that require attention’ (SCP, 2021). The feasibility of a stringent climate target hinges on sufficient public support and, thus, on meeting these three preconditions.

Citizens are more likely to support policies that affect them less directly (Dreijerink and Peuchen, 2020). When asked who should be taking climate measures, 73% point mainly to industry and aviation (CBS, 2023). People are more divided about their own role and responsibility, although those who do see their own role and responsibility are slightly in the majority (SCP, 2021). About three quarters of people are at least somewhat concerned that climate measures will make their lives more expensive and and over a third is extremely worried about this aspect, and about half are concerned about the impact of climate measures on their way of life. Moreover, around 40% of people already seem to feel their freedoms are being restricted, to some extent, by discussions about the environment and climate (SCP, 2021). According to research by Bruegel (2023), only 36% of Western Europeans would continue to support climate targets if this resulted in personal income loss. For Italy, Colantone et al. (2023) show that income losses due to green policies increase the likelihood of people voting for parties that actually oppose green policies. This is why, according to a meta-study of the literature on the social acceptance of climate policies, cost considerations are the most frequently cited reason for not supporting climate policies (Fairbrother, 2022).

At the same time, recent research shows that, in almost every country, a majority of citizens is willing to accept limited reductions in income for the sake of climate policy. Moreover, in every country surveyed, citizens underestimate the willingness of their fellow citizens to do so (Andre et al., 2024). This would indicate that there is broad support for a fair distribution of costs and benefits amongst different groups of citizens and companies. This not only concerns the financial costs and benefits, but is also about the impact on the local environment and citizen engagement (EZK, 2023).

A beckoning prospect is also increasingly recognised as an important precondition for supported policy choices. Only with a shared vision of the future for the Netherlands in 2050 can climate change mitigation gain sufficient momentum, as is argued by the Scientific Climate Council (Scientific Climate Council, 2023). However, SCP (2021) shows that the beckoning prospect of a win-win situation around the climate approach is not yet widely shared within society.

5.4 Coherence between feasibility dimensions and distribution of reductions across sectors

The impact of accelerating the emission reduction pathway depends not only on the degree of acceleration, but also on its implementation. The feasibility of additional reductions depends on the sectors in which additional emission reductions need to take place.

- *Industry:* If industry is required to make additional emission reductions, feasibility depends mainly on technology (including energy infrastructure) and economic conditions. This applies, for instance, to carbon capture and storage (CCS), the application of bio-based fuels, and electrification. The construction of infrastructure touches on the interests of local residents, and the desirability of using biomass and applying CCS have regularly been discussed (De Gemeynt and MSG Strategies, 2020; Akerboom et al., 2021), but institutionally it seems feasible and the number of people directly affected by this development is limited. International competition is a major concern here, though, because if companies were to cease production, this could lead to a decrease in social feasibility.
- *Energy production:* For even more production of low-CO_2 energy, such as electricity or heat, technical and economic dimensions of feasibility are also important. For electricity generation, the social dimension is also emphatically at play, as it changes the local physical environment. In addition, geophysical aspects such as the spatial incorporation of, for instance, wind and solar energy and the electricity grid are also becoming increasingly constraining (NBNL, 2023).
- *Transport sector:* In the transport sector, the technical, economic and social dimensions of feasibility come into play. These include, for example, the question of how to make climate-neutral alternatives for passenger transport accessible to all and the roll-out of energy infrastructure. The lifetime of the fleet of passenger vehicles, ships and trucks limits substantial acceleration, compared to in the current pathway (PBL and TNO, 2024). Shifting to other forms of transport can also contribute (European Commission, 2024a). Furthermore, the sustainability of the transport sector is strongly intertwined with that of the rest of Europe.
- *Built environment.* In the case of the built environment, the technical, economic, institutional and social feasibility dimensions are all relevant. Emission reduction within the built environment involves modifications to almost all buildings, which have different forms of ownership (PBL, 2023a).
- *Agriculture/land use*: For additional emission reduction in agriculture or land use, economic, institutional and societal dimensions are especially relevant. To the extent that technical measures are deployed, this particularly concerns the economic and institutional dimensions. When emission reduction is related to livestock numbers, this has an impact on whether and how businesses can continue their activities. Relocation renders the climate impact negligible if the consumption of animal products is not reduced simultaneously (PBL, 2023a). The technical dimension of feasibility when it comes to alternatives to animal proteins is also a concern.

- *Consumption change:* Policies aimed at reducing consumption have a less direct link to emissions within the Netherlands (PBL, 2022). Feasibility seems to be limited mainly by institutional and societal dimensions. Policy instrumentation is complex (PBL, 2023b) and such policies are perceived very differently by the various social groups (PBL, 2023c; Milieu Centraal, 2023). Policies in this area therefore need to be fair, targeted and effective.

Whether more stringent emission targets are feasible based on technical or societal dimensions, for example, does not depend only on target levels. The sectoral and societal distribution, its mode of implementation and instrumentation are just as important. Fairness between the various groups within Dutch society and public participation is also important with regard to the implementation method. Here, as with the global task, the question of what is fair or just has a partly normative character. Various justice principles, such as equality and responsibility, play a role here (see also Chapters 2 and 3).

Finally, the long-term perspective is also relevant. Rapid emission reductions may, depending on the interpretation, be at odds with working towards a society within planetary boundaries (European Commission, 2024a). For instance, such reductions could lead to an increased use of biomass for non-high-value applications (e.g. SER, 2020). For an accelerated scale up of the extraction of critical materials for the energy transition, it is also important to consider environmental aspects (PBL, 2024a).

6 Balancing global distributive justice and national feasibility

This report discusses the considerations involved in setting emission reduction targets for the Netherlands, in the context of the Paris Agreement. Global distributive justice and national feasibility are crucial concepts, in this respect. Our study shows that a wide range of emission reduction targets is possible, all consistent with the Paris Agreement. This wide range is due to uncertainty and policy choices.

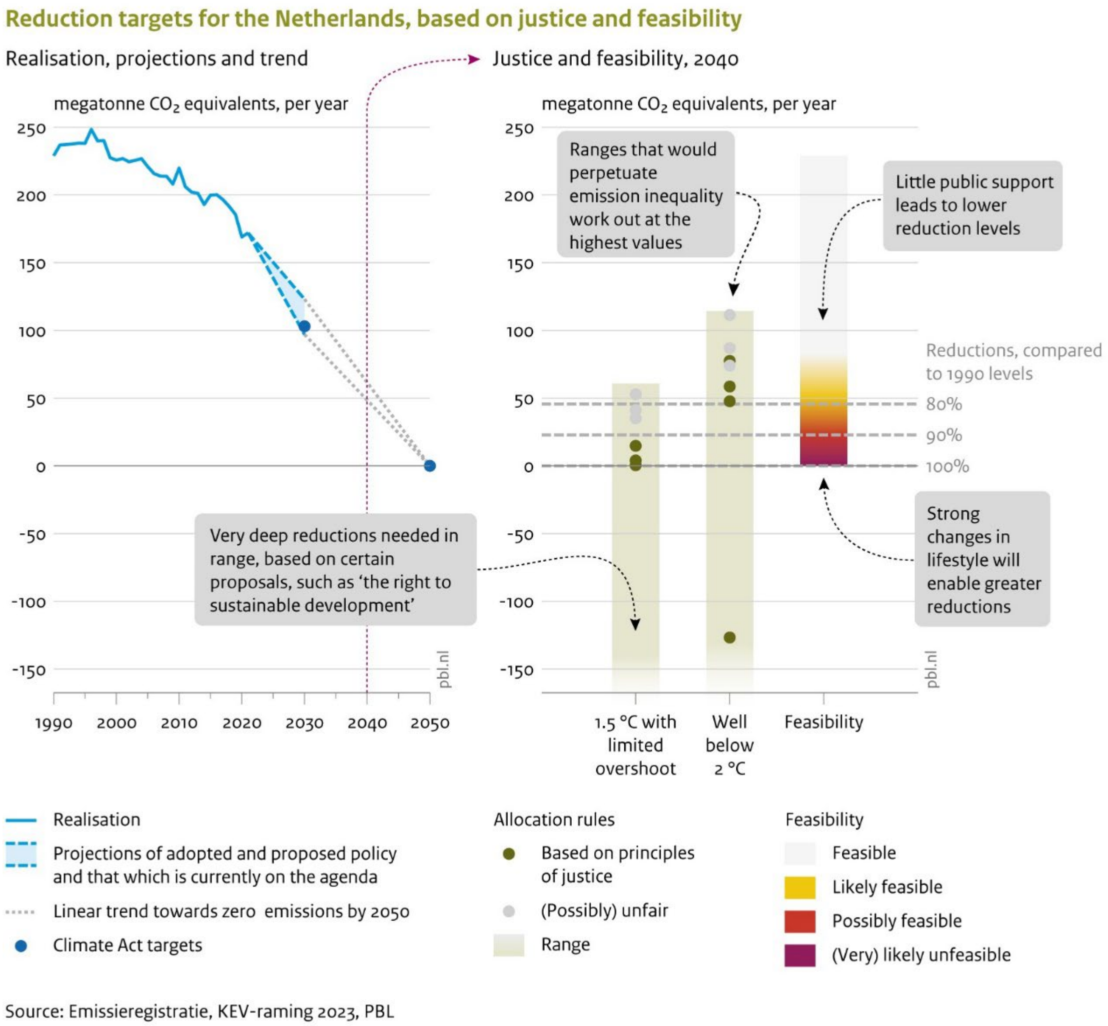
Justice principles imply substantial reduction targets for Dutch emissions. The wide range of reduction targets is related to the choice of global target, the probability of achieving it and the interpretation of what constitutes justice. As reductions become larger, more justice principles are being upheld. It should be noted that not all principles mentioned in this report are consistent with international law. For example, the principle of equal relative emission reductions in all countries leads to higher costs for developing countries than for developed countries, due to faster economic and population growth in these regions. Thus, this principle functions mainly as a reference. The range of reductions for achieving the 1.5 °C target with limited overshoot and consistent with the principles of international environmental law starts for the Netherlands at around 90% by 2040. Several principles lead to reductions well above 100%.

Comparing feasibility with distributive justice principles

Deep reductions in line with the principles of global distributive justice may face the limits of national feasibility. If the necessary policies are initiated in time, emission reductions by 2040 that are consistent with a linear interpolation between the current 2030 and 2050 targets are thought to be technically feasible. But would more be possible? The estimates in Chapter 5 show a preliminary conclusion: emission reductions up to 90% by 2040 are probably geophysically and technically feasible in the Netherlands, provided the European Union as a whole takes similar steps. With far-reaching behavioural change and maximum use of all options, slightly more could technically be achieved. However, lack of social support could lead to a decrease in the full reduction potential. This depends on the implementation of the policy and the extent to which it is perceived as 'just'.

Some allocation rules lead to net negative emissions in 2040 for the 1.5 °C maximum temperature target with limited overshoot. This is almost certainly not feasible in the Netherlands itself. Besides the far-reaching changes, this also entails the geophysical limit around negative emissions. According to PBL (2018), around 13–34 million tonnes of CO_2 in negative emissions per year by 2050 would be realistic, while CE Delft (2023) puts this at a maximum of 39 million tonnes per year. Even in the unlikely event that this amount would already be achieved by 2040, residual emissions are expected to remain.

Figure 6.1



Reductions of more than 100% by 2040 have not been assessed separately but are very unlikely to be feasible

Searching for a balance

Policymakers must find a way to balance things out. On the one side, there are justice principles such as global equality, historical responsibility and capability, while on the other side, there is the question of feasibility, depending on geophysical, technological, economic, institutional and societal dimensions. The feasibility dimensions are strongly interrelated. Choices within one dimension may either increase or decrease the reduction scope according to other dimensions. For example, striving for the maximum rate of reduction based on a geophysical and technological optimum needs also a strong development of the institutional and societal dimensions. Insufficient development may undermine the intended outcome. Placing wind turbines close to cities is technically relatively easy and economically beneficial, but it is socially difficult and therefore not always the most optimal solution. Electrification, for example in industry, seems socially feasible, but sometimes runs into technical or economic feasibility limits. Finding a balance between the various dimensions is therefore normative and based on political consideration. Feasibility has also been proven to be influenced by external factors, as was evident, for instance, during the COVID-19 pandemic and the energy crisis following the Russian invasion of Ukraine. These events led to swift and far-reaching actions by both policymakers and society.

Reductions possible outside the Netherlands

In addition to domestic emission reductions, the Netherlands could also contribute to those abroad. This is also in line with existing policies of the Netherlands, such as the international climate strategy and policies around the Global Biodiversity Framework. Although the rules within the Paris Agreement have yet to be further defined, such investments could already take place now — in addition to reductions within the Netherlands itself. There are several mechanisms for this within the Paris Agreement, via the Climate Fund, agreements between countries and reductions at project level.

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