CPB Netherlands Bureau for
Economic Policy Analysis

Climate change and intergenerational distribution of financial burdens

In this exploratory study we survey the intergenerational effects of climate change and climate policies.
On the basis of initial estimates, most of the additional costs of climate change and associated policies will be borne by future generations.
Moreover, financing these costs with debt could result in them bearing an even larger share.

The estimates of the costs are highly uncertain, particularly as the time horizon grows longer. They are nevertheless likely to be substantial. The extent to which the government meets the costs is a policy choice.

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Summary

The costs of climate change and associated policies, in conjunction with the conduct of fiscal policy, have consequences for the distribution of financial burdens between generations. The government can use debt to shift these burdens from the present to the future. The CPB population ageing studies illustrate the consequences of demographic developments for the public finances. This study explores how these analyses can be supplemented with the financial burdens of climate change. This is an initial step to enable these consequences to be included in deliberations relating to fiscal policy.

Most of the costs of climate change and climate policy are likely to be borne by future generations. The costs of climate change in the Netherlands, as well as the financial burdens of climate policy, are likely to increase further in the future. Moreover, future generations will also experience the negative consequences of climate change that are difficult or impossible to express in monetary units. Financing the costs of climate change with debt could further increase the financial burdens on future generations. This in no way implies that no climate policy should be pursued, but it does mean the financing should allow for a fair distribution of benefits and burdens among different generations. Instead of debt financing, these costs could also be absorbed by increasing the current financial burden or reducing other expenditure.

To illustrate the intergenerational distribution, we estimate the costs of climate change. In this study we examine three channels. First, damage: climate change will confront the Netherlands with changes in the physical environment. Examples are drought, heat, waterlogging, river flooding and sea level rise. Second, in order to cope with these physical consequences, adaptation policies can be pursued, such as raising the level of dykes. Third, there is mitigation policy: the outgoing Dutch cabinet wants the Netherlands to be carbon-neutral by 2050. These three developments all entail costs that may be borne partly by the government. The extent to which the government meets the costs is a policy choice. For example, measures discouraging or prohibiting carbon emissions will cost the government little, whereas subsidies will use up part of the budget. At the same time, the costs that are not met by the government will be borne by households and businesses.

Estimates of these costs are highly uncertain. In the case of the Netherlands, only part of the consequences of global warming have been illustrated for some warming scenarios. The probability and impact of those consequences are also uncertain, and become increasingly uncertain the further one looks into the future, partly due to the possible occurrence of tipping points that could vastly accelerate the pace of warming. The costs of adaptation policies may also be an underestimate because it is uncertain whether the measures considered in our analysis, particularly in the second half of the 21st century, will be sufficient to deal with the consequences of warming. The costs of mitigation policies are less uncertain. Switching to a carbon-neutral economy is complex, but the cost estimate is less uncertain than the estimate of the damage due to climate change and adaptation policies.

The consequences of climate change for the Netherlands will depend greatly on international efforts. At global level, the efforts relating to mitigation, adaptation and physical consequences are to some extent interlinked: a stronger mitigation policy leads to less need for adaptation, while more adaptation limits climate damage to some extent. Given the Netherlands' limited contribution to global greenhouse gas emissions, the effectiveness of mitigation policies depends almost entirely on international efforts.

1 Introduction

This study explores ways of obtaining information on the intergenerational distribution of costs of climate change and associated policies. The government can control not only the distribution within generations but also the distribution between generations, for example by making savings now for future generations – i.e. less national debt – or by making future generations share the costs by shifting the burden and allowing national debt to rise. CPB has traditionally used population ageing studies[1] to show how this distribution between generations is affected by demographic developments. In addition to population ageing, other developments also affect the intergenerational distribution. In this study we use external sources and our own model analyses to explore the effects of climate change on the financial burdens for different generations.[2]

This study aims to outline the intergenerational effects of climate costs rather than to present a comprehensive cost estimate. It has not hitherto been possible to produce a reliable estimate of these costs, and they remain highly uncertain. We have used external sources to estimate their trajectory and order of magnitude, considering only those costs that may be borne by the government. We use this estimate up to 2100 to illustrate intergenerational effects. We make a number of technical assumptions, for example that half of the costs will be borne by the government. This assumption is pragmatic and by no means intended as a recommendation or forecast of the cost distribution between the government, households and businesses. The actual distribution is the result of policy choices: more subsidies lead to higher government costs; more regulation and pricing leads to lower government costs.

There are three cost items relating to climate change and associated policies: damage caused by climate change (climate damage), policies to guard against this damage (adaptation costs) and policies to combat warming (mitigation costs). These three cost items are interrelated. If the climate changes drastically and few adaptation measures are taken, such as raising the level of dykes, the damage may be extensive; if such measures are taken, the damage will be limited. These adaptation measures will have to be funded, however. Effectively combating climate change reduces the costs of damage and adaptation, but is only possible if mitigation policies are pursued worldwide. We will base this document on the ambitions of the outgoing cabinet with regard to the Dutch targets, i.e. a 60% reduction compared to 1990 by 2030 and a 100% reduction by 2050.[3]

The size of the three cost items is highly uncertain; we have identified three reasons for the uncertainty surrounding the estimation of climate damage. First, there is uncertainty with regard to the extent, distribution and speed of warming. With higher and faster warming, the damage will be much greater than with lower warming, particularly if tipping points occur. Second, by no means all negative consequences of climate change have been fully identified. Third, even for the channels for which estimates have been made, there is great uncertainty surrounding the expected value; the probability, impact and time of their occurrence are uncertain.

There are several reasons for the uncertainty surrounding the costs of mitigation policy. First, it is unclear which transition path will be followed, nationally and internationally. The different paths have different cost estimates. Second, it is uncertain whether the measures will be sufficient to achieve the reduction targets; for example, it is uncertain to what extent businesses and citizens will adapt their behaviour. Third, the success of

[1] Adema and van Tilburg (2019)
[2] WRR (2023) also stresses the importance of greater insight into the intergenerational distribution of climate costs.
[3] See https://www.rijksoverheid.nl/onderwerpen/klimaatverandering/voortgang-klimaatdoelen.

the plans depends on their implementation, in both practical terms, i.e. ‘finding people to perform the work', and societal terms, i.e. ‘public support'. Finally, technological developments are expected to put downward pressure on costs, but the extent to which this will happen is difficult to predict.

The costs of adaptation policies depend mainly on the extent of warming and climate change tolerance. As the climate continues to warm, more protection measures are needed to limit exposure to climate damage. The extent to which these costs will rise in the event of further climate change is uncertain; to what height can dykes be raised, for example? More drastic measures will probably entail higher costs, but whether these measures are taken will depend on people's willingness to tolerate the negative consequences of global warming.

Our estimates do not include all the costs of climate change and associated policies. There will also be impacts on the structure of the economy, quality of life and biodiversity. Global warming and the pursuit of net zero greenhouse gas emissions may make certain sectors unviable. In addition to these national effects, the international effects are also relevant, because climate change and associated policies impact the Dutch economy through international relationships. See, for example, IPCC (2022a, pp. 2495-99, 2022b, pp. 359-362) for the impacts of climate change and mitigation policies respectively on GDP and GDP growth. In addition to economic effects, there are also negative effects on well-being in the broader sense. For example, climate change can put pressure on quality of life in certain areas and is one of the causes of biodiversity loss (IPBES, 2019).

In this study we focus on the additional costs compared to the current climate and current policies. This means the total costs of climate change are underestimated because the current climate has already warmed.[4] If, on the other hand, the costs of disasters such as flooding in the current climate were also included, this would lead to an overestimation of the costs. This is because floods, for example, occur even without climate change, and these would then be incorrectly classified as a consequence of climate change.[5] For mitigation and adaptation policies too we determine the costs of additional policies compared to the current policies. The costs of additional policies in particular put pressure on the government budget; funding is already in place for existing policies. As in the case of climate damage, this leads to an underestimate of the total costs of climate policies.

To provide a quantitative illustration of the intergenerational effects, we make a number of technical assumptions. Despite the stated uncertainties, we estimate the expected costs per cost item per year up to and including 2100. Climate disasters are unpredictable. For simplicity, we assume that damage due to climate change will occur in 2050 and 2100. For the costs of mitigation policies, we interpolate the costs in intervening years on the basis of available estimates for someyears in the time horizon. In the case of adaptation policies, we extrapolate cost estimates up to 2050 inclusive through to 2100. We also assume that the government will bear half of the additional costs for the three cost channels and that the remainder will be borne by households and businesses. This assumption is pragmatic and depends on the policies the government will pursue (e.g. subsidies versus pricing/regulation) and the extent to which the government will pay compensation in the event of damage. Finally, we assume that the costs will be covered by spending cuts, so there is no increase in national debt. We use these assumptions in our GAMMA long-term model to quantify intergenerational effects.[6]

[4] The climate in the Netherlands has been on average 1.6 degrees warmer over the past thirty years than at the beginning of the 20th century (KNMI, 2022).
[5] For an overview of flood disasters, see https://watersnoodmuseum.nl/kennisbank/rampen/.
[6] See Van Tilburg, Kuijpers, Nibbelink & Zwaneveld (2019).

2 Climate damage

2.1 Damage due to climate change

The physical consequences of climate change for the Netherlands are uncertain. KNMI (2021), in its Klimaatsignaal '21, focused on the most important physical consequences for the Netherlands: drought, heat, waterlogging, changes in river levels and sea level rise. In our study we focus on the damage caused by these consequences. There are also other negative consequences of climate change, such as an increase in animal diseases.[7] In addition to negative effects, there are also positive effects such as less injuries and damage due to winter weather.

To estimate the damage caused by drought, heat and waterlogging, we use the Climate Damage Atlas (2020) and a report by Stratelligence (2021).[8] We use the additional damage, compared to the damage at the current warming level, as a result of climate change occurring up to 2050 inclusive. We assume average global warming of 2°C in 2050. In the case of the Climate Damage Atlas, a major change in the air flow pattern[9] is assumed in addition to warming. The Stratelligence report uses the Delta Scenarios *Warm* and *Steam*, which also involve a 2°C warming in 2050.[10] For 2100 we assume 3°C of warming.[11] Table 1 shows a breakdown of the damage per year into drought, heat and waterlogging. The Climate Damage Atlas and the Stratelligence study apply specifically to the Netherlands. Not all damage caused by drought, heat and waterlogging has been mapped in these studies.[12] The total damage will therefore most probably be higher.

For river and coastal flooding, the PESETA IV project has estimated the expected damage in Europe as a whole and in each country. This was done by assessing the impact of climate change on extreme events such as floods (European Commission, Joint Research Centre, Feyen, Ciscar, Gosling, 2020). The expected damage from these extreme events was then determined. The probability multiplied by the expected impact results in an estimate of the annual damage (see Table 1). The project is modelled at European level, so the resulting picture is less detailed than if the focus were specifically on the Netherlands. Furthermore, it is assumed that the current level of protection will continue to apply, i.e. no additional adaptation measures are taken. This results in an overestimate of the expected costs (see next section for scenario in which additional adaptation measures are taken into account).

[7] In addition to these consequences, there are other consequences of climate change, see for example Consequences of climate change (europa.eu) for a more extensive overview.
[8] The Climate Damage Atlas was developed by Deltares, Wageningen Environmental Research, HKV, TNO, Amsterdam University of Applied Sciences, Tauw, RIVM, Arcadis, Sweco, KCAF, Aveco de Bondt and Stichting Cas. Stratelligence wrote the report on behalf of the Freshwater sub-programme of the Delta Programme.
[9] See KNMI - KNMI'14 Climate Scenarios - Key figures.
[10] See https://media.deltares.nl/deltascenarios/deltascenarios_nieuwe_blik_op_de_toekomst.pdf. We use *Warm* for the low damage estimate and *Steam* for the high damage estimate.
[11] Current policies worldwide have a 50% probability of causing 2.8°C of warming by the end of the century. If all the promises made are fulfilled, this will decrease to 2.4-2.6°C (UNEP, 2022).
[12] See Climate Damage Atlas.

Table 1: Estimates of damage in the Netherlands from drought, heat, waterlogging and flooding without additional adaptation measures

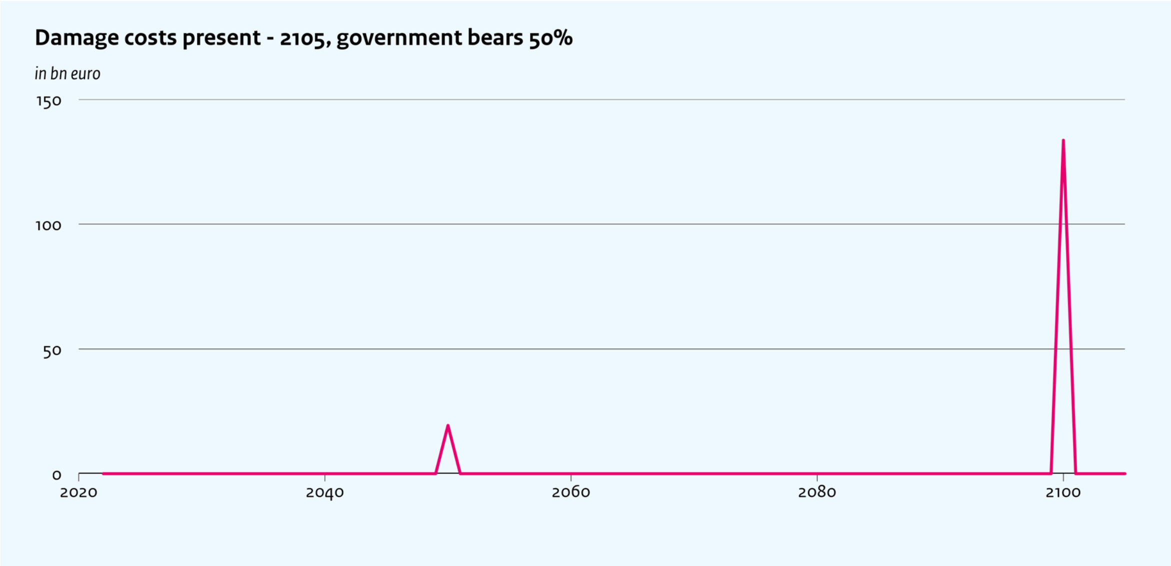
	Low damage	High damage	Channels	Damage year	Warming path
	in billion euros per year, price and volume level 2022				
Climate Damage Atlas	0.3	1.5	drought	2050	2°C in 2050
	0.5	0.5	heat	2050	2°C in 2050
	0.8	1.0	waterlogging	2050	2°C in 2050
PESETA IV - 2050	0.3	0.3	river floods	2050	2°C in 2050
	0.2	0.2	sea level rise	2050	3°C in 2100 – RCP4.5
PESETA IV - 2100	0.5	0.5	river floods	2100	3°C in 2100
	6.0	6.0	sea level rise	2100	3°C in 2100 – RCP4.5
Total in 2050	2.0	3.5		2050	
Total in 2100	8.1	9.6		2100	

Note: This concerns average additional damage in 2050 and 2100 compared to damage based on the current climate and current protection measures conditional on the assumed temperature rise.[13]

We make a number of technical assumptions to estimate government costs for the 21st century. First, we assume a linear rise in damage costs between the years of the time horizon. Table 1 shows the expected damage in 2050 and 2100. For drought, heat and waterlogging we assume a linear increase from 2023 to 2050 inclusive, after which we assume constant damage. In the case of river flooding and sea level rise, we first assume a linear increase from 2023 to 2050 inclusive and then a linear increase from 2050 to 2100 inclusive. Second, for the sake of simplification, we assume that no damage occurs until 2050 and that the 'accumulated' expected damage over the period from 2023 to 2050 occurs all at once in 2050. Here we use the midpoint of the low-high range from Table 1. For the period from 2051 to 2100 inclusive, we assume that all damage occurs in 2100. The resulting pattern of damage can be seen in Figure 1. Third, we assume that the government will bear half of the financial damage. The damage in 2100 for which the government pays compensation is seven times greater than in 2050, at EUR 134 billion. The extent to which the government compensates for damage is a policy choice; our assumption that half of the costs will be borne by the government should not be seen as our expectation.

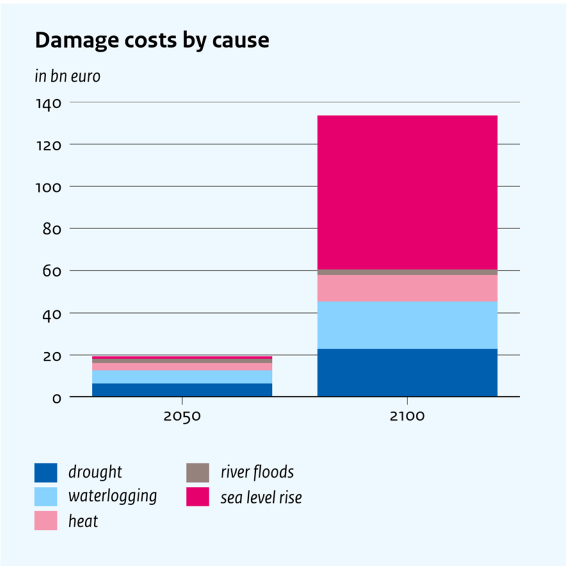
[13] For the amounts of damage, see Climate Damage Atlas (2020), Stratelligence (2021), Vousdoukas et al. (2020) and Dottori, Mentaschi, Bianchi, Alfieri and Feyen, (2020).

Figure 1: Damage is likely to vary widely over time



By far the bulk of the damage in 2100 is the due to sea level rise (see Figure 2)**.** If the protection remains unchanged, the costs of rising sea levels will make up more than half of the expected damage in 2100. In 2050, waterlogging and drought both account for approximately one-third of the damage.

Figure 2: Sea level rise responsible for greatest damage in 2100



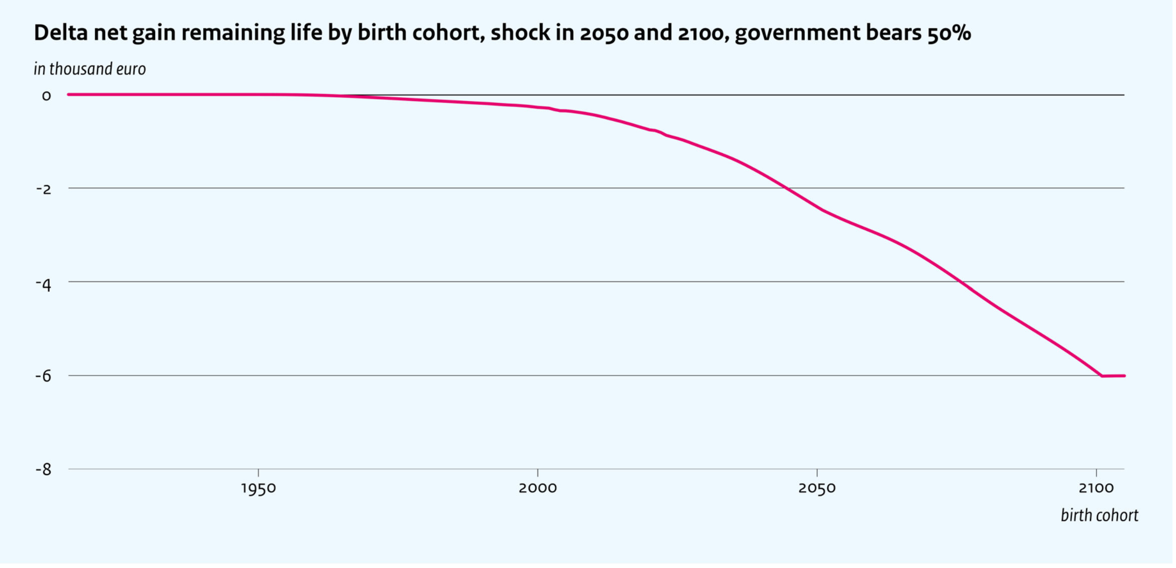
Climate shocks have a greater negative impact on future birth cohorts than current cohorts. In Figure 3 we show the impact of the climate shocks from Figure 1 on the net gains[14] that different birth cohorts enjoy

[14] The net gains are equal to the balance of the income that a birth cohort receives from the government and the expenses that this cohort pays to the government.

from the government compared to the situation without climate shocks.[15] We assume that there is no additional protection compared to the current situation. Once the shock occurs in 2050, we assume that the government will compensate for half of the damage. In 2051, a generic spending cut is implemented, so the additional public expenditure does not lead to ever increasing national debt over the long term, as that would shift financial burdens into the future. In 2051, there will still be people alive who were born in 1944, which means they will have to bear a small part of the spending cut in the final year of their lives (the assumption being that people live to a maximum age of 107). The pink line therefore starts to decline from the 1944 birth cohort. This line then falls because people are impacted by the 2051 spending cut for a larger part of their lives. The fall in the line then accelerates towards 2101 birth cohorts, because the 2100 climate shock is absorbed in 2101 by a generic spending cut. People born in or after 2101 live their entire lives under a government that has made spending cuts in both 2051 and 2101. Over a person's entire life, this means an expected decrease of approximately EUR 6,000 per person, equivalent to 0.6% of the average lifetime wage income.

A number of caveats should be entered with regard to this result. First, the baseline against which the delta of the gains is determined includes additional adaptation measures, whereas the estimate of the damage burden assumes that no additional adaptation measures are implemented. An example of policies pursued and included in the baseline concerns measures taken to meet the legal requirement that the probability of death due to flooding behind dykes in 2050 must not exceed 1 in 100,000 (see also the next section).[16] In this sense, the impact is an overestimate of the actual situation, because these costs of adaptation policies should be deducted from the costs of the climate damage. At the same time, this analysis is not expected to include all damage costs and the estimate of the included damage costs is highly uncertain. Furthermore, the uncertainty surrounding the estimate is asymmetrical (Roe and Baker, 2007) – there is a small probability of large temperature rises – and the negative impact many turn out to be much greater, particularly if tipping points occur (see section 2.3). Finally, it is likely that the climate damage will increase even further after 2100, raising the question of the extent to which protection measures will still be effective at that time.

Figure 3: Future birth cohorts will pay a price for climate shocks



[15] In calculating the net gains, we take into account the time preference rate within a generation but not between generations. If we were to do the latter, generations born later would by definition be worse off in terms of gains than generations born earlier.
[16] See Delta Decision for Flood Risk Management | Three topics | Deltaprogramma.

2.2 Additional protection against climate change

The costs resulting from climate change will be lower with additional adaptation measures than without such additional measures. The previous section shows damage costs for 2°C of warming in 2050 and 3°C in 2100 with the current level of adaptation measures. However, measures are already being taken to protect against the physical consequences of climate change. In the case of floods, there is even a legal requirement that the probability of death due to flooding behind the dykes must not exceed 1 in 100,000 in 2050.[17] As part of the Flood Protection Programme, further protection will be developed in the coming decades to meet this requirement.

Additional protection against flooding reduces the identified damage costs by over eighty percent in 2100 (see Table 2)**.** The costs of flooding due to sea level rise decrease from an average of EUR 6.0 billion per year in 2100 without additional protection to EUR 0.2 billion per year in 2100 with additional protection (Vousdoukas et al., 2020). This damage estimate assumes that only 31% of the dykes are reinforced for which the benefits of strengthening exceed the costs. The legally imposed maximum risk of death of 1 in 100,000 may imply a more extensive strengthening operation and consequently lower average damage levels. In the case of river floods, we have adopted a 69% reduction in the damage burden in 2100 from the PESETA IV study (Dottori et al., 2020). The reduction in damage in the Netherlands due to various adaptation measures is determined in Dottori et al. (2020). Strengthening of dykes proves most effective. If there is also more space to absorb excess water and measures are taken to limit damage in the event of flooding, the damage reduction may be greater. Since these measures will produce benefits not only in 2100 but probably also earlier, we also apply the reduction to the damage in 2050, for both sea level rise and river flooding.

We assume that measures will be taken against drought, heat and waterlogging, reducing the damage burden by fifty percent (see Table 2)**.** We have not found any good, generic estimates for measures to reduce the damage burden in the Netherlands due to drought, heat and waterlogging. A wide range of measures could nevertheless be taken.[18] However, there are few generic estimates of the reduction in the damage burden (Cammalleri et al., 2020). First, making such estimates is difficult because not all possible measures are cost-effective and hence they may not be taken (see Figure 1 in Leusink, 2018). Second, the differences in the reduction in the damage burden will depend on the local situation. Since there are various measures to limit the damage, but the precise extent of the reduction is unclear, we assume that it is possible to limit the damage burden to 50%.

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[17] See Delta Decision for Flood Risk Management | Three topics | Deltaprogramma.
[18] See for example https://klimaatadaptatienederland.nl/publish/pages/160788/de_effectiviteit_van_klimaatadaptatiemaatregelen_2019_1_3.pdf

Table 2: Damage estimates for the Netherlands from drought, heat, waterlogging and floods with additional adaptation measures

	Low damage	High damage	Channels	Damage year	Warming path
	in billion euros per year, price and volume level 2022				
Climate Damage Atlas	0.1	0.8	drought	2050	2°C in 2050
	0.3	0.3	heat	2050	2°C in 2050
	0.4	0.5	waterlogging	2050	2°C in 2050
PESETA IV - 2050	0.1	0.1	river floods	2050	2°C in 2050
	0.0	0.0	sea level rise	2050	3°C in 2100 – RCP4.5
PESETA IV - 2100	0.2	0.2	river floods	2100	3°C in 2100
	0.219	0.2	sea level rise	2100	3°C in 2100 – RCP4.5
Total in 2050	0.9	1.6		2050	
Total in 2100	1.1	1.9		2100	

Note: This concerns annual average additional damage in 2050 and 2100 compared to damage with the current climate and with additional protection measures conditional on the assumed temperature increase. [20]

The expected damage costs decrease due to additional measures, reducing the negative impact on gains for birth cohorts from 2100 by more than three-quarters, although this is offset by additional adaptation costs (see paragraph 4). The pink line in Figure 4 reflects the damage burdens if the same approach is adopted as in section 2.1, but with the damage burdens decreasing due to adaptation measures. The blue line represents the damage burdens from the previous section without additional adaptation measures. The reduction in the shock in 2100 is more than 75%, with a new damage amount of EUR 32 billion that is borne by the government. As a result, the spending cuts required in the years after the shocks are also smaller and the net gains for birth cohorts from 2101 decrease by approximately EUR 1,600 per person (see Figure 5); for the shocks in the previous section this was EUR 6,000.

[19] In Table 1 and Table 6 of Vousdoukas et al. (2020), the amounts of damage with no additional adaptation, damage with adaptation and avoided damage do not add up. After correspondence with the author, we have ascertained that the correct average annual damage amount for the Netherlands with additional adaptation is EUR 0.4 billion.
[20] For the damage amounts, see Vousdoukas et al. (2020) and Dottori, Mentaschi, Bianchi, Alfieri and Feyen, (2020).

Figure 4: Expected damage costs decrease substantially with additional adaptation measures

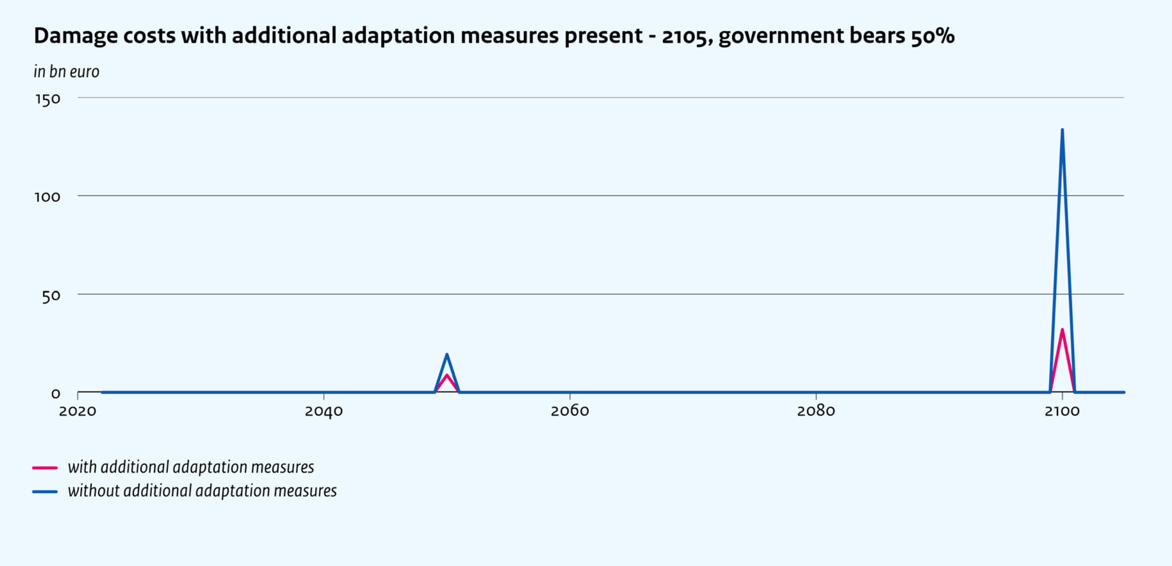
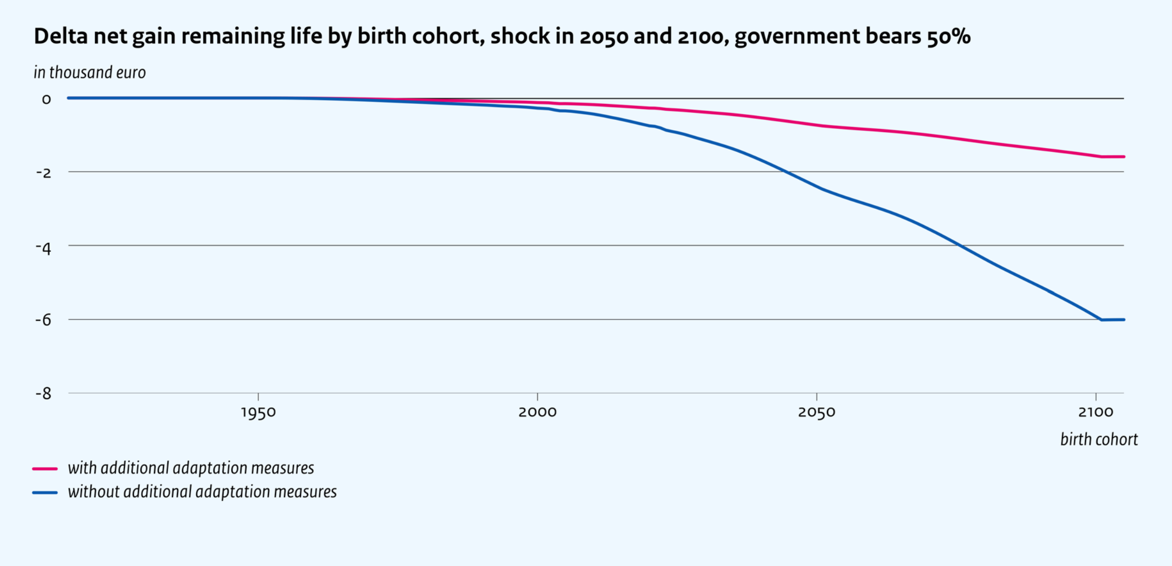


Figure 5: Negative impacts of physical climate change with additional adaptation measures decrease for all birth cohorts



2.3 Uncertainty and tipping points

The uncertainty in the estimation of damage costs is high and increases even further when tipping points are also taken into account. We have already emphasised in several places that the estimates of damage costs as a result of climate change are uncertain. Moreover, the studies on which we focused rule out the occurrence of tipping points. The already high level of uncertainty in the models used increases even further when the possible occurrence of tipping points is included in the analysis. Because of these uncertainties, it is quite possible that a much more extreme scenario, with more extreme consequences, will occur. For example, in a negative scenario the reinsurer Swiss RE (2021) assumes 3.2°C of warming in 2050. This scenario is at the tail end of the distribution of warming in 2050. By comparison, in section 2.1 and 2.2 we assume 2°C of warming in 2050.

If tipping points occur, the climate damage factors will increase. Tipping points can cause sudden, irreversible and dangerous changes in the climate (Armstrong McKay et al., 2022). An example is the melting of ice caps, which reduces the reflection of sunlight, causes the climate to warm further and causes ice caps to melt even faster. Armstrong McKay et al. (2022) show that even if the Paris climate goals are achieved, various tipping points may still occur. The occurrence of tipping points is not included in Swiss RE (2021) and in the analysis of the previous sections. If tipping points occur, the damage is likely to be far greater.

The occurrence of tipping points will lead to higher costs. If tipping points occur, global warming may accelerate and/or the effects of warming may be amplified. In IPCC (2022a), the figures on page 2497 show the dispersion of GDP losses at different levels of warming. At more than 3°C of warming, there are estimates that the global loss in GDP could amount to 30%. In the case of tipping points that multiply the damage estimates in the previous sections, the negative impact on generations will be multiplied by the same factor.

3 Climate policy: Mitigation

Estimates of the costs of Dutch mitigation policies vary widely; the extent to which the Dutch government will bear the costs depends on the policy implementation. Dutch mitigation policy reduces the Netherlands' contribution to global warming.[21] However, the extent to which the earth warms will depend on global mitigation policies. Here we use the concept of national costs, the balance of the costs and benefits of climate policy for the Netherlands as a whole. This is the sum of the net costs for the government, private individuals and businesses.[22]

The cost of future mitigation policies to meet the goals set by the government is uncertain. The Interministerial Policy Review entitled 'Scherpe doelen, scherpe keuzes' (Strict goals, stark choices) maps out how, on top of the existing policy, the reduction target (60% reduction compared to 1990) can be achieved in 2030 with additional regulation and pricing policy (Government of the Netherlands, 2023). Up to 2030 the national costs rise to EUR 7.2 billion per year on top of the policy already implemented (see Table 2 in CE Delft and Berenschot, 2023).

Uncertainty about the magnitude of the costs will increase further towards 2050, when the Netherlands has set itself the goal of no longer emitting net CO_2. If the target in the Interministerial Policy Review is adopted, a remaining reduction of 90 Mton will have to be made by 2050. The Integrated Energy System Review 2030-2050 estimates the national costs of the energy system under four future scenarios (Netbeheer Nederland, 2023). The additional national costs in 2050 range from EUR 18.5 billion to EUR 31.1 billion (also see the box for an overview of government costs of the current policy). This estimate does not include the costs of achieving net zero emissions in agriculture, meeting demand for renewable carbon and storing carbon.

[21] In addition to the reduction in carbon emissions and hence a reduction in the contribution to climate warming, there are other positive externalities, such as a reduction in particulate emissions.
[22] For a more detailed interpretation of differences between government costs and national costs, see Hof, Van der Wal and Mot (2020).

Government costs of climate policy

Government costs of climate policy differ from national costs. [a] The national costs are the costs for the Netherlands, without any distinction as to who bears them: households, businesses or the government. Government costs are the balance of government revenue (taxes) and expenditure (subsidies or investments). It is therefore possible that the national costs of climate policy will be high, but that government costs will be limited if the policy is conducted only by means of pricing and regulation (orders and prohibitions).

There is no comprehensive overview of the government costs of climate policy (mitigation and adaptation policy). The lack of a comprehensive overview at government level was the main conclusion of an investigation by the Netherlands Court of Audit.[b] It is due to the fact that government-wide overviews differ from each other and from ministerial budgets because climate expenditure is not clearly recorded and defined. In addition to the lack of a comprehensive overview at central government level, there is no overview of the climate policy conducted by sub-national government authorities. We also focus on the central government level in our estimates below, because we have no information on the climate policies of sub-national government authorities. We have produced the following estimate of what does and does not belong to climate expenditure and revenue ourselves, so it only provides an estimate and not a full overview.

The extent of the government costs of mitigation policy is determined by the implementation of climate policy: subsidies, pricing or regulation. All three have the aim of reducing greenhouse gases. In the case of subsidies, a transfer takes place from the government to households and businesses. This consequently results in additional public expenditure. In the case of pricing, for example energy tax on gas consumption, the government actually receives revenue paid by citizens and businesses. Regulation involves a prohibition or order, an example being the obligation to switch to a more sustainable alternative when replacing central heating systems from 2026. [c]

Up until now, subsidies have predominated in climate policy (Government of the Netherlands, 2023). In 2021, the Dutch government spent EUR 4.1 billion on policies aimed at reducing greenhouse gas emissions. The bulk of this (70%) was used for energy supply subsidies. The built environment is the next largest expenditure item at 9%. In addition to climate mitigation policies, adaptation expenditure also takes place at central government level; in 2021 this amounted to more than EUR 1.1 billion, the bulk of which was intended for the Delta Fund.

In 2021, government revenues as a result of climate policies amounted to EUR 2.7 billion. This consists of EUR 2.5 billion from policy up to and including the conclusion of the Climate Agreement (CPB, 2019) and EUR 0.2 billion in respect of measures since then.

The most recent climate package once again opts mainly for the subsidy instrument. A package of measures has been presented to achieve the 22 Mton reduction target.[d] This matches the target stated in Government of the Netherlands (2023). The choice was mainly to use the subsidy instrument, whereas Government of the Netherlands (2023) focused on regulation and pricing. Approximately EUR 25 billion has been drawn from the Climate Fund to finance the measures.

(a) For a more detailed explanation of differences between government costs and national costs, see Hof, Van der Wal and Mot (2020).
(b) See https://www.rekenkamer.nl/binaries/rekenkamer/documenten/kamerstukken/2023/01/25/inzicht-in-uitgaven-klimaatbeleid/WR+Brief+Uitgaven+klimaatbeleid+DEF+met+logo.pdf.
(c) See https://www.rijksoverheid.nl/actueel/nieuws/2022/05/17/hybride-warmtepomp-de-nieuwe-standaard-vanaf-2026.
(d) See Draft Multi-Year Climate Fund Programme 2024 | Parliamentary document | Rijksoverheid.nl.

National costs for the additional policy compared to the current policy will increase significantly towards 2050: between EUR 21 billion and EUR 36 billion per year. Table 3 provides an estimate of the additional national costs per year in 2030 and 2050 of EUR 7.2 billion and a range of EUR 18.4 billion to EUR 32.7 billion respectively. This concerns the additional policy compared to the Climate and Energy Outlook 2022 (Hammingh, Van Soest, Menkveld, Daniels and Koutstaal, 2022).

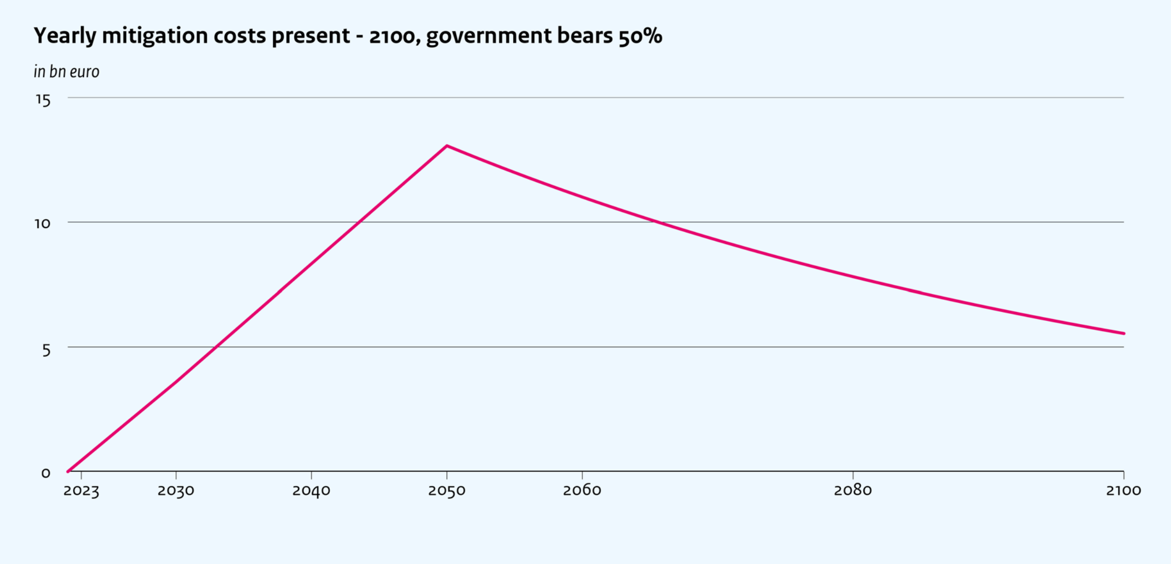
Table 3: Costs of mitigation policy: national costs (additional costs compared to current policy) per year

	Low	High	Year	Reduction path
	in billion euros per year, price and volume level 2022			
Government of the Netherlands (2023)	7.2	7.2	2030	60% reduction in 2030 compared to 1990
Netbeheer Nederland (2023)[23]	18.4	32.7	2050	100% reduction in 2050 compared to 1990

We make a number of technical assumptions to determine the government costs of the mitigation policy. First, we again assume that the government will bear half of the costs. The actual distribution will depend on policy implementation. If the majority of the measures are financed with subsidies, the bill may increase further. If regulation and pricing prevail, a smaller share will be borne by the government. Second, we assume that the mitigation costs in 2050 will be the median of the cost estimates of the four future scenarios in Netbeheer Nederland (2023). Third, we assume that the additional policy will be introduced in 2023 on a phased basis and that the costs will therefore increase on a straight line basis to EUR 3.6 billion in 2030 (with the government bearing half of the costs). This linear increase will continue to over EUR 13 billion per year in 2050.[24] After 2050, we assume that the Netherlands will no longer emit any net CO_2 and that the costs will decrease by 1.7% per year (Barrage and Nordhaus, 2023). This results in an estimate of the costs in the 21st century as shown in Figure 6.

[23] This only concerns the national costs of the energy system and is therefore an underestimate of the total national costs (Netbeheer Nederland, 2023). The costs in the Energy Transition Model are updated as soon as new insights give cause to do so. Our figures may therefore differ slightly from the most recent figures on the Energy Transition Model website.
[24] The assumption of linear cost growth is the result of two conflicting forces. In line with Barrage and Nordhaus (2023), we assume that costs will decrease by 1.7% annually as a result of technological developments. For example, a heat pump is currently more expensive than a central heating boiler, but the additional costs will decrease as the heat pump is further developed. This gives rise to a levelling-off pattern in the costs. At the same time, the cost function becomes steeper over time, because saving additional CO_2 becomes increasingly difficult as much has already been saved. This results in a linear cost structure.

Figure 6: Annual national costs will rise until 2050 and then gradually fall[25]

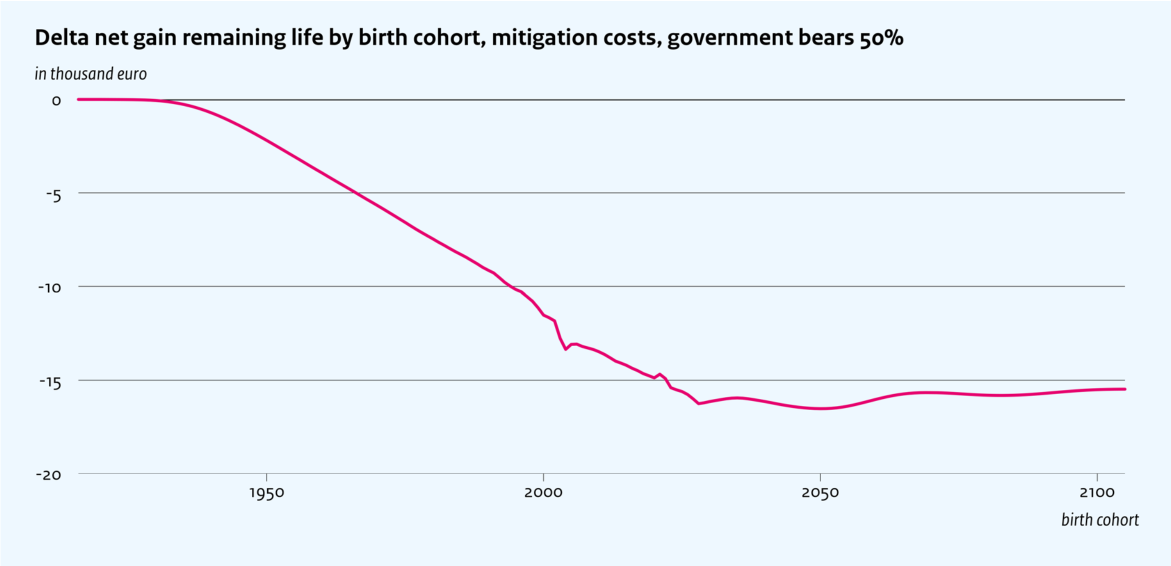


Future generations will, in financial terms, experience a greater negative effect of mitigation policy than current generations. In the analysis we assume that the annual additional national government costs for mitigation policy are fixed according to the estimate in the previous section. We therefore assume that we already know what the total mitigation costs will be. We will then implement a generic spending cut in 2028, so the national debt remains constant in the future. These costs of additional mitigation policy are taken into account. [26] In this way, no financial burdens are passed on through the national debt. This spending cut means that all cohorts born from 1921 onwards will experience a negative impact on their net gains (see Figure 7). This decline will increase up to and including the 2028 birth cohort, because these cohorts will experience the spending cut for an ever greater part of their lives. This financing choice therefore does shift a larger part of the financial burdens to future generations. After the 2028 birth cohort, the impact remains roughly the same and is negative at around -EUR 15,000 per person. For reference, that is equivalent to 1.5% of the lifetime wage income.

[25] In our approach we seek to determine the costs for the government of additional mitigation policy. However, resources for additional mitigation policy have already been set aside in the Climate Fund. Furthermore, in our baseline we extrapolate these expenditures after 2030. Hence resources have already been set aside for part of the additional government costs, both explicitly (funds) and implicitly (extrapolation).

[26] In sections 2.1 and 2.2 we assumed that we would only implement a spending cut in the year after the damage occurred, in either 2051 or 2101. Now this spending cut for all additional costs in the future will occur at once in 2028.

Figure 7: Future birth cohorts will pay a larger share of the costs of mitigation policies than current generations



4 Climate policy: Adaptation

Local and regional adaptation measures are needed to deal with climate change. Global warming leads to various negative physical consequences (see section 1.1). The impact of climate change can be limited with the aid of adaptation measures, such as strengthening flood defences, draining excess water, adapting to drought, heat and waterlogging. These measures affect the living environment: for example, people will more often spend time in air-conditioned rooms and less often in heated rooms.

There are various programmes aimed at making adjustments in the Netherlands in the context of climate change. Following the 1953 flood disaster, a Delta Committee was established as a prelude to the Delta Works. Flood safety, availability of freshwater and spatial adaptation now make up the three pillars of the Delta Programme. In addition to the Delta Programme, the Implementation Programme of the National Climate Adaptation Strategy is also an important pillar of the climate adaptation policy. The institutional embedding of protection measures and available financial resources means that the Netherlands is well placed to adapt to limited climate change (Chen et al. 2023).

The additional costs for flood safety and water supplies on top of already budgeted amounts as a result of climate change will be limited in the coming decades, but thereafter they are uncertain and could become substantial. For example, there are regular programmes at various levels of government for the first two pillars of the Delta Programme, sufficient freshwater supplies and protection from flooding. Central government resources are available in the Delta Fund to finance the measures in the Delta Programme.[27] Sub-national government authorities, water boards and drinking water companies also contribute to the implementation of the Delta Programme.[28] The additional costs of adaptation measures, on top of the

[27] Not all funds in the Delta Fund are intended for the Delta Programme and other actors also contribute to the programme without requiring money from the Delta Fund (Delta Programme, 2023).
[28] See, for example, an overview of the annual costs for water management in 'De Staat van Ons Water' (The State of Our Water), a report on the implementation of water policy in 2022 (Ministry of Infrastructure and Water Management, the Union of Dutch Regional

budgets already reserved for water protection and water supply, are likely to be limited in the coming decades. If climate change continues, with a consequent rise in sea levels, adaptation costs could increase enormously because it is unclear whether existing adaptation techniques will remain effective.

Leusink (2018) estimates annual additional adaptation costs for the built-up area of EUR 1.9 billion per year up to and including 2050 for waterlogging due to heavy precipitation, heat and drought. This provides an estimate of the costs of the third pillar of the Delta Programme. These are additional costs compared to the current climate. They take account of the scope for savings through coordination with regular reconstruction and maintenance work. The estimate assumes 2°C of warming in 2050 and a major change in the air flow pattern (scenario W_h).[29] Adaptation costs for rural areas have not been included in this analysis.

To estimate the adaptation costs for the government in the 21st century, we make a number of technical assumptions. We estimate the total annual adaptation cost at EUR 2.7 billion (see Table 4). To estimate the adaptation costs for waterlogging, heat and drought, we use the estimate by Leusink (2018). For flood protection and freshwater supplies, we assume that adaptation costs increase by 10% compared to the total annual costs identified in Ministry of Infrastructure and Water Management et al. (2023).[30,31] In addition, we assume that the government will bear half of these additional costs, i.e. EUR 1.4 billion per year. Finally, we assume these additional costs will be incurred from 2023.

Table 4: Estimated adaptation costs per year

Source	Costs	Channels	Period
	in billion euros per year, price and volume level 2022		
Leusink (2018)	1.8	waterlogging	2018-2050
	0.1	heat	2018-2050
	0.1	drought	2018-2050
Ministry of I&W et al. 2022	0.8	flood safety, freshwater supplies, drought, waterlogging	2022
Total	2.7		

Future generations will experience a greater negative effect, in financial terms, of adaptation policy than current generations (see Figure 8). Although the effect of adaptation costs on the net gains is smaller than in the case of mitigation costs (see section 3), the pattern is similar. We again assume that the actual adaptation costs correspond to the estimated costs and also assume in the model calculation that a spending cut will be implemented in 2028, so the additional costs do not lead to an increasing national debt. It is important to enter a caveat here, since it is extremely uncertain to what extent the identified adaptation costs are complete. Adaptation costs could also rise substantially in the next century if sea levels rise significantly. Based on our cost estimate and assuming a spending cut in 2028 to cover these costs, this will lead to a decrease in the gains

Water Authorities, the Union of Water Boards, the Association of Water Companies in the Netherlands, the Association of Provinces and the Association of Dutch Municipalities, 2023). These costs are borne by central government, provinces, municipalities, water boards and drinking water companies. They are offset by revenue from the collection of water taxes, payments to drinking water companies and generic taxes.

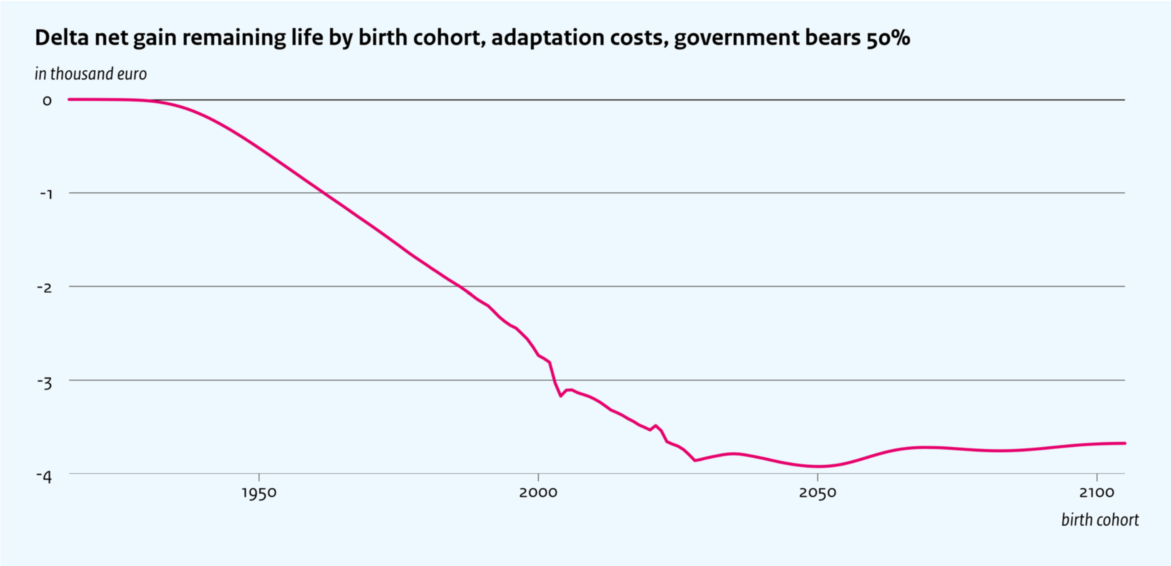
[29] See KNMI - KNMI'14 climate scenarios - key figures for further information on the KNMI '14 climate scenarios.

[30] We do not include costs from the Delta Programme separately, because they probably overlap to a large extent with the central government costs included in 'The State of our Water'.

[31] Part of the costs in 'The State of our Water' (Ministry of Infrastructure and Water Management et al. 2023) relate to waterlogging and drought, for which costs for the built-up area are also included in Leusink (2018). Hence there may be some overlap.

from the 1921 birth cohort onwards. This decline will increase up to 2028 inclusive and will lead to a decrease in net gains of more than EUR 3,500 per person.

Figure 8: Future birth cohorts will pay a larger share of the costs of adaptation policy than current generations



5 Conclusion and discussion

Future generations are likely to pay a larger share of the additional bill for climate change and the associated policies than current generations. The negative impact of climate change will increase further in the Netherlands in the future and the largest and most difficult part of the transition has yet to take place. Moreover, if further warming occurs, additional adaptation measures will be necessary on top of the current measures.

There are major uncertainties surrounding the financial consequences of climate change and the associated policies when it comes to public finances and intergenerational distribution. Key causes of this uncertainty are that it is unclear to what extent the climate will warm, what the consequences will be at different levels of warming, how the transition will take place and to what extent adaptation policy will be able to cope with the consequences of climate change. Moreover, we by no means take into account all the consequences of climate change and associated policies. These include the impact on the economic structure, the negative impact on biodiversity and quality of life, and the size of migration flows.

Particularly for the physical consequences of climate change and adaptation policy, the cost estimate is imprecise and incomplete. Heat, drought, waterlogging and floods are the main negative physical consequences of climate change for the Netherlands. For the first three topics in particular, only an incomplete inventory of costs has been available to date. In addition, only a partial estimate has been made of the adaptation measures to be taken, particularly in the second half of the 21st century. It is important to obtain a more complete picture of the costs in order to make an adequate estimate of the consequences for public finances and intergenerational distribution.

On the basis of current insights, it is the additional costs of mitigation policy that will be highest for the Netherlands in the coming century; damage and adaptation costs will probably increase further from the next century onwards. Although there is also uncertainty surrounding the transition path for the costs of the energy transition, an estimate of the costs has been made for different trajectories for the Netherlands. The costs of the transition will increase in the coming decades, after which they will start falling. These costs are expected to be greater than the costs of the other two channels for this century. A fuller understanding of the physical consequences and the required adaptation policy may change the relationship. Nevertheless, the difference in costs is so great that the physical consequences and adaptation costs will probably remain relatively limited over this century. However, if the climate warms faster than expected, the costs of physical consequences and the costs of adaptation policy could increase enormously. For example, the costs of physical damage in a negative scenario, for example if tipping points occur, will be several times higher than the costs of mitigation policy. In addition, existing protective measures may be ineffective and we will not be able to avoid taking costly measures in the future. In the 22nd century, it is expected that the costs of mitigation policy will decrease further, whereas damage and adaptation costs will increase.

The costs of the various channels are related to each other and to international efforts. If the Netherlands makes the transition to net zero CO_2 emissions, but international efforts lag behind, the climate will warm faster than if an effective transition policy is also pursued internationally. As a result, the damage and/or adaptation costs will increase further. The number and speed of adaptation policies needed to prevent damage will increase the faster the warming occurs. If international efforts lag behind, greater demands may be placed on the Netherlands. The goal could then be tightened from net zero emissions to negative emissions or there could be higher direct financial transfers to countries abroad. This could lead to additional mitigation costs.

The technical assumptions we have made about when and how the costs of climate change and associated policies are borne impact the intergenerational effects. We have assumed that a spending cut will be made to meet the costs, so national debt will not increase in the long term. We have also assumed that the government will bear half of the costs. This assumption means that the costs are distributed between current and future generations through additional national debt and, as a result, an additional spending cut. The other half, however, will also be borne by households and businesses. If a disaster occurs, for example, the uninsured damage will be borne by households and businesses that experience the damage. The actual costs for the government depend on policy choices. If the choice is to implement policies with subsidies, the costs borne by the government will double compared to the situation we have considered. Choosing pricing and regulation, on the other hand, will limit the costs for the government.

Financing the costs of climate change and associated policies with government debt could further increase the burdens on future generations. The costs of all three channels fall mainly on future generations. They also experience the negative consequences of climate change that are not or cannot be expressed in monetary units. This does not imply that no climate policy should be pursued, but that its financing must allow a fair distribution of benefits and burdens among the different generations.

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