TRANSITION PATHWAYS TO SUSTAINABLE LOW-CARBON SOCIETIES

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# Low-carbon pathways: challenges & opportunities

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## Summary

Limiting global climate change to less than 2 °C poses serious challenges: it requires a more or less completely decarbonized power sector by 2050 and sustained decarbonisation rates of 2-3 times the level historically observed. Clearly, achieving this will require fundamental societal transitions and coordinated policy action. The PATHWAYS project combines the strengths of quantitative systems modelling, transition studies, and participative action research to better understand how such a transition pathway could be governed. Based on several country case studies, we develop alternative storylines for transition pathways. Such a pathway could mainly involve technological changes or, next to these changes, more comprehensive changes in societal structures as well. The mix of mitigation options implemented in these pathways may differ significantly. This implies that transitions may work out very differently in different countries depending on governance structures. For the short term it is important to broaden participation, create a wide sectoral coverage, and aim for synergies with other policies.

## Context

To prevent dangerous interference in the climate system, countries, worldwide, have agreed that international efforts should be aimed at keeping the global mean temperature increase below 2 °C compared to pre-industrial levels. It should still be evaluated whether, alternatively, a 1.5 °C target should be set. The EU has set an ambitious long-term policy target for 2050, consisting of a reduction in greenhouse gas emissions of 80% relative to 1990. At the climate conference in Paris, December 2015, countries are expected to agree on a legal post-2020 international climate policy framework. Clearly, achieving the above-mentioned international climate targets goals will require fundamental societal transitions and coordinated policy action. The climate conference in Paris is a crucial step to achieve this. This policy brief describes the challenges and opportunities for achieving long-term climate targets.

## Understanding transitions

In order to understand the challenges that lie ahead and opportunities for action, the PATHWAYS research project aims to advance the understanding of socio-technical transition

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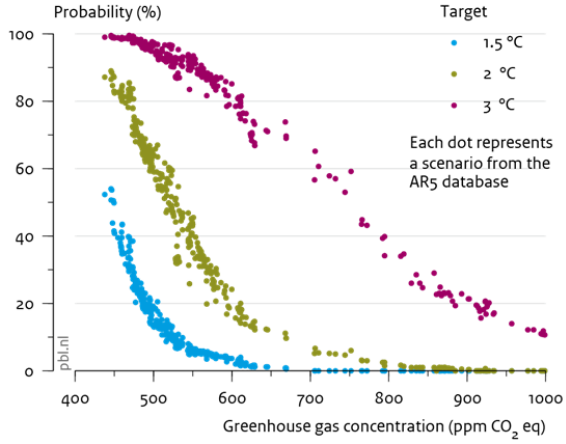
pathways, which lead to the emergence of new technologies, institutions, behaviour and values. The project combines the strengths of quantitative systems modelling, transition studies and participative action research approaches. This policy brief describes the challenges to achieve long-term climate targets based on lessons learned from quantitative systems modelling, and describes which kind of low-carbon pathways could be envisioned based on results from transition studies and participative action research.

## Required concentration levels

The exact relationship between greenhouse gas concentrations (the main cause of climate change) and a change in global mean temperature is subject to considerable uncertainty. As a result, it is not possible to directly indicate which greenhouse gas concentration level would be consistent with achieving the 2 °C target. Instead, only probabilities that a certain concentration level would stay below a certain temperature target can be given. Figure 1 shows that achieving the 2 °C target with a likely chance requires keeping greenhouse gas concentrations at a level of around 450 ppm $CO_2$eq (Figure 1). Lower concentration levels not only increase the probability of achieving the 2 °C target, but also decrease the chance of more extreme climate change. For instance, a concentration level of 450 ppm $CO_2$eq has a more than 95% probability of keeping global temperature change below 3 °C. For a concentration level of 600 ppm $CO_2$eq, the probability of keeping temperature change below 2 °C is about 20%, but there is also a 20% probability of overshooting 3 °C, which would lead to more severe climate impacts.




Source: MAGICC6 calculations using IPCC AR5 WG III database 2014

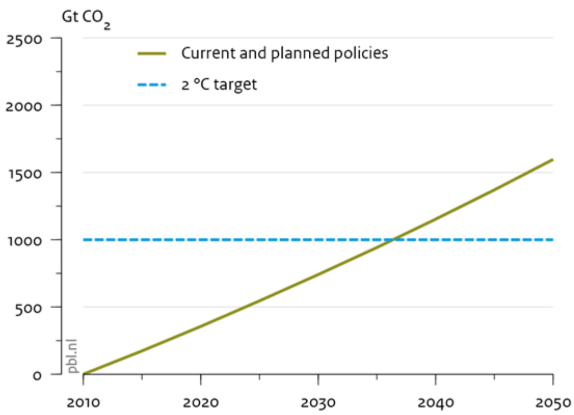
**Figure 1** *Probability of achieving temperature targets as a function of greenhouse gas concentration levels*

## The carbon emission budget

The long atmospheric lifetime of $CO_2$ implies that concentration levels can directly be related to cumulative $CO_2$ emissions. As a result, there is also a relationship between temperature increases and cumulative emissions. A so-called 'carbon budget' required for achieving the 2 °C target with a likely chance can be derived from this relationship. Here as well, there is a wide range of uncertainty especially due to uncertainty in the climate system and, to a lesser degree, future non-$CO_2$ emissions. Taken these uncertainties into account leads to a carbon budget in the range of 630-1180 (IPCC 2014). Stated more simply, total cumulative $CO_2$ emissions must remain below around 1000 $GtCO_2$. The strength of the carbon budget concept is that it emphasises the cumulative nature of the climate problem: it emphasises that delays in policy formulation will cause the need for more stringent action in the long term to compensate for the additional emissions over the period of delay.

## Current policy pathway

Many countries have formulated climate and energy policies, such as carbon taxes, feed-in tariffs, and emission standards. In some cases, these policies lead to emission reductions which are even more ambitious than the pledges they made under the UNFCCC for 2020. The effectiveness of policies not only depends on the projected policy impact, but also on the degree to which supporting communication, voluntary, regulatory and economic policy instruments are in place. The expected global greenhouse gas emission level taking into account the climate policies in all major emitting countries is about 53 $GtCO_2eq$ in 2020 (Roelfsema et al. 2014). For comparison, the total emission level was about 48 $GtCO_2eq$ in 2010. If this emission trend continues after 2020, the carbon budget would completely be used before 2040 (Figure 2).




Source: Van Vuuren et al., 2014

**Figure 2** *Cumulative $CO_2$ emissions as a result of current and planned policies*

## Breaking the trend

Given the currently increasing trend in greenhouse gas emissions, the crucial question is how can we reduce emission to such a degree to stay within the carbon budget? The possibility of negative emissions plays a crucial role here. Negative emission can result from reforestation and using biomass to generate electricity and capture and store the resulting $CO_2$ emissions. Negative emissions in the second half of the century could possibly compensate some overshoot of the carbon budget. Model analysis has shown that given the expected 2020 emission levels, it is still technically possible to stay within the carbon budget – but very rapid emission reductions are needed. The decarbonisation rates consistent with these reductions are 2-3 times higher than observed over the last decades (and only achieved for brief periods in individual countries), which requires a radically transformed energy system (van Vuuren et al. 2014). Further delaying action will require extremely rapid annual reduction rates of 4% or more, associated with higher costs and lower probabilities to stay within the carbon budget. Moreover, the dependence on negative emissions becomes much higher.

## Transition storylines

Over the past years, there have been many model comparison exercises to inform how low-carbon pathways could look like (van Vuuren et al. 2006; Clarke et al. 2014; Kriegler et al. 2014). These exercises strongly focused on the role of mitigation technologies and delayed action in achieving climate targets. In PATHWAYS, a more elaborate approach is taken. Instead of focussing on cost-optimal pathways under key assumptions, we are developing alternative consistent low-carbon storylines, based on results from quantitative systems modelling, transition studies, and participative action research. Next to technology, these pathways take into account economic, political and social dynamics and special attention is given to the the role of actors. In one alternative pathway, we assume that sustainability objectives are achieved without fully reordering of the existing societal structures (*technical component substitution*). A key assumption in this scenario is that key structures remain unchanged (e.g. user practices, lifestyles, governance arrangements), and the significant technology changes are thus implemented by so-called incumbent actors. In the other alternative pathway, coined *broader regime transformation*, not only technical changes occur, but also wider behavioural and cultural changes, new user practices and institutions. Incumbent industry actors are assumed to be overthrown by new entrants (possibly entering into new alliances). There is also a greater role for social move-ments, civil society actors, and multi-level governance (with new relations between cities and local administrations, national governments and transnational policy-makers).

## The role of technology

The mix of mitigation options implemented in these scenarios may differ significantly. For instance, large scale-scale technologies (like nuclear, or carbon-capture-and-storage) might better fit the first scenario, while lifestyle change does better fit the second. In some cases, In the same technologies could play important roles in both storylines, although for different reasons. Onshore wind power, for instance, is largely owned by large utilities (incumbents) in the UK while in Denmark and Germany farmers (new entrants) have a large ownership (Geels et al. 2015; Rogge 2015). This means that even though the technological landscape looks similar, different actors play a key role, which implies a different role for policy. For other technologies, such as offshore wind, country case studies in Germany and the UK suggest that incumbents are the most important actor, resembling a *technical component substitution* pathway.

## Conclusions for power generation

Studies show that power generation plays a key role in low-carbon scenarios. Compared to other sectors, more alternatives seem to be available. As a result, mitigation scenarios might in fact include a further electrification of other sectors (e.g. the transport sector using hybrid and full electric cars). We therefore focus first on this sector. Model analysis shows that in order to achieve the long-term EU target of an 80% reduction in greenhouse gas emissions by 2050, the power sector needs to be more or less completely decarbonized by 2050. First PATHWAYS results suggest that in a *technical component substitution* pathway, CCS, wind power, and nuclear could play an important role in reducing emissions. In a *broader regime transformation* pathway, (onshore) wind, other renewables, and behavioural changes could become important. Large negative emissions are less likely in a *broader regime transformation* pathway, which implies that in such a pathway, it is difficult to compensate further delay of reducing emissions later in the century. The two pathways show that there are multiple pathways towards a near zero emission level in 2050 in Europe. The choice of technologies does not only depend on economic or technology consideration, but also significantly on the governance structure. This also implies that is likely that the transitions may work out very differently in different countries depending on governance structures.

## Policy implications

In the short term, credible climate policies are needed to encourage investments in innovation and transition towards a low-carbon economy. Although emission pathways and emission budgets provide insight into the relationship between climate consequences and emission reductions, they should not de-emphasise the importance of stimulating investments in a long-term transition. Emission reductions are clearly not only bound by economic and technical factors but also by governments' ability to agree on climate policy on national and international levels. More reductions in the short run (with additional costs) allow for more flexible technological choices portfolios in the long run. A slower transition implies less rapid reductions in the short term, but would be more expensive over the whole century, and also implies that meeting the the 2 °C target depends on negative emissions in the second half of the century. Although it may be impossible to create the exact conditions assumed in optimal scenarios, policymakers nevertheless may wish to try and come close to such conditions. This would include broadening participation, creating a wide sectoral coverage, and aiming for synergies with other policies. The costs of meeting the 2 °C target with a likely chance would be lowest if the global emission level were to peak within the next 10 years. Given the difficulty of reaching an overall international agreement so-far, it will be important to focus on domestic interests in climate policy and seek progress through pragmatic approaches that aim to achieve multiple targets such as those of energy security, economic opportunities and risks, air pollution and ecosystem degradation. Often, synergetic policies can be defined that achieve short-term objectives while also reducing greenhouse gas emissions. To identify such policies, it is important to concentrate on sectors and policies with the clearest room for progress, such as the power sector, smart infrastructure investments, the abolition of fossil-fuel subsidies, tax-reform, and improving energy efficiency. In the short term, in high-income countries, there could be an additional key role for innovation in low-carbon technologies, partly because stimulating innovation probably would meet with less public resistance than other measures. On the demand side, policies could be considered that address energy-intensive consumption patterns.

## Literature

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## About the PATHWAYS project

The EU FP7 project PATHWAYS is a unique project that explores the possibilities for transitions to a low-carbon, sustainable Europe. The essence of PATHWAYS is that it combines the analysis of different scientific approaches: integrated assessment modelling, transition science research, and participative action research. By combining and coordinating information from these different approaches for selected cases, PATHWAYS aims at providing better policy advice for European, Member State and local policy-maker.

## Partner Institutes

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