Carbon removal for climate policy

Analysis of the need, supply and policy for negative emissions in the Netherlands

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Summary

Negative emissions or carbon removal — processes that remove greenhouse gases from the atmosphere on a long-term or lasting basis — are increasingly seen as a component in the climate policy toolbox. All IPCC scenarios, for example, require negative emissions to achieve climate neutrality by 2050. This study, commissioned by the Ministry of Economic Affairs and Climate, maps the technical and policy aspects related to this topic. It provides a current picture of future needs, supply and likely timelines for negative emissions, it addresses the role of CCS, and provides insights into policy needs and options.

In this report, we used the following definition of negative emissions: *measures aimed at removing CO_2 from the atmosphere on a long-term or lasting basis*. We leave room here for non-lasting storage, as clear consensus on this does not exist yet in the European policy context, but a distinction is made between these two categories in the analysis.

Need for negative emissions

The need for negative emissions stems from two objectives. Firstly, the goal that both the Netherlands and the EU should be climate neutral by 2050. Since residual emissions will remain in some sectors in 2050 and beyond, an at least equal amount of negative emissions will then be needed to arrive at a net zero balance.
Secondly, negative emissions should offset global overshoot[1]. The world is headed towards overshoot of the carbon budget still available to limit global warming to 1.5°C, as agreed in the Paris Agreement, and the EU climate law also stipulates net carbon removal from the atmosphere from 2050.

The residual emissions after 2050 were mapped on the basis of existing scenarios for a (nearly) climate-neutral economy by 2050. All scenarios still take residual emissions into account. This means that the Netherlands will need negative emissions between 8.8 and 38.3 Mt of CO_2 per year by 2050. These residual emissions are mainly in agriculture, industry and transport. In agriculture, (non-fossil) emissions from livestock and arable farming are very difficult to avoid, which is why agriculture accounts for a large share of residual emissions in all scenarios. Scenarios in the Netherlands where industry is less sustainable end up with higher residual emissions (up to 38.3 Mt/year), while scenarios that assume a full transition, including from industry, result in around 9-10 Mt/year residual emissions. Residual emissions in EU scenarios range from 541 to 602 Mt in 2050.

We used the IPCC scenarios, and two different assumptions for allocating the global overshoot to the Netherlands to estimate how many negative emissions are needed to offset the overshoot of the global carbon budget for a maximum warming of 1.5°C. This gives a range of required negative emissions of 1.6 - 33 Mt/year, from 2050 onwards.

[1] It is worth noting that above 1.5°C warming, some irreversible processes may also occur. Removal of CO_2 from the atmosphere at a later date will not succeed in reversing those effects in full or in part.

Table 1 - Residual emissions, offsetting global overshoot and total need for negative emissions in the Netherlands in 2050

Category	Emissions (Mt CO_2 eq./year)
Residual emissions after deduction of fossil CCS	8.8 - 38.3
Compensation for global overshoot	1.6 - 33
Total need for negative emissions	**10.4 - 71.3**

Potential supply of negative emissions

The estimated potential and *technology readiness level* (TRL) of different routes for negative emissions are provided in the following table.

Table 2 - Potential, cost and TRL for the different routes

No.	Technology	Netherlands potential (Mt/year)				TRL
		Technical	Realistic by 2030	Realistic by 2050	Cumulative between 2030-2050	
I	Afforestation	3.6	0.35	0.7	10.5	N/A
IIA	Bioenergy with CCS-BECCS (various routes)	12-19	>3.9*	>16.2*	>201*	8
IIB	Biochemistry with CCS-BECCS (different routes)		3.0	10.8	138	5-9
IV	Carbon storage in soil	2.3	0.6	0.9	15	8-9
V	Biochar	5.5	0	0.05	0.5	3-6
VI	Mineralisation	14	0.7	5.4	61	4-9
VII	Marine NETP	N/A	N/A	N/A	0	4-6
VIII	DACCS	17	0	>0**	>0**	4-8
IX	Timber construction	3.9	0.4	3.9	43	8-9
X	Biomaterials (chemistry)		0.4	0	4	4-9
Total			**9.4**	**39**	**473**	
Of which CCS			**6.9**	**27**	**339**	

* This does not include the realistic potential of BECCS from biomass power plants, which, although large, is highly policy-dependent.

** The potential of DACCS is very uncertain.

Not all methods result in lasting carbon removal. Carbon sequestration in soil, forestry, timber construction and biomaterials can be long-lasting, but the time period of storage can vary.

Many of these methods employ renewable biomass. The limited availability of sustainable biomass is therefore a potential barrier in many of these routes, moreover, it means that these potentials do not necessarily add up. Competition is expected on available biomass and renewable CO_2 - not only between negative emission methods, but also with other applications and value chains in the economy, such as bioplastics and transport fuels. A similar situation applies to the Netherlands' potential of CO_2 from direct air capture (DAC). The future availability of this CO_2 is still very uncertain, and even then the question remains to what extent it will become available for carbon storage (DACCS). The CO_2 can also be used for other applications (such as synfuels).

Subsurface storage of CO_2

The Netherlands has significant underground capacity for CO_2 storage (currently: empty gas fields under the North Sea), sufficient for several decades of storing CO_2 from its own emission sources. Developing a CO_2 storage site, right from an initial storage capacity analysis to commencement of construction of injection facilities, takes many years: from 5-7 years for empty oil or gas fields to at least 9 for saline aquifers.

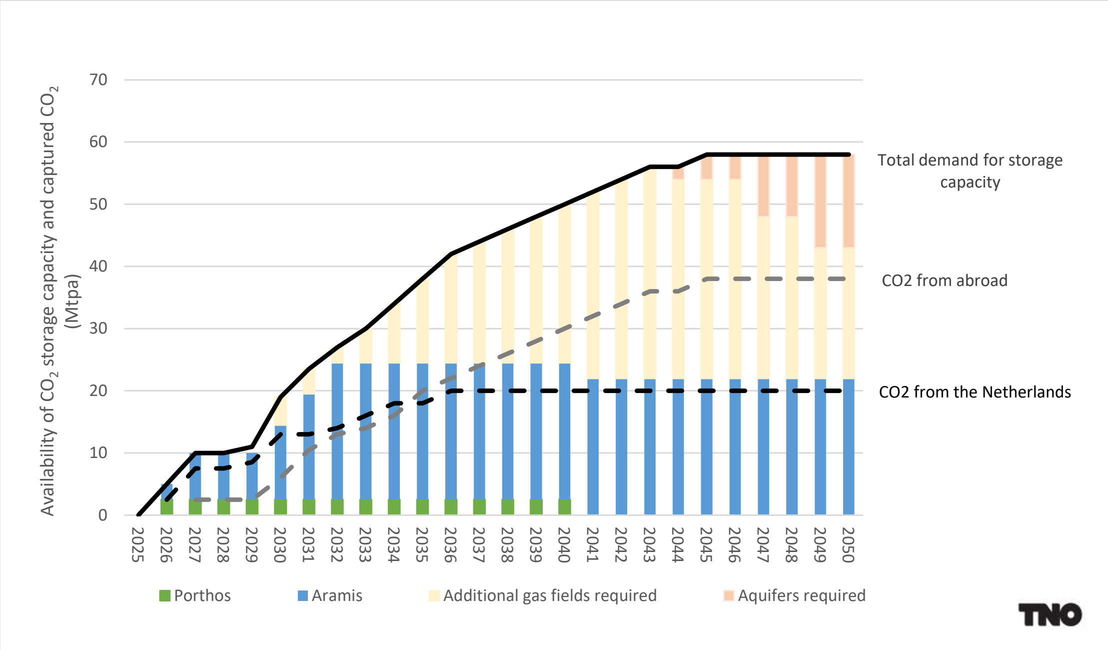
The demand for storage capacity currently under consideration stems from both Dutch fossil emission sources and CO_2 imports from Germany and Belgium. A CCS demand for negative emissions will be added in the future. The analysis of this study focused on underground storage in the Netherlands, but there are also storage sites in other countries (e.g. Norway, the UK) where “Dutch” CO_2 could be stored in the future. More detailed research on the future supply and demand for foreign storage, and consequently on the potential availability of storage capacity for Dutch negative emissions, fell beyond the scope of this study.

Table 3 - Summary of estimated demand for CO_2 storage capacity from fossil CO_2 emission sources. Supplies from Belgium and Germany are included due to limitations in storage capacity in those countries

Year	Estimated capture volumes of fossil CO_2 at Dutch emission sources	Expected CO_2 imports from Germany (excluding what is stored elsewhere)	Expected CO_2 imports from Belgium (excluding what is stored elsewhere)	Estimated storage outside the Netherlands from emission sources in Belgium and Germany	Total demand for storage capacity in the Netherlands
2030	13 Mt/year	0	7 Mt/year	0	20 Mt/year
2050	20 Mt/year	28 Mt/year	9.5 Mt/year	Approximately 25 Mt/year	57.5 Mt/year

The fully-developed storage capacity could look as follows:

Figure 1 - Representation of storage capacity under development and expected supply of captured CO_2, up to 2050



It is expected that there will be sufficient capacity in offshore gas fields to store CO_2 until 2050. This would nevertheless necessitate a continuous supply of new storage sites to accommodate the expected growth in the supply of CO_2, from both emission reductions and negative emissions. Ultimately, CO_2 storage is an international activity. International infrastructure will therefore need to be built and regulations should be developed in time to facilitate this.

Potential evolution of negative emissions over time

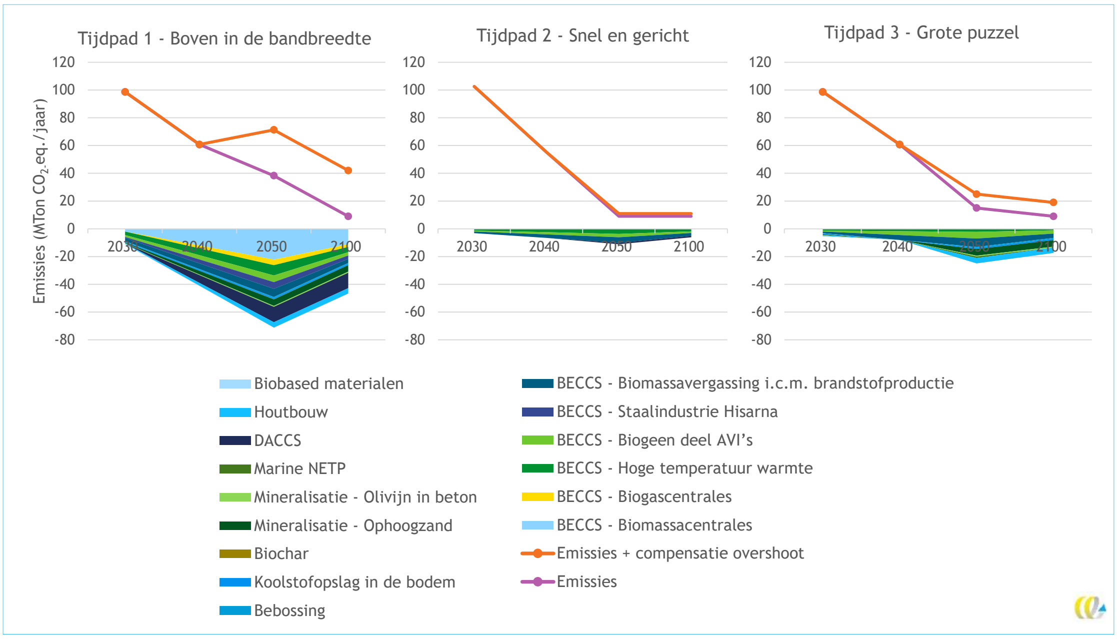
We have developed three timelines, with different futures, to understand how the need and supply of negative emissions might converge over time:

1. **Timeline 1 - Top of the range.** In this timeline, the need for negative emissions remains high because emissions are not being phased out fast enough. Maximum effort is needed with all technologies to compensate for these high emissions. Large-scale additional expansion of CCS storage capacity is also required.

2. **Timeline 2 - Fast and focused.** This timeline is marked by a rapid phase-out of emissions and a successful transition to a fossil-free economy. As a result, there is limited need for negative emissions. This is targeted by CCS, in particular bioenergy or biochemistry with CCS (BECCS) and direct air capture with CCS (DACCS). There is sufficient Direct Air Capture with Carbon Storage capacity.

3. **Timeline 3 - Major puzzle.** A medium need for negative emissions is assumed here. There is no biomass or direct air capture specifically for negative emissions. The development of negative emissions focuses on innovations and exploiting linking opportunities (synergy) with the circular economy.

Figure 2 - Overview of the evolution of the need and supply of negative emissions over time in the three timelines for the Netherlands



This analysis shows that the greater the need for negative emissions, the more challenging it is to achieve sufficient supply and the greater the risk that this will not succeed. It is very unlikely that a large range of negative emissions — as in the 'Top of the Range' timeline — is feasible for the Netherlands. The reason for this is that many of the technologies require further development before they can be deployed on a large scale, but also because of uncertain developments in the industry, the limited availability of biomass and the risk that the required CCS storage capacity will not become available in time. Reducing residual emissions and the overshoot of global climate targets must therefore remain at the heart of climate policy.

Bottlenecks

We have identified different types of bottlenecks and indicated in broad terms for each technology whether they apply. First of all, there are bottlenecks that are largely inherent in the technology: use of space, use of energy and the extent to which storage is temporary or lasting. These bottlenecks cannot be solved by policy, but can be mitigated by opting for technologies that are appropriate for the available local supply of space, energy, etc.

Second of all, there are bottlenecks that can (largely) be managed through policy instruments. This refers in particular to the current lack of regulation of negative emissions, and specifically the lack of a financial incentive. Technological innovation can also be achieved (to some extent) through targeted policies.

Finally, some of the bottlenecks are essentially a conflict between negative emissions policy goals and other policy goals. These lead to policy dilemmas and trade-offs. We see this, for example, in the competition for sustainable carbon, in the competition for carbon storage capacity and in the potentially adverse effects of some technologies on the environment and biodiversity.

Policy implications

Taking all things into consideration, we have concluded that the development and realisation of large-scale, lasting carbon removal from the atmosphere is crucial to achieve global and national climate goals. The remaining residual emissions should also be removed in the long term (after 2050) to counter further climate change.

Currently, there are not many policies that are specifically aimed at the development and actual realisation of negative emissions. Given the importance of carbon removal to climate policy and the long lead times of both the policy processes and the various technologies, it is therefore strongly recommended to accelerate policy development for this in the coming years.

In this report, we provide a roadmap for policy development, many aspects of which require further elaboration. This concerns setting up a policy framework that contains definitions and principles, developing incentive policies for achieving and scaling up negative emissions, R&D and innovation policies for making low-TRL technologies marketable, and creating the right framework conditions.

It is important in this respect that the policy makes a clear distinction between lasting and temporary carbon storage. In this respect, we recommend only viewing lasting carbon removal as offsetting residual emissions. Temporary carbon storage that has a temporary effect on the climate can be considered a positive side effect of, for example, timber construction or soil storage, but it serves other purposes.

The topic of negative emissions brings together many different policy areas. The continued development of negative emissions therefore requires an integrated approach and a vision from the central government on the role of carbon removal in the climate policy of the future. This would allow opportunities for synergy with the transition to a climate-neutral and circular economy to be exploited, and negative side effects (trade-offs) to be avoided or mitigated.

This study shows that timely CO_2 reduction must remain at the heart of climate policy. The reduction of (residual) emissions to meet climate targets and limiting the global overshoot of the 1.5°C target remain crucial. Developing and scaling up negative emissions to a level that is sufficient to offset residual emissions and global overshoot will take considerable time and effort, and involve significant uncertainties. From the perspective of climate goals, we therefore conclude that it is inadvisable to offset certain emissions now with uncertain disposal in the future.

1 Conclusion

This report is comprehensive, and most chapters end with conclusions on that specific topic. Below, we provide a brief reflection on the whole, with some overarching conclusions that follow from the findings of the different parts of this study.

The development and realisation of large-scale, lasting carbon removal from the atmosphere is crucial to meet global and national climate goals. Residual emissions will remain that should also be offset in the long term (after 2050) to counter further climate change.

This study shows that timely CO_2 reduction must remain at heart of climate policy. The reduction of (residual) emissions to meet climate targets and limiting the global overshoot of the 1.5°C target remain crucial. Developing and scaling up negative emissions to a level that is sufficient to offset residual emissions and global overshoot will take considerable time and effort, and involves significant uncertainties. From the perspective of climate goals, we therefore conclude that it is inadvisable to offset certain emissions now with uncertain disposal in the future.

Many different technologies are available for negative emissions, but it is uncertain what volume of CO_2 can actually be removed in the Netherlands (and beyond). This depends on a number of factors, which can be roughly divided into three categories:

- **Policy commitment**. We provide some suggestions in this report on how this could be structured, but further elaboration is required. This concerns setting up a policy framework that contains definitions and principles, developing incentive policies for achieving and scaling up negative emissions, R&D and innovation policies for making low-TRL technologies marketable, and creating the right framework conditions.

- **Developments in energy supply and industry**. The first issue here is the extent to which biomass will be used for energy and raw material in the future, in processes that lend themselves to CO_2 capture. The follow-up question is then to what extent this biogenic carbon will be used as a sustainable raw material for industry (e.g. for synfuels), or can be sequestered using CCS.
  We recommend developing a better understanding of the future (sustainable) carbon economy of the Netherlands, what it will look like during and after the transition from fossil fuels to renewable raw materials, and what policy instruments will be in place to manage this.

- **The success of research and innovation processes**. Many technologies still require further development before they can become widely adopted. This entails the risk that the technology does not develop as quickly as was hoped, or even ceases altogether and is unable to grow to large-scale application, e.g. for technical or economic reasons. Some technologies also require further research to avoid any potential negative side effects (e.g. on biodiversity). The various technologies can be further developed as quickly as possible through a targeted research and innovation programme.

A further conclusion of our research is that policy should clearly distinguish between lasting and temporary carbon storage. Although we have examined a wide range of technologies, it is important to see only lasting carbon removal as offsetting residual emissions. This distinction should be reflected in policy. Temporary storage may be considered a positive side effect of timber construction or soil storage, for instance, but it also only has a temporary effect.

The topic of negative emissions brings together many different policy areas: climate, energy, CCS, circular economy, forestry and agriculture, biodiversity, mobility and transport (especially fuels), innovation, etc. The continued development of negative emissions therefore requires an integrated approach and a vision of the role of carbon removal in society and in the climate policy of the future. This would allow opportunities for synergy with the transition to a climate-neutral and circular economy to be exploited, and negative side effects (trade-offs) to be avoided or mitigated.

Given the lead times of both policy processes and different technologies, it is important to quickly establish a policy framework for negative emissions. This should primarily be done through the Netherlands' engagement in European policy developments to ensure a timely roll-out of effective carbon removal policies at EU level, as well as through national policies that focus on encouraging actual deployment of technologies with high potential in the Netherlands (e.g. BECCS routes), and encouraging, promising innovations.