Bern, 18 May 2022

# Carbon capture and storage (CCS) and negative emission technologies (NETs)

How they can gradually contribute to the long-term climate target

Report by the Federal Council

# Contents

# Foreword

According to the Intergovernmental Panel on Climate Change (IPCC), achieving the goals of the Paris Agreement[1] will require a very rapid global expansion of carbon capture and storage (CCS) and negative emission technologies (NETs), in addition to a substantial reduction in greenhouse gas emissions.[2] CCS and NETs are also key to meeting Switzerland's target of net-zero greenhouse gas emissions by 2050. They will be necessary to render difficult-to-avoid emissions at that time harmless to the climate. The approaches are largely known but are not yet being actively deployed on a climate-relevant scale. Scaling-up raises various questions about the framework conditions at both international and national level, including regulatory responsibilities, financing, environmental impacts and, last but not least, acceptance. As the latest IPCC Assessment Report of April 2022 makes clear, developing and applying these technologies quickly and resolving the outstanding issues is a matter of urgency for the climate.[3]

The Federal Council's Long-Term Climate Strategy of January 2021 made initial estimates of Switzerland's potential need for CCS and NETs.[4] To ensure that these can be rolled out in an environmentally friendly, cost-efficient and socially acceptable manner, work needs to start now on improving the necessary framework conditions. The time frame for this is around 30 years, which is relatively short compared with normal innovation cycles. In this report, the Federal Council aims to make clear to policymakers, industry and society what framework conditions are envisaged and what decisions need to be made.

Eliminating greenhouse gas emissions as far as possible by 2050 in line with the strategic principles of the Long-Term Climate Strategy and the Paris Agreement remains critical. The fewer greenhouse gas emissions that need to be dealt with by means of CCS and NETs by 2050, the more feasible the upscaling of these technologies will be: technically, financially and politically. Moreover, it is becoming clear that global $CO_2$ emissions will have to move onto a definite net-negative trajectory after 2050 and through to the end of the century if global warming is to be kept as close as possible to 1.5 °C: in other words, significantly more $CO_2$ will need to be permanently removed from the atmosphere than is still being emitted.[5] As a party to the Paris Agreement, Switzerland will have to make its due contribution to this. Given that resources, and in particular $CO_2$ storage capacities, are limited, it is important that carbon reservoirs are not filled up with avoidable emissions.

Swiss research and industry are among the world's leading players in CCS, and especially in NETs. The Confederation is also making progress with innovative approaches to international climate cooperation – both between states and through voluntary carbon markets.[6] CCS and NETs are therefore not only necessary in terms of climate policy; they are also a chance for Switzerland to expand its pioneering role and to take advantage of national and international development opportunities for research and industry.

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1 SR 0.814.012
2 Global Warming of 1.5 ºC — (ipcc.ch)
3 AR6 Climate Change 2022: Mitigation of Climate Change — IPCC
4 Climate protection: Federal Council adopts Switzerland's long-term climate strategy (admin.ch)
5 See footnote 2.
6 Treaties under Article 6 (admin.ch)

# 1 2050 target under the Long-Term Climate Strategy

Switzerland's Long-Term Climate Strategy, published in January 2021, sets out the path to meeting the 2050 climate goal of net-zero greenhouse gas emissions. The strategy states that greenhouse gas emissions must be reduced as far as possible in every sector. However, there will be emissions from some industrial processes, such as cement production, or the incineration of fossil waste fractions, that will be difficult to avoid with conventional approaches. These will need to be avoided largely by means of CCS. Other difficult-to-avoid emissions that cannot be directly captured – from agriculture, for example – will need to be offset by the permanent removal of $CO_2$ from the atmosphere, i.e. by negative $CO_2$ emissions. From a climate perspective, and according to the strategy, 'permanent' means at least a few decades, or ideally several centuries. Potential NETs, both plant- and technology-based, are described in detail in the Federal Council report responding to postulate 18.4211.[7]

### CCS and NETs required on a significant scale for difficult-to-avoid emissions

Based on the Energy Perspectives 2050+ (EP2050+) drawn up by the Swiss Federal Office of Energy (SFOE),[8] the Long-Term Climate Strategy estimates that annual difficult-to-avoid emissions from industry, waste recycling and agriculture will total around 12 million tonnes of $CO_2$eq in 2050, around 5 million tonnes of which could be avoided by means of CCS plants. The greenhouse gas emissions remaining after the use of CCS technologies – totalling just under 7 million tonnes of $CO_2$eq – would have to be offset by negative emissions. According to the Federal Council strategy, the focus here should be on domestic measures. However, since the achievable potential for permanent $CO_2$ storage in Switzerland is limited by environmental, economic and social factors, the Federal Council also remains open to measures abroad.

To be able to deploy carbon storage on a larger scale in Switzerland and abroad, appropriate infrastructure for transporting $CO_2$ by rail, ship and pipeline will be needed. A large proportion of the negative emissions will stem from direct air carbon capture and storage (DACCS) facilities located abroad. Other approaches such as biochar storage make only a small contribution in the model, owing to various uncertainties (Figure 1). The energy required for CCS and NETs in Switzerland was factored into the modelling for the EP2050+. The costs of CCS and NETs for the modelled development trajectory rise to around CHF 2.3 billion a year, mostly due to the costs of DACCS abroad. The modelling is naturally subject to uncertainties and the results depend heavily on the assumptions made.

In the context of CCS and NETs, the EP2050+ did not factor in the use of captured $CO_2$ in products (known as carbon capture and utilisation, or CCU). In the case of short-lived products, such as synthetic fuels, this usually just results in delayed emissions. With very long-lasting products such as construction materials (e.g. $CO_2$-enriched concrete, timber), negative emissions could potentially be claimed if the $CO_2$ came from the atmosphere or biogenic sources. Storage in long-lived products combined with carbon capture at plants is often referred to as CCUS (carbon capture, utilisation and storage).

[7] www.parlament.ch > Postulate 18.4211 (in German)
[8] Energy Perspectives 2050+ (admin.ch)

## Carbon capture and storage (CCS) and negative emission technologies (NETs)

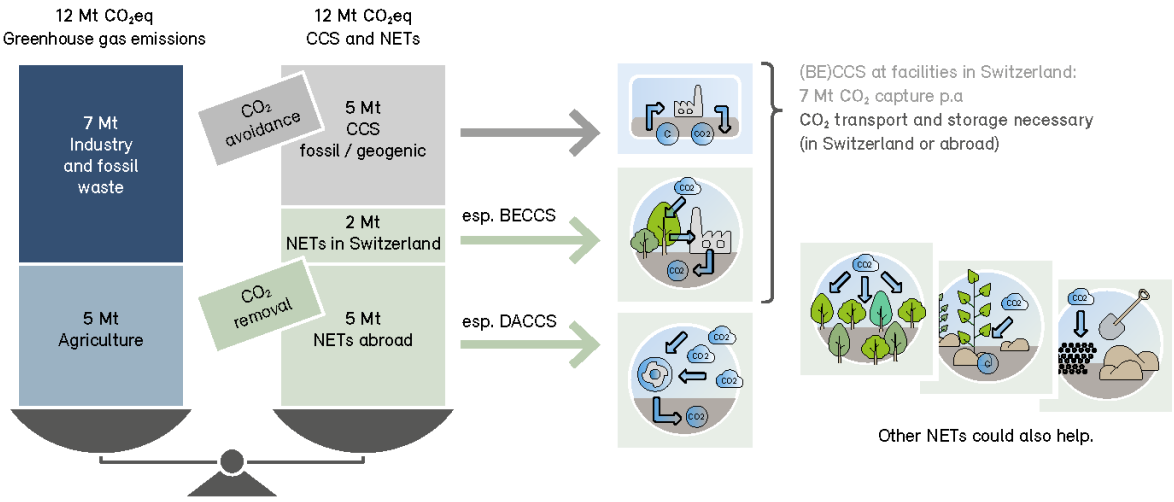


**Figure 1.** The difficult-to-avoid emissions remaining in 2050 may be avoided with CCS and balanced by means of NETs. NETs can be deployed both in Switzerland and abroad (according to the model assumptions, primarily BECCS [bioenergy with carbon capture and storage] in Switzerland, and primarily DACCS abroad). Source: Long-Term Climate Strategy (Federal Council, 2021).

### Strategic cornerstones for optimal handling of uncertain developments

The Long-Term Climate Strategy discusses a plausible scenario. Other development trajectories – and costs – are also conceivable. These will depend to a large extent on technical developments and future framework conditions. How great the need for negative emissions will be in 2050, and the associated cost, must be continuously reviewed in the light of the latest developments and scientific findings.

Factors that could change the need for negative emissions in the future include new metrics for calculating the climate impact of greenhouse gas emissions (especially short-lived ones such as methane)[9] or of carbon sinks,[10] which are currently considered in relation to a reference development in line with international requirements. New scientific work could also become more relevant in the future, for example on the active removal of methane from the atmosphere[11] or the extent to which one tonne of negative $CO_2$ emissions actually balances out the climate impact of one tonne of $CO_2$ emissions when global carbon fluxes are taken into account.[12]

The ten strategic principles of the Long-Term Climate Strategy provide guiding cornerstones for dealing as effectively as possible with the inherent uncertainty of future developments and maintaining room for manoeuvre. They also apply to the necessary development of CCS and NETs. The following are of particular note:

[9] See Federal Council opinion on interpellation 21.4357 by Pierre-André Page ('Other methods for measuring short-lived greenhouse gases')
[10] Land use, land-use change and forestry (LULUCF)
[11] See for example Atmospheric methane removal: a research agenda | Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences (royalsocietypublishing.org)
[12] See IPCC (2021): Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Chapter 5.

- **Exploit opportunities, specifically for Switzerland as an innovation and research location** (Principle 1). When it comes to NETs in particular, Switzerland is already well positioned, boasting some world-leading companies and researchers. The Federal Council is committed to ensuring the best possible framework conditions in Switzerland so that the country can continue to play its pioneering role in the field of NETs.
- **Reduce emissions primarily, and if possible entirely, within Switzerland** (Principle 3). Because of their limited potential, CCS and NETs are reserved for emissions that are technically very difficult to avoid.
- **Use energy sources sparingly** (Principle 5). With CCS and NETs as elsewhere, attention must be paid to renewable energies, energy efficiency and optimal use, including across sectors (e.g. cascade use).
- **Align federal and cantonal planning** (Principle 6). Careful planning, especially in connection with spatial planning, urban development and energy planning, can support a targeted expansion of CCS and NETs and help to avoid mis-investment.
- **Make development sustainable** (Principles 7–9). The roll-out of CCS and NETs should be designed in such a way as to be socially acceptable, economically viable and environmentally sound.
- **Remain open to different technologies** (Principle 10). CCS and NETs are developing rapidly, partly due to increasing global demand. They can contribute most effectively to meeting Switzerland's climate target if the country remains open to different technologies and pursues multiple promising approaches in parallel (portfolio approach).

The intermediate steps and measures outlined below are also based on these principles.

# 2 Intermediate steps towards the 2050 target and action plan

## 2.1 Pioneering phase and targeted scaling

**First steps by 2030 within reach, scaling by 2050 a collective challenge**

By way of guidance for the public sector as well as for research and industry, the following section outlines intermediate steps that are currently deemed advisable to achieve the required expansion of CCS and NETs up to 2050. Given the significant challenges of handling large amounts of captured $CO_2$ and the learning curve this will inevitably entail, an exponential rather than a linear expansion is expected. The roll-out is therefore divided into two phases in this report: a pioneering phase from 2022 to 2030 and a targeted scaling phase from 2031 to 2050. In the Federal Council's view, the pioneering phase is achievable in principle with the current framework conditions and developments, subject to carefully coordinated action by the relevant players. For implementation of the scaling phase, it is likely that further-reaching preparations will be necessary, including potentially at the constitutional level (see section 2.2).

The intermediate steps and guide values outlined here are based on the trajectories modelled in the EP2050+ (Figure 2). They also take account of a new agreement between the waste industry and the Federal Department of the Environment, Transport, Energy and Communications (DETEC), which

commits the industry to commissioning at least one carbon capture plant with an annual capacity of at least 100,000 tonnes of $CO_2$ by 2030.[13] The cement industry also intends to commission its first carbon capture plants from 2030, given suitable framework conditions.[14]

**Pioneering phase up to 2030: moving quickly to initial industrial application**

Guide value for carbon capture at plants and storage by 2030: The first steps towards the application and expansion of CCS and NETs are to be taken in the pioneering phase through to 2030. As a guide, the target for 2030 could be to permanently store around 500,000 tonnes of $CO_2$ in Switzerland and/or abroad. The $CO_2$ could come from fossil or process-based sources (= CCS, reduction of emissions) or from the atmosphere or biomass (= negative emissions).

Intermediate steps for carbon capture at plants: An ETH Zurich-led pilot project running from 2021 to 2023 (DemoUpCARMA) aims to transport biogenic $CO_2$ from Bern to Iceland for the first time and permanently store it there (approximately 1,000 tonnes of $CO_2$), as well as to optimise the targeted storage of $CO_2$ in concrete (around 500 tonnes of $CO_2$, carbonation).[15] The project, which is financially supported by the SFOE through the Pilot and Demonstration programme, with additional support from the Federal Office for the Environment (FOEN), should provide valuable insights, particularly regarding the feasibility of $CO_2$ exports, energy and environmental performance, and upscaling issues. Before carbon capture is implemented on an industrial scale after 2025, for example at waste incinerators or cement plants, a logical next step in the upscaling process is the targeted collection and storage of $CO_2$ at biogas upgrading plants, where $CO_2$ is generated as a by-product.

$CO_2$ transport: The anticipated volumes of $CO_2$ should be able to be transported by truck, train and ship, including to destinations abroad. Initial shorter $CO_2$ pipeline sections could be built, where appropriate. In connection with this phased expansion, the question of possible intermediate storage of $CO_2$ in Switzerland and abroad also needs to be examined in greater depth (including technical solutions, responsibilities and financing).

$CO_2$ storage in Switzerland: Up to 2030, the main option for domestic storage of $CO_2$ captured at plants will be construction materials such as concrete (targeted carbonation), since geological storage sites will not have been developed by that time. According to SFOE estimates, these sites will be ready for operation in 15–20 years at the earliest, assuming that the subsurface exploration is successful. A national subsurface exploration programme is being developed to this end (see section 2.2, motion 20.4063). Initial pilot tests on $CO_2$ storage in the Swiss subsurface could begin at suitable sites before 2030 (i.e. sites where the subsurface geology is well known, and which are suitable in principle for safe and permanent storage).

$CO_2$ storage abroad and investment in NETs abroad: As regards geological $CO_2$ storage abroad, foreign consortia currently plan to have commercial transport and storage services up and running by around 2025 (e.g. Northern Lights in Norway, Coda Terminal in Iceland, Aramis in the Netherlands and Acorn in Scotland). As well as contractual agreements concluded directly between emitters in Switzerland and foreign providers of transport and storage services, international treaties will also be necessary to ensure compliance with international regulations such as those of the Paris Agreement and the London Protocol[16] (see section 2.2). Such treaties could also provide the framework for the

[13] $CO_2$-Emissionen: Vereinbarung zwischen Bund und Kehrichtverbrennungsanlagen – DETEC (admin.ch) (in German)
[14] cemsuisse (2021): *Roadmap 2050: Klimaneutraler Zement als Ziel.* Available (in German and French) at www.cemsuisse.ch.
[15] DemoUpCARMA | Website (ethz.ch); DemoUpCARMA – Demonstration and Upscaling of CARbon dioxide MAnagement solutions for a net-zero Switzerland – Texts (admin.ch)
[16] SR 0.814.287.1. The export of $CO_2$ abroad for sub-seabed storage is regulated and in principle prohibited under international law by Article 6 of the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (London Protocol). An amendment to the London Protocol adopted in 2009 was supposed to lift this ban, but it is not yet in force. In 2019, provisional application of the 2009 amendment was agreed for states that deposit a declaration of provisional application of the 2009 amendment.

commercial financing and accounting of negative emissions generated abroad, for example from DACCS.

In this phase, research and innovation projects and participation in relevant research infrastructures will be key to enabling the rapid deployment of CCS and NETs at the required scale. The aim is to develop and/or advance technologies and, if possible, test them 'in the field', as well as to investigate technical and non-technical issues linked to scale-up, including energy and environmental performance (see section 2.2).

### Targeting scaling from 2031 to 2050: new $CO_2$ networks and infrastructure required

Guide values for carbon capture at plants and storage as well as NETs abroad in 2031–50: Based on the Energy Perspectives 2050+, a targeted scale-up of domestic carbon capture from around 500,000 tonnes to around 7 million tonnes per year could be achieved between 2031 and 2050 (2035: approx. 1 million tonnes; 2040: 2 million tonnes; 2045: 5 million tonnes). The EP2050+ indicate that around 5 million tonnes of this $CO_2$ would come from fossil or process-based sources (= CCS, emissions avoidance) and 2 million tonnes from biomass (= BECCS, negative emissions) in 2050. In view of assumed limited NET capacity in Switzerland, an additional 5 million tonnes of negative emissions will probably have to be realised abroad by 2050 in order to balance residual emissions, for example from agriculture, and meet the net-zero target. According to the EP2050+, this would primarily be achieved through DACCS in suitable locations (with plenty of renewable energy and geological storage sites). Based on current knowledge, plant-based approaches are less likely to be considered, as they may not guarantee sufficiently long-lasting storage and, if scaled up to the levels required to affect the climate, could, depending on the location, entail significant potential for conflict over the use of biomass.

$CO_2$ transport: $CO_2$ transport infrastructure will need to be built to convey the large quantities of $CO_2$ from emitters to storage sites. To the best of our current knowledge, such large volumes would require a network of $CO_2$ pipelines,[17] which would have to be connected to other countries' transport networks to ensure access to foreign storage sites. However, international discussions on this subject, notably in the EU, are only just beginning.

$CO_2$ storage in Switzerland: Under the Long-Term Climate Strategy, the $CO_2$ captured in Switzerland should, if possible, be stored in Switzerland, either underground or in long-lasting products such as construction materials. This reflects the fact that exporting $CO_2$ is likely to remain a challenge, despite some promising international developments – not least because of high European demand for $CO_2$ storage solutions. The guide value for domestic geological $CO_2$ storage according to the EP2050+ is 3 million tonnes of $CO_2$ in 2050. This would require several geological storage sites that would have to be successfully explored and developed (according to initial SFOE estimates, around 1–2.5 million tonnes of $CO_2$ per year could be stored at five geological storage sites). Theoretically, by 2050 a further 2.5 million tonnes of $CO_2$ per year could be stored in all of Switzerland's demolition concrete, via targeted carbonation.[18] However, more recent estimates suggest that the achievable potential is likely to be significantly smaller.[19]

$CO_2$ storage abroad: Due to limited storage capacity in Switzerland, the EP2050+ expect significant quantities of domestic $CO_2$ to be exported to foreign storage sites, even in the long term (guide value of 4 million tonnes of $CO_2$ per year by 2050).

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[17] See for example CO2NET Grobes Design und Kostenschätzung für ein $CO_2$ Sammel-Netzwerk in der Schweiz – Grunddaten (admin.ch)
[18] See report on postulate 18.4211 submitted by Adèle Thorens Goumaz 'What significance could negative $CO_2$ emissions have for Switzerland's future climate policy measures?'
[19] See Frontiers | Technological Demonstration and Life Cycle Assessment of a Negative Emission Value Chain in the Swiss Concrete Sector | Climate (frontiersin.org)

## Carbon capture and storage (CCS) and negative emission technologies (NETs)

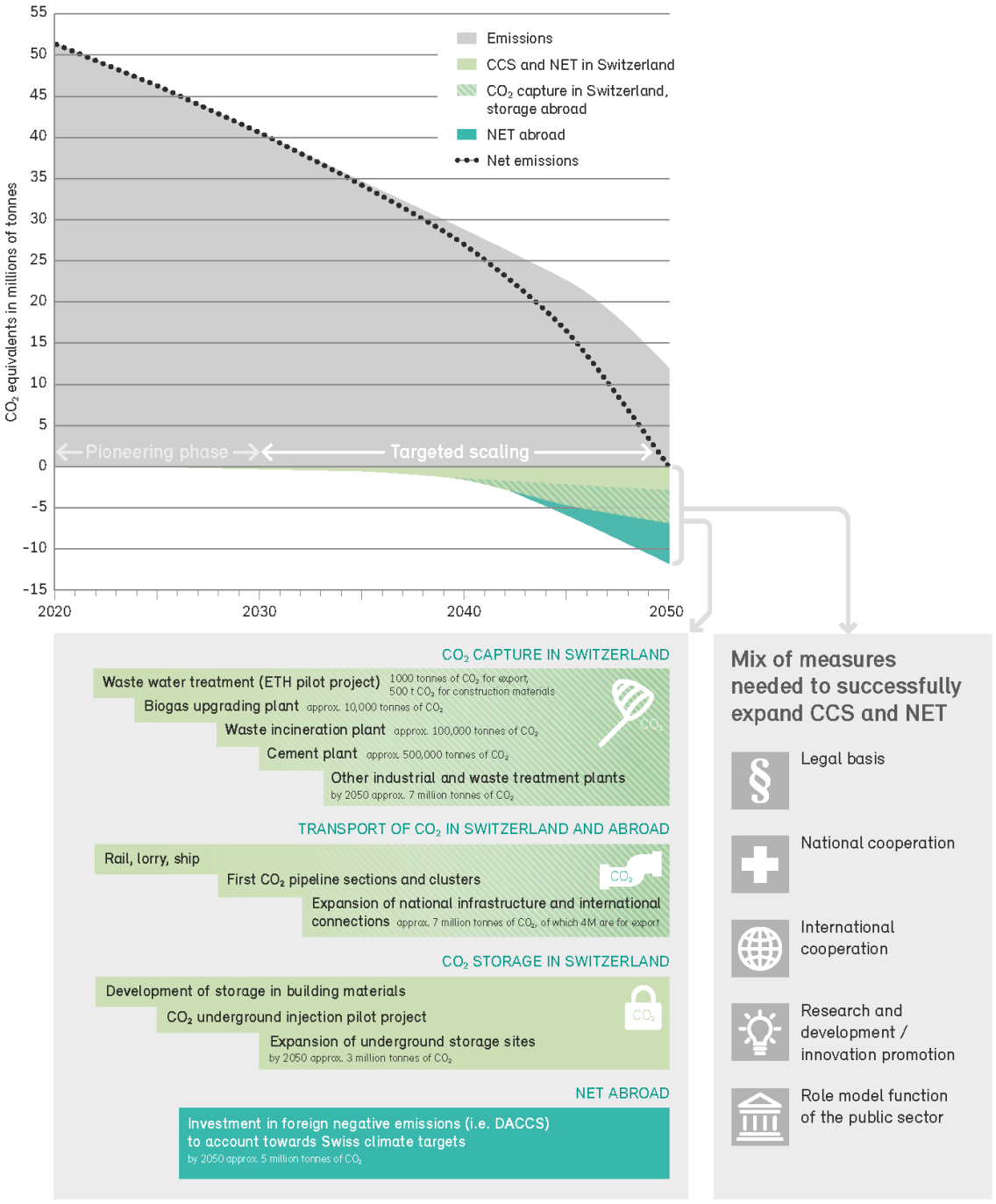


**Figure 2.** To expand CCS and NETs in line with the Long-Term Climate Strategy, a two-phase approach is recommended ('pioneering phase' up to 2030, 'targeted scaling' up to 2050). This approach envisages the gradual roll-out of carbon capture plants in Switzerland, of infrastructure for transporting $CO_2$ to storage sites in Switzerland and abroad, of $CO_2$ storage sites in Switzerland (construction materials, underground), and of investment in NETs abroad. This will require a mix of measures to create a favourable environment (see section 2.2). Raw data: Long-Term Climate Strategy (EP2050+ ZERO basis scenario, including international aviation).

### No guide values for NETs not requiring new $CO_2$ infrastructure

There are other NETs at different stages of development that promise 'permanent' storage for several decades, if not centuries. These include the long-term use of timber in buildings, the incorporation of biochar into soil or buildings, and enhanced weathering of finely ground minerals. In line with the EP2050+, this report does not provide guide values for the roll-out of these approaches over the period 2022–50. Given the many demands on and uses of biomass, forests, wood and soils, such NET approaches should be upscaled appropriately, in a way that is consistent with other relevant policies, in particular the Swiss Biomass Strategy,[20] the Forest Policy,[21] the Wood Resource Policy[22] and the Soil Strategy.[23]

A mix of measures comprising five elements – a strengthening of the legal basis, national and international cooperation, the promotion of innovation, and the role model function of the public sector – should help to underpin this process.

## 2.2 Action plan

### Seizing opportunities for climate, research and industry: priorities for strengthening investment security

In the Federal Council's view, it is not primarily technological hurdles that are holding back the expansion of CCS and NETs today, but rather a lack of investment security for the actors involved. As such, the framework conditions should be principally geared towards increasing security in the investment environment so that the opportunities around NETs can be optimally exploited, for the benefit of the climate as well as of Swiss research and industry. A number of thematic priorities have been identified ('what needs to be done'), along with a range of measures for addressing them ('how to do it'). The measures in the tables below are based on the mix of measures in Figure 2. They are geared particularly to the 'pioneering phase' up to 2030, but also lay foundations for the planned 'targeted scaling' through to 2050.

- **Priority 1: Further specify long-term targets, split them into stages, and enshrine them in law**. Separate climate targets for ambitious reductions and, where relevant, negative emissions could create a clearer basis for driving forward both the reduction of greenhouse gas emissions and the generation of negative emissions in a targeted manner. A net-negative emissions trajectory and/or the possibility of Switzerland's emissions balance having an overall cooling impact on the climate in the period after 2050 should also be examined. The targets should be reviewed regularly based on the latest scientific findings (e.g. assessment of the climate impact of short-lived greenhouse gases such as methane or of non-$CO_2$ emissions from aviation).
- **Priority 2: Define quality criteria and standards for permanent and sustainable sink services** in line with current scientific knowledge and international standards. These concepts could also serve as the basis for requirements for CCS in the case of fossil or process-related emissions. As well as nationally, Switzerland could also work towards greater clarity at the international level (creation of precedents through requirements in bilateral treaties,

[20] Biomassestrategie Schweiz legt übergeordnete Ziele fest (admin.ch) (in German)
[21] Waldpolitik (admin.ch) (in German)
[22] Ressourcenpolitik Holz (admin.ch) (in German)
[23] Swiss National Soil Strategy (admin.ch)

establishment of NET certificates on the international $CO_2$ market and their recognition under the Paris Agreement, ISO standards and life cycle assessment (LCA) databases, etc.).

- **Priority 3: Create economic incentives and markets for private actors**. New and upgraded market-based instruments (e.g. the current requirement for fuel importers to offset emissions or the national emissions trading system) could drive the expansion of CCS and NETs in a cost-efficient and effective way. Bilateral treaties regulating cooperation in the area of NETs and $CO_2$ export could allow these efforts, within and outside of such markets, to be counted towards the Swiss climate target under the Paris Agreement. These legal frameworks could be open to voluntary markets – e.g. for the voluntary commitments of companies, cantons or communes – thus creating additional sources of income for negative emissions providers. Other government instruments such as calls for tenders, $CO_2$ (storage) standards or quotas are also a possibility, for example in the public procurement of buildings or of certificates to balance federal emissions (public sector as role model).
- **Priority 4: Develop physical and virtual infrastructure for $CO_2$ transport and storage**. The roles of the Confederation, the cantons and the private sector in the development of $CO_2$ transport infrastructure ($CO_2$ pipelines), its connection to future foreign transport networks and its financing need to be clarified. The role of rail freight transport should also be examined because $CO_2$ transport by rail will play an important part in the development phase and could also be a relevant addition to pipelines in an upscaled system. Similarly, for domestic geological $CO_2$ storage sites, the technically achievable potential should be determined at an early stage by means of exploration. Responsibilities and financing for the identification, construction and operation of geological storage facilities should be clarified and secured. At an early stage, and until a functioning and mature market is in place, the need for government interventions should be examined with a view to establishing a functioning business model that allows the private sector to take a leading role in this brand-new sector. As CCS and NETs are scaled up, a virtual 'certification system' could help to create transparency regarding $CO_2$ flows for market participants and regulators. The 'guarantee of origin' concept for electricity could potentially serve as a basis for this.
- **Priority 5: Promote innovation**. While the technological approaches are already, in principle, mature enough to be tested in pilot or demonstration projects or even to operate in niche markets, there is still a need for research and innovation throughout the innovation cycle, particularly for the later phases. On the one hand, a number of issues concerning application still need to be clarified (e.g. measurability of $CO_2$ storage, energy and environmental performance, safety aspects, optimisation of processes especially in terms of costs and of energy and resource efficiency, systemic issues such as transport infrastructure). On the other hand, more research is also needed in the area of policy design, for example in relation to effective business models. Last but not least, social-science and humanities issues around CCS and NETs (e.g. acceptance, questions of fairness) should be examined in greater depth.

### Responsibility of the public sector as well as research, industry and society

The Confederation has a responsibility to create a favourable environment and to act as a role model, since Switzerland's need for CCS and NETs is a direct consequence of its obligations under the Paris Agreement, which the Confederation is tasked with implementing. The Confederation does not currently have the necessary powers and competencies to perform certain tasks. For example, there is no constitutional basis for the comprehensive regulation of $CO_2$ transport and storage infrastructure by the Confederation. Competence for this therefore lies with the cantons. The Confederation could potentially take action in individual cases for specific projects in the national interest (under Article 81 of the Federal Constitution). The cantons and communes also play a central role in spatial planning, issuing permits for plants and promoting innovation. Research, industry and society are key players when it comes to driving innovation, investment and acceptance. Where Switzerland reaches the limits of its domestic capability, international partners may provide assistance. Accordingly, the Confederation should strengthen cooperation with all these actors.

The Confederation has already taken various measures within its power (see mix of measures, Figure 2). While mainly geared towards the 'pioneering phase' up to 2030, they should also, as far as possible, pave the way for the 'targeted scaling' through to 2050.

| Measure [the lead federal entity is shown in square brackets] | Implementation timeframe |
|---|---|
| § **Improving the legal, strategic and enforcement basis at national level** | |
| Admission of carbon **sinks as compensation projects** under the $CO_2$ Ordinance (in conjunction with parliamentary initiative 21.477 on extending the reduction target until the end of 2024); refinement of quality criteria for carbon sinks. [FOEN] | Effective from 2022 |
| **Industry agreement with Swiss waste incinerators** requiring them to have at least one carbon capture plant in operation by 2030. [FOEN] | In force 2022–31 |
| Accounting for **CCS into the emissions trading system (ETS)** (proposal in the context of the consultation on the revision of the $CO_2$ Act[24]) with the possibility of storage in Switzerland (in long-lasting products) or in the EU (underground);[25] admission of **BECCS at ETS installations as compensation projects.** [FOEN] | Planned entry into force in 2025 |
| Definition by the FOEN of guide values for **pollutant emission limit values related to carbon capture at plants** (e.g. nitrosamines) for interested cantons and plant operators; incorporation of the limit values into the Ordinance on Air Pollution Control in the medium term. [FOEN] | Guide values from mid-2022 |

[24] Klimapolitik: Bundesrat eröffnet Vernehmlassung zum revidierten CO2-Gesetz (admin.ch) (in German)
[25] The legal framework for counting underground storage in Switzerland towards climate targets will be created as soon as there is any prospect of domestic storage sites being developed.

**Carbon capture and storage (CCS) and negative emission technologies (NETs)**

| Measure [the lead federal entity is shown in square brackets] | Implementation timeframe |
|---|---|
| Examination and development of **legal bases concerning the permitting** of the construction and operation of capture plants, including intermediate storage and transport, to the extent that this is within the competence of the Confederation (e.g. with regard to requirements for environmental impact assessments and major accidents). [FOEN] | From mid-2022 |
| Examination and development of legal bases for **separate long-term climate targets** (reduction target and, if applicable, negative emissions target) as part of the debate on the Glacier Initiative. [FOEN] | Examination from early 2022 |
| Examination of long-term adjustments to the legal bases to enable the necessary expansion of CCS and NETs within the framework of **post-2030 climate policy** (including issues concerning the competence of the Confederation/cantons/private sector, financing solutions, need for adjustment of the constitutional basis). [FOEN] | Examination from mid-2022 |
| Development of a national **exploration programme for geological $CO_2$ storage sites** (as part of motion 20.4063). [SFOE] | Report expected by 2023 |
| Development of a **Swiss subsurface strategy** as a contribution to holistic, sustainable 3D spatial planning (governance, knowledge and processes). [swisstopo] | Report expected by 2023 |
| Further exploration of the **possibilities and limits of carbon storage and conservation in soil** in the report in response to postulate 19.3639 ('Soil carbon sequestration'). [FOEN] | Report by summer 2022 |
| **Updating of the sink potential of forests/timber**: climate change mitigation services of the Swiss forestry and timber industry. [FOEN] | Report by spring 2023 |
| Comprehensive **forest and timber strategy** under development. [FOEN] | Report from 2025 |
| Updating of the ***Ökobilanzdaten im Baubereich 2009/1*** **(LCA data in the construction sector 2009/1)**[26] by the Coordination Group for Construction and Property Services (KBOB). [FOBL] | 2022 |
| Ongoing revision of the Environmental Protection Act (EPA) as part of parliamentary initiative 20.433 ('Strengthening the Swiss circular economy', Art. 35j EPA and Art. 45 para. 3 let. e of the Energy Act); new requirements for **resource-conserving construction**, such as limit values for embodied greenhouse gas emissions and embodied energy of built structures. This would benefit local building and insulating materials such as timber, hemp or straw, which in turn sequester $CO_2$ over the lifetime of the structure. The Confederation is intended to act as a role model. [FOEN] | Revised legislation to come into force in mid-2023 at the earliest |

[26] Ökobilanzdaten im Baubereich (admin.ch) (in German)

**Carbon capture and storage (CCS) and negative emission technologies (NETs)**

| Measure [the lead federal entity is shown in square brackets] | Implementation timeframe |
|---|---|
| **National cooperation** | |
| Establishment of a **national working group on CCS/NETs** at the request of the cantons, with the involvement of the relevant offices and private sector players; discussion of overarching questions about responsibilities, financing aligned as closely as possible with the 'polluter pays' principle, and the legal framework, taking into account actual ongoing projects. [FOEN] | Establishment of group in summer 2022 |
| FOEN and SFOE support for the **Swiss Carbon Removal Platform** launched by the Risk Dialogue Foundation (forging links between stakeholders, disseminating knowledge, fostering debates, promoting the sustainable expansion of NETs, safeguarding Switzerland's lead role). | Since 2021 |
| **International cooperation** | |
| Creation of conditions under international law, specifically the **London Protocol, for $CO_2$ export for sub-seabed storage** (deposit of instrument of acceptance of the 2009 amendment and declaration of its provisional application). [DIL] | Implementation in 2022 |
| Signing of **declarations of intent** with other countries on cooperation in the field of CCS and NETs. [FOEN] | 2021 (with Iceland)<br>2022 (with the Netherlands) |
| Conclusion of **at least two international agreements** on the export and storage of $CO_2$ abroad, as well as on the procurement of negative emissions abroad and their counting towards Switzerland's climate targets or voluntary targets of Swiss actors, in compliance with the requirements of the Paris Agreement and the London Protocol. [FOEN] | Discussions since 2021, completion planned for 2023–25 |
| Establishment of **internationally harmonised requirements** for CCS and NETs under the Paris Agreement and on the international carbon market; launch of discussions on governance in appropriate international fora. [FOEN] | 2023–30 |
| Expansion of **international agreements to other partner countries.** [FOEN] | By around 2030 |

**Carbon capture and storage (CCS) and negative emission technologies (NETs)**

| Measure [the lead federal entity is shown in square brackets] | Implementation timeframe |
|---|---|
| **R&D, innovation promotion** | |
| Incorporation of NET research requirements into the **Environment Research Master Plan 2021–24;**[27] support for or commissioning of corresponding research projects. [FOEN] | Covers period 2021–24 |
| SFOE support for the **NET pilot projects DemoUpCARMA** and DemoUpStorage led by ETH Zurich (Pilot and Demonstration programme, P+D). | Project duration 2021–23 |
| Support for the ZAR Foundation's **$CO_2$ Competence Centre** through FOEN environmental technology funding (CCS preliminary project for the KVA Linth waste-to-energy plant). | Project duration 2022–26 |
| Adaptation of the existing contract between the **Climate Cent Foundation** and the Confederation so that the foundation's assets can be used for NET projects within Switzerland. [FOEN] | Effective from mid-2022 |
| Support for **CCS/NET preliminary studies** with a view to the SWEET call for proposals (see below); financing under existing instruments. [FOEN/SFOE] | Duration of preliminary studies 2022–24 |
| CCS/NET call for proposals under the **SWEET research funding programme** run by the SFOE in cooperation with the FOEN. | Programme duration c. 2024–32 |
| Examination of the SFOE's **P+D call for proposals on BECCS at biogas upgrading plants.** [SFOE/FOEN] | Examination from 2022, call planned from 2023 |
| Examination of the SFOE's **P+D call for proposals on (BE)CCS in industry.** [SFOE/FOEN] | Examination from 2023, call planned from 2024 |
| Submission by the FOEN of a proposal for a **National Research Programme (NRP)** on NETs and CCS. | Submission in Q1 2022 |
| Implementation of **motion 21.4333 on strengthening the promotion of NETs and CCS**, and in particular examination of the increased use of existing promotion instruments. [FOEN] | Examination from 2022 |
| **Forest Policy**: objectives and measures 2021–2024: Objectives 1, 2, 6: Sustainably managed forests and the use of wood help to mitigate climate change. Support measures to adapt forests to climate change and to strengthen the use of wood as a contribution to clean technologies (cleantech). [FOEN] | Implementation 2021–24 |
| **Wood Resource Policy 2030**, Strategy, Objectives and Wood Action Plan 2021–2026: priority areas 'Climate-appropriate buildings' and 'Innovation', new action plan since spring 2021. [FOEN] | Implementation 2021–26 |

[27] Forschungskonzept Umwelt für die Jahre 2021–2024 (admin.ch) (in German)

**Carbon capture and storage (CCS) and negative emission technologies (NETs)**

| Measure [the lead federal entity is shown in square brackets] | Implementation timeframe |
|---|---|
| Continuation of the experiments in Opalinus Clay as caprock for the geological storage of $CO_2$ in the **Mont Terri Rock Laboratory.** [swisstopo] | Since 2011 |
| Support for various collaboration projects with significant Swiss participation under the **ERA-NET ACT international research programme**.[28] [SFOE] | 2018–23 |
| Swiss participation in the **Clean Energy Transition Partnership (CETP) international research programme**,[29] whose Transition Initiative 3 (TRI3) issues calls on CC(U)S. [SFOE] | 2022–27 |
| Representation of Switzerland at the **International Energy Agency (IEA)**, which has a number of working groups engaged on CCS and NET issues, in particular the **IEA Greenhouse Gas R&D Programme (IEAGHG)**.[30] [SFOE] | Ongoing |
| **Role model function of the public sector** | |
| Examination of the **partial balancing of federal government emissions** by negative emissions (see motion 21.4596). [FOEN] | From 2022 |
| Implementation of **Article 34*b* of the Forest Act** (rules on the use of timber in federal buildings and installations and on the purchasing of wood products). [FOEN] | Ongoing since 2017 |
| Updating of the rules on the **eligibility of carbonation in concrete structures to count towards climate targets, in KBOB recommendation** *2009/1:2022 Ökobilanzdaten im Baubereich* (LCA data in the construction sector). [FOBL] | From 2023 |

[28] ACT (act-ccs.eu)
[29] CETP SRIA v1.0-endorsed (eranet-smartenergysystems.eu)
[30] IEAGHG

# 3 Conclusion

There is a growing understanding, in Switzerland and worldwide, that CCS and NETs have become indispensable for meeting international and national climate targets. Both domestically and globally, this is reflected not least in the momentum within research and industry, in political debates and in the increasing efforts of the public authorities to identify and remove hurdles.

In this report and in the measures already initiated, the Federal Council shows how CCS and NETs can be expanded in the years ahead so that can they make their due contribution to achieving the climate targets. Fundamental challenges exist, particularly with the development of a comprehensive $CO_2$ transport and storage infrastructure. Clarification is needed on the roles of the Confederation, the cantons and the private sector in the development of this infrastructure, on its financing and on the legal framework. There has to be a public debate about what Switzerland wants overall and in the longer term in the area of CCS and NETs. This then needs to be translated into policy, appropriately regulated and, as far as possible, financed in line with the 'polluter pays' principle. The Federal Council will continue to endeavour to take account of the latest scientific findings, anticipate developments, exploit opportunities for Switzerland, proactively foster the development of framework conditions and perform a coordinating role. Meanwhile, it invites all stakeholders to (continue to) reflect on the roles they can play and the contributions they can make to future climate policy as well as on their needs, and to participate in the necessary debates and activities.

# Abbreviations and glossary

| | |
|---|---|
| BECCS | Bioenergy with carbon capture and storage (→ CCS, NET) |
| Carbon reservoir | Component of the climate system (other than the atmosphere) that can store, accumulate or release carbon (C). The origin of the carbon is unspecified; it could be extracted from the atmosphere (→ NET) or captured directly at a plant (→ CCS). Consequently, carbon storage can lead to a reduction in $CO_2$ emissions or to negative emissions. |
| CCS | Carbon capture and storage: technology that captures $CO_2$ at a plant and then stores it over the long term. CCS in combination with biomass energy can generate negative $CO_2$ emissions (→ NET). |
| CCU | Carbon capture and utilisation: capture and use of $CO_2$ in new products, such as construction materials or synthetic fuels (→ CCS, CCUS, NET) |
| CCUS | Carbon capture, utilisation and storage: capture, use and storage of $CO_2$ in products over a climate-relevant period, e.g. in long-lasting construction materials (→ CCS, CCU, NET) |
| CDR | Carbon dioxide removal: human activities to remove $CO_2$ from the atmosphere and permanently store it (synonymous with → NET in this report) |
| $CO_2$eq | $CO_2$ equivalents |
| DACCS | Direct air carbon capture and storage: use of machines to extract $CO_2$ from the air and store it |
| IPCC | Intergovernmental Panel on Climate Change |
| KBOB | Coordination Group for Construction and Property Services |
| LULUCF | Land use, land-use change and forestry |
| Negative emissions | Permanent removal of $CO_2$ from the atmosphere by human activities (→ NET, CDR), resulting in a net negative effect in system and life cycle terms (i.e. more $CO_2$ is absorbed than emitted) |
| NET | Negative emissions technology: used as a synonym for 'carbon dioxide removal' (→ CDR) in this report |
| Sink | A process that removes greenhouse gases from the atmosphere (as more $CO_2$ is absorbed than emitted) and stores it. It can also occur without human intervention and is not necessarily permanent (→ NET). Since $CO_2$ is the most significant and longest-lived greenhouse gas and processes for removing other greenhouse gases from the atmosphere are still largely unknown, the discussion about greenhouse gas sinks focuses on $CO_2$. The term 'carbon sink' is also used (→ carbon reservoir). |