Swiss Carbon Removal Platform

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Carbon Dioxide Removal Policies for a Net Zero Switzerland and Beyond.

Policy Pathways and Visions.

White Paper by the Working Group “CDR Policy” of the Swiss Carbon Removal Platform (CDR Swiss).

Imprint

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Summary

This White Paper offers an overview of key considerations in the development and implementation of policies to mobilize carbon dioxide removals (CDR) towards the Swiss goal of reaching Net Zero greenhouse gas emissions by 2050.

With its net zero emission targets, Switzerland also committed to carbon dioxide removal (CDR). As set out in the CDR Roadmap released by the Swiss Federal Office for the Environment in 2022 and the recent Swiss Climate Act, CDR will enable balancing residual emissions from hard-to-abate sectors. While CDR requires investments and regulation, it has the potential to provide economic opportunities across sectors in addition to its contribution to climate mitigation.

In this White Paper, we focus on characteristic policy pathways, analyzing and discussing policy needs and possible alternative approaches over three distinct phases: the **short-term** (*pioneering* phase), the **mid-term** (*scaling* phase), until reaching Net Zero emissions in 2050, and the **long-term**, after 2050, whereby the climate goal is to achieve Net Negative emissions.

In the first chapter, we highlight the motivations for examining CDR policies (Chapter 1.1.) and specifically discuss the Swiss context (Chapter 1.2.). We then discuss ethical and governance considerations that should underpin CDR policy-making more generally (Chapters 1.3 and 1.4.).

In the second chapter, we dive into specific policies to demonstrate and initially deploy CDR in the short-term, and to then scale up CDR such as to enable Net Zero emissions by 2050. After discussing **policy needs** to enable CDR at the scale foreseen by the Swiss CDR Roadmap (Chapter 2.1.), we discuss short-term policy actions that are needed to **prepare the ground** (Chapter 2.2.). Further, we introduce types and characteristics of different existing and potential policy instruments and deep-dive into three **climate governance models** to enable both niche markets for CDR in the *pioneering* phase and sustained finance flows in the *scaling* phase (Chapter 2.3.). From these governance models, we derive three distinct policy pathways: (1) *Polluters-Pays*, (2) *Only Carrots and No Sticks*; and (3) *Command and Control.* We highlight differences in how these policy pathways enable CDR, distribute costs, and assign decision-making power. We discuss the potential benefits and risks of each pathway and identify policy mixes and sequences to optimally overcome trade-offs entailed by each approach. Finally, we show three technology-specific case studies (Chapter 2.4.) of how such mixes could

look like for biochar (PyCCS), bioenergy with carbon capture and storage (BECCS), and direct air capture and storage (DACS).

In the third chapter, we present a long-term perspective on CDR by examining visions of a Net Negative Switzerland. To answer the question “What comes after net zero?”, we highlight why policy discussions on Net Negative Switzerland should take place and discuss alternative governance paradigms for Net Negative emissions (Chapter 3.1.).

In the fourth chapter, we invite the reader on a speculative journey into a Net Negative Switzerland in the year 2065.

Finally, **in the conclusion** (Chapter 5), we discuss the implications for tailored and adaptive policy design of the wide spectrum of challenges and policy requirements for different CDR methods.

Overall, we conclude that to both accomplish net zero domestically and contribute to the global mitigation of climate change, Switzerland needs to take a leadership role in advancing the commercial maturity of CDR and overcoming the barriers hampering its development and scale-up. Policies need to focus on both the short-term and long-term deployment of CDR while minimizing unintended consequences and maximizing the potential benefits.

Key Takeaways:

In the **short-term, scaling CDR** in Switzerland requires a series of actions:

- Define separate, legally binding targets and paths for greenhouse gas emission reduction and CDR;
- Demonstrate and pilot novel CDR methods and integrated, cross-sectoral approaches;
- Engage with the EU and particularly neighboring countries to govern CO_2 transport and storage;
- Develop regulatory frameworks and standards for trading CDR certificates as well as for national and cross-border CO_2 transport and storage, comparable across CDR methods and compatible with the EU;
- Develop and support niche-markets, tackle administrative and financial hurdles and mobilize early investments by absorbing part of their risk;
- Accelerate the deployment of carbon capture and storage (CCS) at major point sources to pave the way for CO_2 transport and storage infrastructure needed for some CDR methods;
- Assess and transparently discuss and navigate side-effects, co-benefits, and trade-offs of CDR methods implemented.

In the **mid-term,** to achieve **Net Zero emissions**, niche markets need to be expanded into a business model enabling continuous finance flows. To achieve that, optimal policy mixes should combine initial technology-pushing supply-side policies (e.g., Contract-for-Difference, tax break, reverse auctioning) with the policy-driven expansion of CDR markets (e.g., by increasingly including CDR in existing emission pricing schemes). The phase-in of mandates, such as obligations to combine with a finite carbon budget, would also enable more direct control of the climate impacts of Swiss emissions. At the same time, separate targets for CDR and emission reduction, as well as safeguards for long-term sustainability and planned adaptive governance should be integral to all policy pathways.

In the **long-term**, as a society, we might want to consider a broader spectrum of paradigms for reaching and governing **Net Negative emissions**. We encourage exploring alternative policy paradigms early on and appropriately approaching them through adaptive planning. Such paradigms could include channeling financial flows to CDR by pricing residual non-CO_2 emissions, adopting a toxic-waste treatment paradigm (with historical polluters or taxpayers contributing to financing the “clean up” of the atmosphere), or extending carbon prices in the inter-temporal space via a “carbon debt” levied on emissions starting at a particular time.

1. Introduction and Key Concepts

This White Paper offers an overview of key considerations in the development and implementation of policies to mobilize carbon dioxide removals (CDR) towards the Swiss goal of reaching Net Zero greenhouse gas (GHG) emissions by 2050 and beyond.[1]

We start in Chapter 1 by introducing the motivation for examining CDR policies in the Swiss context, types of policy instruments, and ethical considerations.

In Chapter 2, we examine policy pathways in the short- to mid-term to reach net zero. This chapter includes an assessment of CDR policy needs, near-term actions, policy pathways to enable the mid-term scale-up of CDR, and, finally, CDR method-specific case studies of policy mixes.

With Chapter 3, we offer a long-term perspective and examine visions of a Net Negative Switzerland.

In Chapter 4, we present a speculative retrospection from the future, narrating a transformative pathway beyond 2050 – and the different paradigms of action that might persist in a future with "Net Negative" emissions.

Finally, in Chapter 5, we conclude with key observations, takeaways, and an indication of imminent policy developments that might get us started on this path.

Motivation for the White Paper

Limiting global temperature increase to 1.5°C or well below 2°C, as set out by the Paris Agreement, requires remaining within a finite budget of Greenhouse Gas emissions (GHG) (Masson-Delmotte et al., 2021). Thereby, long-lived GHG emissions, such as carbon dioxide (CO_2), need to reach net zero while short-lived GHG emissions, such as methane, need to be drastically reduced (Fuglestvedt et al., 2018; Rogelj et al., 2015). Thus, CDR will likely be necessary to bend net-emissions paths, achieve Net Zero emissions, and, in the long-term, remediate overshoots of the carbon budget (IPCC, 2018, 2022; see Figure 1 on the next page). CDR is a summary term for methods that remove CO_2[2] from the atmosphere and store it durably (for an overview, see Minx et al., 2018 or Table A1 in the Annex). With its goal of reaching

[1] Press release, Federal Council, 2022: https://www.bafu.admin.ch/bafu/de/home/dokumentation/medienmitteilungen/anzeige-nsb-unter-medienmitteilungen.msg-id-88850.html

[2] In principle, other GHGs could be removed from the atmosphere and stored permanently. The primary focus of this White Paper is set on CDR, although most of our considerations are equally applicable to GHG removal more generally.

Net Zero GHG emissions by 2050, Switzerland also committed to CDR[3].

The Swiss Energy Perspectives 2050+ project claims that after applying absolute emission reduction measures, including carbon capture and storage, residual emissions of greenhouse gases equivalent to about 7 million tons of CO_2 will remain each year from 2050 onwards to be counterbalanced by removals (SFOE, 2020). Policy measures to scale up Swiss removals to this extent are, however, missing to date despite being needed for at least three reasons (see Text Box 1 on the next page).

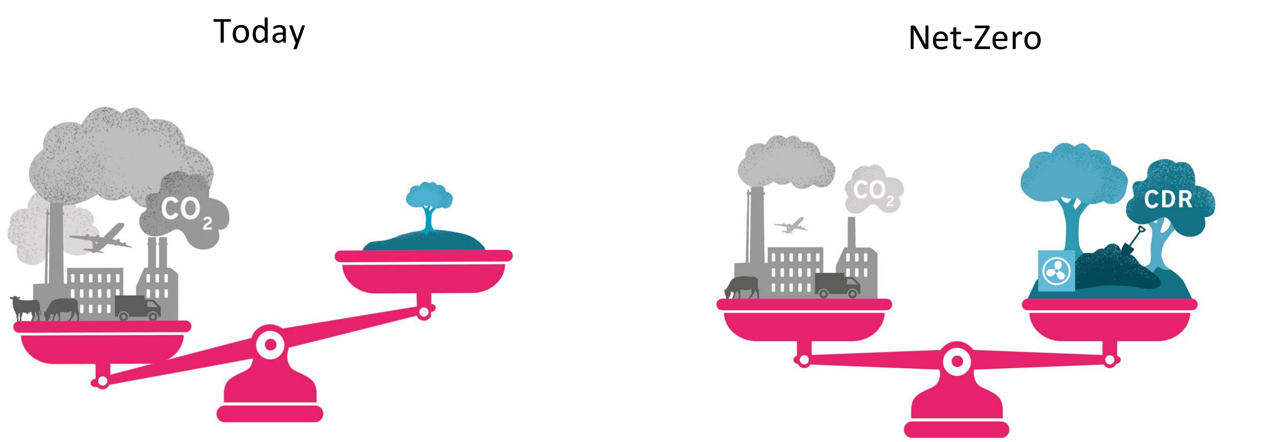


Figure 1: To reach Net Zero greenhouse gas emissions, both a drastic reduction of emissions (left side in gray) and Carbon Dioxide Removal (CDR) at a scale (right side in blue) balancing the residual emissions are needed. Image: Risk Dialogue Foundation, 2023.

[3] In Swiss policy documents and official communications, the term for CDR currently predominantly used is Negative Emissions Technologies (NETs). In the context of this White Paper, we treat the terms NETs and CDR as synonyms. We thereby include traditional land-based CDR methods, such as soil carbon management, afforestation and agroforestry, ecosystem restoration, as well as novel CDR methods, such as bioenergy with carbon capture and storage (BECCS), direct air capture and storage (DACS), and enhanced rock weathering.

Three Reasons for Policies Targeting CDR

1. **Deliver the Public Good**

   Mitigation of climate change has often a public good nature: benefits are global, yet costs fall on individuals. Since only a few CDR methods have some monetizable co-benefits (e.g., improved soil quality) and these are often insufficient to fully incentivize CDR, policies need to provide the public good of removing CO_2 from the atmosphere.

2. **Drive Down Cost, and Narrow Down Uncertainties**

   Many CDR methods are not technologically or commercially mature, are very capital and energy intensive, and their future potential is highly uncertain. Policies can accelerate innovation, technology learning, and market scale-up to reach the critical size to unlock cost reductions and mobilize infrastructures.

3. **Steer Design and Application Towards the Desirable**

   Not all CDR methods are equally desirable in all local or national contexts, and not all applications and policy designs are equally desirable. Policies can ensure that CDR deployment simultaneously pursues multiple societal goals, such as mitigation, sustainability, and fairness.

Text Box: 1: Three Reasons for Policies Targeting CDR.

Define “Hard-to-Abate” Carefully!

Within the context of net-zero emissions targets, carbon removal rates are profoundly intertwined with “hard-to-abate” emissions. In a net-zero economy, not all the emissions will be abated, thus leaving it up to CDR to counterbalance their climate impacts. These emissions are typically defined on vague principles of technical feasibility and economic viability (Buck et al., 2023), and traditionally include sectors such as aviation, shipping, agriculture, and industry (Luderer et al., 2018). Some of these sectors have, however, point-source emissions that can be captured via CCS and thus do not affect national CDR targets. For example, in cement and steel production - two sectors historically considered as “hard-to-abate” - emissions can be captured and stored and thus prevented from reaching the atmosphere. For diffuse sources of emissions, such as in agriculture or aviation, the elimination of emissions relies either on major behavioral and consumption shifts or on major technological breakthroughs (e.g., in battery technology for electric aircraft). And only where these turn out infeasible after trying every other option, removals may be used to balance out any residual emissions. We urge that the quantification of the needed carbon removals becomes reliant on precise definitions of “hard-to-abate” emissions and the careful assessment of alternative mitigation strategies, including demand-side ones. In the future, what is “hard-to-abate” will need iterative renegotiation from a technical, political, and economic perspective, considering currently unforeseen innovation, regulated market solutions, and societal transformations.

Text Box 2: Define “Hard-to-Abate” Carefully!

Worldwide, public support for broad policy mandates is uncertain and levels of awareness of CDR are low (Cox et al., 2020; Cummings et al., 2017). Moreover, policies are weakly supported beyond those fostering research and development (Bellamy et al., 2019). Low levels of knowledge mean that public opinion is susceptible to any particular influence. Thus, caution and balance are necessary when communicating risks and acknowledging any concerns, such as regarding over-reliance on CDR. Policies must therefore bring clarity to the intended role of CDR and ensure their long-term need is minimized by limiting residual emissions as much as possible (cf. Text Box 2 above). Early and sustained public participation in decisions surrounding how CDR is to be implemented allows identifying critical narratives early on and allows to co-develop policy designs that enjoy broad and sustained support (Honegger et al., 2021). Finally, policies need to transparently address risks associated with specific CDR methods (e.g., reversal of storage for some methods, double-counting, and potential undesirable biophysical or economic effects of some CDR methods especially at very large scales). Possible solutions include ensuring robust and compatible measuring, reporting, verification, and accounting of results and procedural steps for flagging and preventing adverse side effects (Honegger et al., 2021).

Fundamentally, we – the authors of this White Paper – want to see Switzerland implement a meaningful, coherent, and effective ensemble of climate policies for CDR, that ensures meeting or exceeding its fair share of efforts in keeping global temperatures to well below 2°C or even at 1.5°C and enables other countries to do the same. To obtain broad public support, policies will need to be designed transparently and performed fairly, effectively, and efficiently and in line with sustainable development objectives. We view these conditions as fundamentally interlinked with sustained and broad public support corresponding to a stable policy mandate. Our White Paper seeks to support the next steps toward this vision.

1.1 The Swiss CDR Context

The Swiss Net Zero GHG emissions ambition[4,5] implies a significant need for carbon removals to counterbalance residual GHG emissions e.g., from aviation, agriculture, and industry. This target leaves much room for political and technological developments to influence the distribution of effort between individual methods and the overall "landing zone" for the contribution of CDR compared to absolute reductions in Swiss emissions. As an economically and technologically advanced nation, Switzerland has the capacity to be a leader in CDR development, application, and international support for other countries' CDR efforts – much as it has long done for mitigation overall.

The Swiss Federal Office for the Environment (FOEN) has developed a Roadmap for CDR and Carbon Capture and Storage (CCS)[6] (Federal Council, 2022) addressing several fundamental

[4] Announcement by the Federal Council in March 2019: https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-76206.html

[5] Swiss Climate Act (KIG): https://www.fedlex.admin.ch/eli/fga/2022/2403/de

[6] Carbon capture and storage (CCS) describes the activity of capturing CO_2 (of fossil or biogenic origin) at a point source (e.g., cement plant) and storing it permanently underground or in building materials. If this activity uses CO_2 of biogenic origin (BECCS), CDR is achieved. CDR describes the CO_2-removal from the atmosphere into some form of storage. While the roadmap considers both fossil CCS and CDR, we here focus on the methods that can contribute to negative emissions, namely all CDR methods, including Bioenergy with CCS (BECCS). Please refer to Table A1 in the Annex for more information on BECCS and other CDR methods.

questions on the envisaged role of CDR and fossil CCS on the path to and upon achievement of Net Zero emissions. This administrative document traces the path of CDR first for a pioneering phase up to 2030 and then for a scaling phase (to 2050). Yet, it sets the beginning rather than the endpoint of the Swiss CDR deliberations and policy development. Most notably, it largely omits setting intermediate targets for e.g., 2030 and 2040 and it does not indicate the respective contributions of current and planned interventions to climate neutrality. Insufficient detail on achieving long-term climate targets has successfully been challenged legally in Germany and in the UK before, so this could also be a risk in Switzerland. Also, not all CDR methods with potential in Switzerland (c.f., Table A1 in the Annex) receive equal attention in the roadmap[7]. One reason for this is the variety in opportunities and risks associated with the deployment of different CDR methods in Switzerland as elaborated in a study mandated by TA Swiss (Cames et al., 2023).

While the Swiss Climate Act approved in the June 18, 2023 referendum provides a legal framework for ambitious mitigation efforts and a clear role for CDR, there are several barriers to the encompassing implementation of this policy mandate: the rejection of the revised CO_2 Act in 2021[8] indicated lacking support for climate policy if it is measurably affecting consumer prices. The Swiss CDR roadmap also points to the need for a constitutional amendment in order to, for example, regulate and incentivize a national pipeline system to transport CO_2 for storage inland or abroad. Decisions on policy design will need to be taken at national and sub-national levels (cantons, municipalities), as well as in response to and shaping international policy developments at European Union (EU) and United Nations (UN) levels. Swiss governance is characterized by a very strongly articulated subsidiarity principle, which gives a lot of influence on municipalities and cantons. Many municipalities, for example, (co-)own infrastructures such as sewage treatment plants, utilities, or waste-incineration plants and can thus critically influence investment decisions that could include the capture of CO_2 for storage. Pipeline permitting is in the hands of the cantons. However, CO_2 storage in Switzerland, but also transportation abroad and cooperation with foreign countries will require a dedicated federal mandate that would likely have to be conferred via a referendum.

At the national level, Switzerland started implementing specific policies including a

[7] The roadmap's focus is on CDR pathways involving CCS in Switzerland and direct air capture (DAC) abroad. Please refer to Brunner and Knutti (2022) for estimates of the technical potential and cost developments.

[8] https://www.bafu.admin.ch/bafu/de/home/themen/klima/dossiers/klimaschutz-und-co2-gesetz.html

sectoral agreement with the waste sector for the development of (BE-)CCS capacities, innovation, and technology-development support (e.g., other developments include the projects DeCIRRA[9], DemoUpCARMA[10], and the SWEET call[11]), for the pursuit of pilot and demonstration projects and general technology learning. The Klimarappen Foundation will also provide funds for the scale-up of CDR methods and CC(U)S based on the voluntary contribution of mineral oil importers to offset emissions from motor fuel use from 2005 to 2012. Following the introduction of the legal carbon offset obligation in 2013, the Stiftung Klimaschutz und CO_2-Kompensation (KLiK foundation) – the new carbon offset grouping for fossil motor fuels – has already incentivized some CDR projects on wood[12]. The federal government also has more instruments at its disposal – both technology-neutral (e.g., the domestic Emissions Trading Scheme, of which the amendment is however constrained by its links to the EU Emissions Trading Scheme (EU ETS) and technology- or sector-specific (e.g., waste incineration or construction sectors) that could be tweaked for mobilizing CDR activities (see Chapter 2).

The federal climate and innovation act (KIG) was approved by the Swiss electorate on 18 June 2023[13]. It includes a relevant framing for the role and funding of CDR in Switzerland on the path to net zero emissions.[14]

[9] https://www.zhaw.ch/en/research/research-database/project-detailview/projektid/5392/

[10] http://demoupcarma.ethz.ch/en/home/

[11]https://www.nlt.admin.ch/f/view.aspx?1EE9774CB52EC8585B864E1988DB864EB9A8DCB52EC998AC16994B6593

[12] https://ssh-pbs.ch/projekt-information-senken-projekt/

[13] https://www.bafu.admin.ch/bafu/de/home/themen/klima/dossiers/klimaschutzgesetz.html

[14] For more details on what the KIG entails for CDR, see the CDR Swiss blogpost from just before the vote in June 2023: https://www.carbon-removal.ch/the-swiss-climate-act-vote-2023-policy-at-a-crossroads/

CDR Policy Developments in Europe and the US

The Swiss CDR context does not exist independently of international markets, standards, and regulations. Thus, international developments in regulation and certification, especially in the EU and the US, are determining factors for Swiss CDR pathways. The EU is moving towards an ensemble of policies addressing CDR. The European Commission recently finalized a Carbon Removal Certification Mechanism (CRCF), which is to offer a basis for defining and tracking CDR for potential use toward voluntary market demand, Land use, land-use change and forestry (LULUCF) sector targets, EU ETS compliance, and trading, member states' effort-sharing or other national climate targets. The EU is also further advancing CCS and Carbon Capture and Utilization (CCU) pilots via its Innovation Fund, and by fostering networking and learning among industrial actors through Horizon projects towards the implementation of carbon capture, use, and storage (CCUS) hubs and clusters.

Some countries, such as Sweden, the Netherlands, the UK, Denmark, and the US, have also moved forward in recent years and either already have or are expected to adopt dedicated policies in the near future. Sweden's policies are targeting a single CDR method (BECCS) as within its national circumstances and resource-availabilities, the corresponding industries (pulp and paper and biomass-based energy generation) hold particular relevance. The US, on the other hand, appears to approach CDR methods involving underground storage more decisively – first through its tax break "45Q" and more recently through dedicated research and development (R&D) and piloting investments that seek to build up four major direct air capture and storage (DACS) hubs. Even Germany – previously firmly rejecting domestic CCS – appears to move toward enabling infrastructures for decarbonizing industry and for enabling CDR.

Text Box 3: CDR Policy Developments in Europe and the US.

Instruments for International Cooperation

Different CDR methods have heterogeneous deployment potential around the planet. Switzerland does currently not have the capacity for large quantities of storage, as the possibility of underground storage of CO_2 within Switzerland remains highly uncertain. Hence, developing policies on CDR methods requires not only understanding the domestic potential of different methods to remove emissions durably, but potentially establishing international cooperation when the conditions for CDR methods abroad are more favorable than domestically. This could be, for example, in locations with suitable geological formations and an abundance of renewable energy for engineered CO_2 capture processes.

To govern the international CDR regime, principles will emerge from a "context of internationally shared norms that include governance objectives, legal provisions and informal expectations, and societal expectations" (Honegger et al., 2022). International policy instruments to leverage CDR are emerging, for example, from within the Paris Agreement. The rules in Article 6, agreed at the United Climate Change Conference COP26[15], pave the way for carbon markets and other forms of international cooperation on emissions reductions and – potentially – removals. An amendment thereof to explicitly include CDR was proposed, but not yet adopted, at COP27. Accordingly, the Swiss government has started conversations with northern European countries to cooperate on the topic of transborder transportation and storage of CO_2 and – potentially – buy removals from Direct Air Capture and Storage (DACS) projects. For this, Switzerland can build on the experiences from the eight existing Article 6 agreements to purchase offsets (not CDR) for compensating for emissions of fossil motor fuels from twelve countries, including Peru, Ghana, and Georgia.

1.2 Ethical Considerations

"Forget neither those suffering from climate change nor those threatened by CDR itself. That is the central challenge in thinking about the ethics of CDR." – Christian Baatz[16], 2022

Ethical concerns and questions regarding long-term side-effects are central to discussions of CDR. One major concern has been whether CDR would slow emissions reduction efforts (so-called "mitigation deterrence") and how this may be avoided. Since the 2018 Intergovernmental Panel on Climate Change (IPCC) 1.5°C special report (IPCC, 2018), scientific research has emphasized the necessity of CDR to reach climate targets. Such acceptance has shifted the focus of ethical discussions toward the justice implications of CDR implementation policies, especially at large scales. In Switzerland, political debates also reflected these normative dimensions – especially regarding its proposed ban on fossil fuels whereby domestic CDR could have been

[15] https://unfccc.int/process-and-meetings/the-paris-agreement/the-glasgow-climate-pact/cop26-outcomes-market-mechanisms-and-non-market-approaches-article-6

[16] https://twitter.com/CDRterra/status/1593526171831975936; Junior Prof. Christian Baatz is an environmental scientist and philosopher at Kiel University.

used to offset CO_2 emissions that do not qualify as "hard-to-abate".

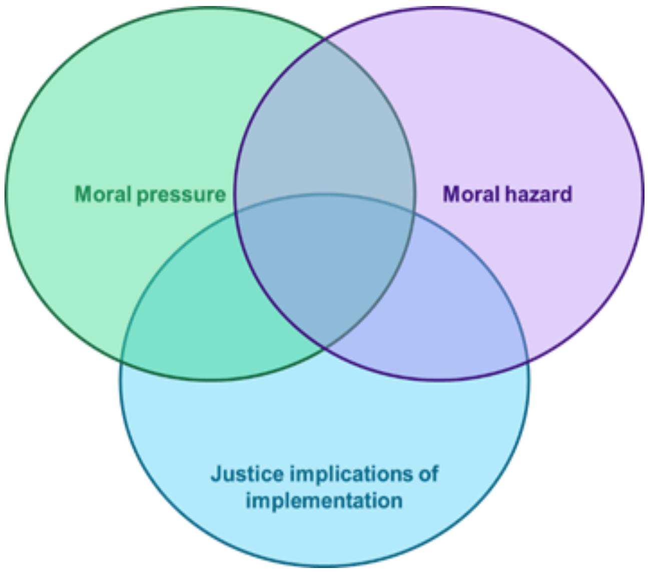


Figure 2: Structuring Ethical Concerns in Current Debates (Schübel, in Prep.).

Figure 2 proposes a structure of ethical concerns in current debates on CDR: "moral pressure", "moral hazard", and "justice implications of implementation" (Schübel, in preparation). All three dimensions need attention, including their intersections to enable fair, sustainable, and politically viable CDR scale-up. In the following, we will give a more detailed account of the three dimensions – and introduce the concept of adaptive governance for navigating long-term uncertainties and risks in policymaking.

1.3 The Dimensions of Ethical Concern

Moral Pressure	Moral Hazard	Justice Implications of Implementation
The urgency of the climate crisis, its current and future risk of harming people, the responsibility to save others from harm, and the responsibility to comply with climate targets, result in moral pressure for CDR action. Yet, uncertainties with regard to potential side-effects and trade-offs associated with CDR must be weighed against the urgency of implementing CDR. Some environmental, social, and policy risks for outcomes may be delayed and hard to identify. The moral pressure to act quickly is in tension with the requirement for well-deliberated decisions.	A case of moral hazard and mitigation deterrence occurs "when consideration of a climate intervention introduces the prospect of reduced or delayed mitigation, in comparison with a situation without such introduction or consideration" (Markusson et al., 2018). The burden of action should not be shifted to future generations based on uncertain socio-technological pathways. Separate targets for CDR and ambitious emission reductions are a basis to mitigate moral hazard[17]. This includes a societal debate on which emissions count as hard-to-abate.	CDR implementation involves negative and positive effects, which should be distributed fairly. Intergenerational and global distributive justice arise from sustainability challenges in large-scale CDR deployment: Impacts on food production, soil degradation, energy poverty, and biodiversity. Procedural justice issues emerge in transformation processes and when risks are imposed on disadvantaged groups without including them in relevant decisions. Justice concerns can also arise in the case of concentrated profit-taking, e.g., profits by historical polluters and windfall profits at the expense of the public (e.g., in the case of subsidies)

Table 1: The Dimensions of Ethical Concern.

[17] The main measure proposed to minimize moral hazard consists of assuming mitigation pathways with low amounts of CDR. Separating CDR and emissions reduction targets can also help achieve climate strategies that are robust to CDR failure and can enable deeper decarbonization (Grant et al., 2021; McLaren et al., 2019).

Swiss policymakers will always be confronted with uncertainties and risks associated with CDR (c.f. Cames et al., 2023), which give rise to moral pressure, moral hazard, and hard-to-foresee justice implications of their policies. Balancing benefits and risks is complex and essentially a function of social and political cultures, as well as local ecosystem conditions. What is needed now are policy decisions that show awareness and balance planning security with safeguards about these challenges – both in an international and the Swiss context.

2. Short- to Mid-Term Policy Pathways to Reach Net Zero Emissions

In this chapter, we assess policy needs and pathways both in the short-term, until 2030, and in the mid-term, until 2050, leading to Net Zero emissions in Switzerland. While for the short-term horizon, we compile a list of necessary steps to prepare the ground for CDR, for the mid-term horizon, we explore alternative policy pathways stemming from distinct climate governance models. Finally, we discuss optimal mixes and sequences of these distinct pathways for the case of three distinct CDR methods, namely PyCCS/Biochar, BECCS, and DACS.

2.1 Policy Needs of CDR Methods in Switzerland

With its 2050 Net Zero GHG emissions target, Switzerland implicitly committed to deploying CDR to counterbalance those residual emissions that cannot be eliminated (Geden and Schenuit., 2020). This means that, in the short-term, Switzerland must focus in parallel on decarbonizing its society and on developing the sociotechnical apparatus needed to enable sufficient carbon removals to balance all remaining emissions by 2050. The national CDR needs are identified in the newly released CDR roadmap (The Federal Council, 2022), which maps CDR and CCS deployment milestones for two phases, a "*pioneering* phase" (up until 2030) and a "*scaling* phase" (up until 2050). According to the roadmap, Switzerland should yearly capture at Swiss point-source and store around 7 MtCO_2/year via CCS by 2050. Out of this, 5 MtCO_2/year count as emissions from fossil and geological sources that are avoided, while 2 MtCO_2/year of biogenic origin count as CDR, thus contributing to negative CO_2 emissions. An additional 5 MtCO_2/year of negative CO_2 emissions are to be achieved via CDR abroad (e.g., in Iceland). The role of further CDR methods implemented within Switzerland is not quantified in the roadmap.

First estimates found that the roadmap's CDR targets are in line with the domestic potential for carbon removal (Brunner & Knutti, 2022), which consists mostly of agricultural practices enhancing primary carbon sinks (e.g., agroforestry, regenerative management practices, etc.), biomass-based carbon removal methods (prominently BECCS and biomass use for the building sector), CO_2 storage in building materials, and enhanced rock weathering. Yet, this potential is constrained by economic and socio-political factors. The Swiss CDR roadmap, thus, foresees only about 2 MtCO_2/year by 2050 to be removed via CDR domestically, with the remaining 5 $MtCO_2$/year to be removed abroad via DACS. We build on the rationale and assumptions of the roadmap in regard to the number of residual emissions to be balanced, the predominance of engineered methods, and the potential of storage abroad. As a result, we take into consideration a broad set of CDR methods, both domestically implementable or realized via bilateral agreements, when assessing Switzerland's policy needs and pathways. Cames et al. (2023) provide a list of recommendations for the regulation, financing, and planning, and de-risking of several CDR methods for Switzerland.

Yet, the potential for CDR in Switzerland and the reliance on it to meet Swiss long-term targets do not suffice for CDR to spontaneously happen. We identify a list of CDR policy needs for Switzerland to eliminate barriers hampering the fast development and scale-up of CDR needed to enable the roadmap's vision and visualize them in Figure 3.

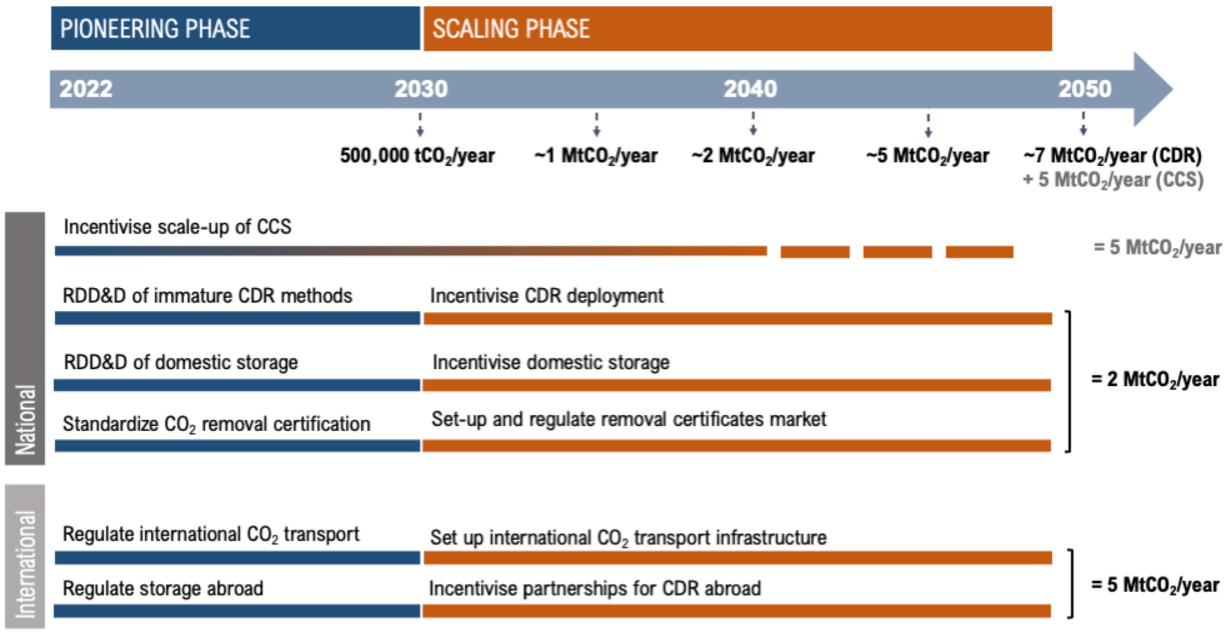


Figure 3: Policy needs, identified by the authors of this White Paper, following the Swiss CDR roadmap (Federal Council, 2022), are divided by phase (pioneering vs. scaling) and geographical scope (national vs. international) for both CCS and CDR deployment (own figure).

In the *pioneering* phase in the Swiss context, policies need to:

1. **Incentivize the scale-up of CCS especially from biomass sources** by reducing risks for project developers and investors. While CCS will only enable negative emissions if the carbon is captured from biogenic sources (including waste-to-energy plants), it can help to pave the way for CDR deployment. Policies enabling CCS can build up both regulatory frameworks and infrastructures (e.g., pipelines for CO_2 transport to storage sites abroad) needed for future CDR deployment, and assess, test, and demonstrate domestic geological storage options. Moreover, the more CCS is deployed in industries that have limited alternative options to abate emissions, the smaller the reliance on CDR to meet net neutrality will be (cf. Text Box 2).

2. **Explore and assess novel CDR methods** and **improve the performance** of more mature ones e.g., their cost, supply chain emissions, and process efficiency. Moreover, R&D policies should promote experimenting with different types of domestic CO_2 storage options (including exploring options for underground storage as well as storage in stable products

such as concrete) to better understand their potential and limits.

3. Develop **standards and regulatory frameworks** guaranteeing that CDR projects deliver permanent removal of CO_2 based on full lifecycle assessments and robust standards for monitoring, reporting, and verification. Moreover, environmental and sustainability criteria should ensure that CDR deployment minimizes unintended consequences for the environment and preserve incentives to deter mitigation.

4. **Engage with other countries** on future CDR imports and CO_2 transport to meet the roadmap's reliance on CDR development abroad. Moreover, clear plans on how CO_2 transport will look in the future are needed to de-risk long-term investments in infrastructures and transport contracts.

5. **Support the creation and maintenance of niche markets**, first for already scalable technologies, and later for emerging technologies. The roadmap foresees, in fact, around 500,000 tCO_2/year of CDR to be deployed already by 2030. Policies should create incentives for short-term deployment while mitigating risks for investors and project developers, thus tackling both supply and demand of CDR. The goal of such policies is for example to create protected markets in which CDR can be traded, develop business cases for a wide range of CDR options, and incentivize and de-risk supply e.g., by ensuring the purchase of CDR at fixed prices.

In the *scaling* phase, Swiss policies need to overcome the substantial challenge of incentivizing scaled domestic CDR deployment and international CDR trading. In this phase, policies need to:

1. Mobilize **large-scale CDR finance flows** to enable reaching the target quantity of CDR. This should be achieved both by policies increasing the security of the investment environment and by instruments enabling sources of revenues for CDR, such as markets, mandates, or government provisions. In fact, the scale-up of CDR is conditional on the robustness of their business cases, which should not just depend on unreliable and possibly discontinued government support.

2. Revise **legal frameworks** to minimize barriers to the rapid diffusion of CDR and to the scoping of domestic CO_2 storage underground and in soils domestically. As learned from lessons in renewable energy projects, permitting processes should be facilitated and made quick and effective, while having participatory and social characterization elements enhancing the acceptance of new storage projects.

3. **Develop effective instruments** and **stringent standards** for international cooperation on CDR projects. These instruments and standards should minimize risks for the host countries of CDR projects, clarify liabilities, and ensure that double counting does not happen.

Alleviating Innovation Risks

The speed of innovation and implementation required – in combination with long planning cycles usually spanning decades for CDR – comes with ethical and sustainability risks and the danger of stranded assets and technological lock-ins. To alleviate these risks, we propose adaptive policy frameworks combined with iterative learning through pilot and demonstration projects. Decision frameworks should take both environmental and policy risks into account – including concepts from ethics, responsibility, responsible research and innovation, regulation, and liability (Florin, 2022; Sovacool & Baum, 2023). The most relevant risks associated with CDR policy design and best practices to address them are summarized in Table A3 in the Annex.

Planned adaptive governance for example is a policy paradigm that aims at robustness to avoid irreversible damage. It can help to address the trade-offs as those appear after an initial decision is being made and progressive deployment brings new knowledge. Adaptive CDR policies could e.g., allow for modifications in quality requirements, (co-)funding levels, sources of funding, and other key design aspects. The risk of technological lock-ins and stranding assets may be dealt with through transparency provisions and iterative milestones that trigger a repeated mandate to revisit and potentially adapt policy designs. As an example, CDR strategies in the waste and biomass sectors should be planned and adapted in close interaction with other sustainability strategies, such as circular economy and waste reduction.

Piloting and Demonstration Projects

Implementing high-quality[18] pilots and demonstration projects that iteratively grow in scale and scope can further help reduce outcome uncertainties of scale-up scenarios and transformation pathways – and enable investments in the necessary transformation and scale-up of CDR in the first place.

Building on these identified policy needs, we first review, in Chapter 2.2, ancillary and regulatory instruments needed to prepare the ground for CDR deployment at the scale

[18] It is important to ensure the use of high-quality methods that ensure high durability, additionality, verifiability, and safety of the stored carbon (Rogelij et al., 2021), but also the assessment of side-effects and trade-offs. Thus, ensuring that the storage of the carbon does materialize, as techniques prove to be as effective as expected.

compatible with the CDR roadmap. In Chapter 2.3, we then discuss different climate governance models and how they relate to the task of creating niche markets and long-term finance flows for CDR.

2.2 Near-Term Action to Prepare the Ground

The policy needs that we discussed in Chapter 2.1 translate into a series of auxiliary actions, agenda-setting policies, and regulatory frameworks. Here, we discuss how near-term auxiliary actions, to be undertaken in the *pioneering* phase, can prepare the ground for future large-scale CDR deployment, and what they could look like.

1. To enable the deployment of **(BE)CCS**, individual actors and stakeholders should be interlinked and connected in hubs and clusters, especially to exploit synergies for transportation, utilization, and storage of CO_2. Importantly, networks to enable cooperation and participation in EU pipeline plans should be established. Moreover, the government should initiate the process for a referendum giving the federal government, and not cantons, the mandate for coordinating pipelines and storage. The legal framework to enable domestic CO_2 storage should be finalized. Finally, legal mechanisms should catalyze CO_2 sequestration in certain industries, like Waste-to-Energy or biomass, e.g., by increasing the garbage fee in a nationally harmonized way.

2. To **assess and demonstrate novel CDR methods**, R&D policies should develop and demonstrate new CDR methods, further drive down costs and energy intensity of mature methods, and test and assess cross-sectoral integrating methods. The closing of missing links should stand front and center in R&D efforts, such as soil carbon sequestration and domestic CO_2 storage, which are currently being assessed (Das Schweizer Parlament, 2019). Such technology-pushing policies are for example R&D grants, innovation policies, and support instruments for the early stages of diffusion of novel technologies.

3. To **engage with the EU and neighboring countries** like Germany, Switzerland should make bilateral and multilateral agreements on the regulation, financing, and mandating of CO_2 transport (and storage) infrastructure ensuring Swiss access to foreign CO_2 storage sites. To de-risk investments in transport contracts (e.g., long-term rail tank car rental contracts), the Federal administration should develop transport guidance with a clear infrastructure development plan (e.g., specifying when access to pipelines will be granted). Moreover, certification mechanisms should integrate CDR in Art. 6 of the Paris Agreement. Finally, due to the linking of the Swiss and EU emissions trading schemes, a unilateral inclusion of removals in the Swiss scheme will not be

possible. Thus, Switzerland should engage with the EU to influence the terms of CDR inclusion in the EU scheme.

4. To **develop regulatory frameworks and standards**, lessons from voluntary markets should be considered while improving monitoring, reporting, and verification (MRV) practices. Moreover, the Swiss government should engage in pioneering evaluation standards for MRV for all relevant CDR methods. The waste regulation currently affecting CO_2 storage should be reviewed to allow for the development and implementation of a vast array of CDR methods domestically, tackling issues with both the transport and storage of CO_2 and the deployment of biochar in soil. Rules should also be developed to account for CDR that is completely or partly realized abroad, such as DACS abroad, or foreign storage of biogenic CO_2 captured in Switzerland (BECCS). These rules should be mindful of international agreements and the EU Carbon Removal Credit Framework[19], and exploit synergies with it.

5. To **develop niche markets and mobilize early investments** increasing the certainty of future CDR deployments, clearer and more fine-grained targets for CDR deployment should be translated into law. 2030 and 2050 climate strategies should thus set clear mitigation targets, including yet separating emissions reductions from removal targets, and tailoring them to different sectors, building on KIG[20], Art 4. Policy and target milestones beyond the 2030 horizon should moreover allow for iterative planning and public scrutiny. Moreover, public policies should support first movers across all CDR methods by using public tools to share the initial investment risks. Finally, the government should establish the legal basis for contracts-based public sector procurement of CDR, which could provide an initial demand-pull to CDR (building on KIG, Art 10).

[19] See https://climate.ec.europa.eu/eu-action/sustainable-carbon-cycles/carbon-removal-certification_en

[20] Bundesgesetz über die Ziele im Klimaschutz, die Innovation und die Stärkung der Energiesicherheit (KIG), https://www.fedlex.admin.ch/eli/fga/2022/2403/de

2.3 Policy Pathways to Develop and Scale Up CDR in the Short- to Mid-Term

While the way to go for most of the auxiliary and regulatory actions underpinning the CDR Roadmap is relatively clear (as outlined in Chapter 2.2), the fundamental question of how to incentivize CDR projects in the short-term and enable sustained finance flows in the long-term is subject to different answers. These answers stem from different viewpoints on climate governance (called here *climate governance models*) which put the responsibility, economic burden, and risks of climate actions on different actors. A glossary of policy instruments for CDR can be found in Table A2 in the Annex.

Here, we discuss how different climate governance models could tackle the same goal of enabling niche markets for CDR in the *pioneering* phase and sustained finance flows to CDR in the *scaling* phase. We identify three distinct policy pathways that correspond to three distinct climate governance models and could fit different strategies of countries (Harrison, 1998; Pacheco-Vega, 2020). These models are **"Polluter Pays"**, **"Only Carrots and No Sticks"**, and **"Command and Control"** (see Figure 4 on the next page). Under the *Polluter Pays* model, a penalty on CO_2 emissions can incentivize emission reductions while funding CDR to neutralize residual emissions. Using *Only Carrots and No Sticks*, on the contrary, governments directly support CDR via subsidies, substantial R&D spending, and other targeted incentives. Finally, the *Command and Control* model dictates the deployment of (fixed) rates of carbon removal and ensures compliance.

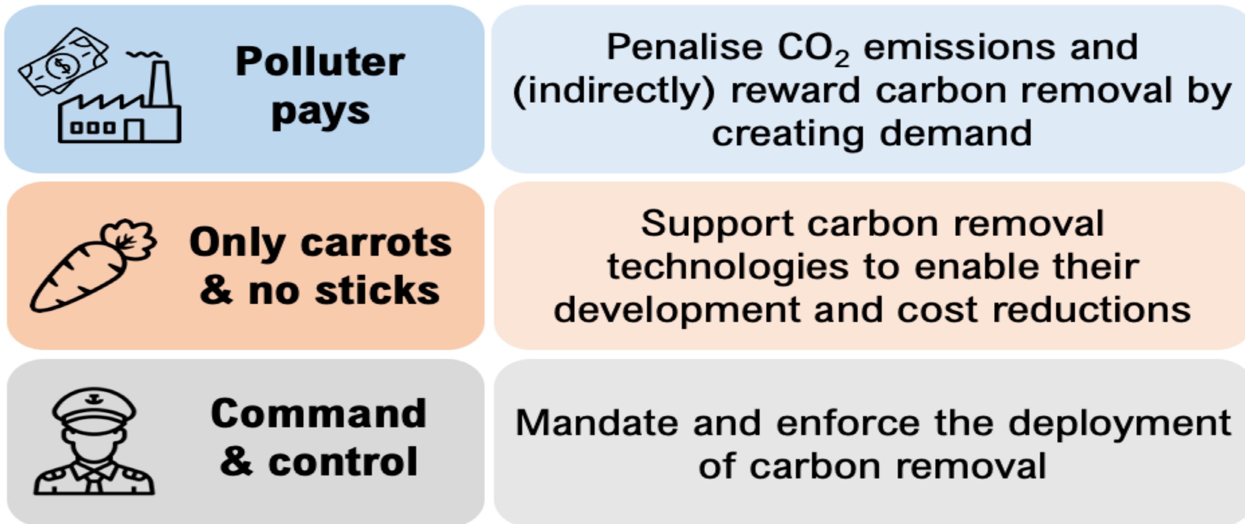


Figure 4: Three Policy Pathways Stemming from Distinct Climate Governance Models.

While policy instruments stemming from these different climate governance models can equally mobilize CDR, the distribution of the costs, risks, and decision-making power to different actors varies between policies. Moreover, they differ in how stringent they are in setting CDR targets, enabling investment certainty, catalyzing the development of less mature CDR techniques, making CDR compete for economic and political resources with other low-carbon technologies, and in their political feasibility and public acceptance. It is thus essential that CDR policies not only consider factors such as their cost-efficiency, but also consider the desirability of outcomes relative to the specific broader socio-political and environmental context they would be embedded into.

In Table A4 in the Annex, we review guiding questions to explore crucial differences between CDR policy pathways.

Moreover, since all approaches come with trade-offs, policies need to be thoughtfully mixed and sequenced. While we discuss optimal mixes in Chapter 2.4., in the following Chapters 2.3.1, 2.3.2 and 2.3.3, we analyze these different climate governance models in an isolated fashion to thoroughly discuss their implications, advantages, and pitfalls. In order to span through a wide range of possible policies, we do not discuss these pathways in relation to the current institutional and regulatory framework, but rather at a more abstract level. While the focus of our analysis is on policies that mobilize CDR, many policies relate to CCS as well, since the development of CCS can pave the way for the CDR method BECCS (e.g., through the set-up of CO_2 transport infrastructures)

The *Polluter Pays* Pathway

2.3.1 The Polluter Pays Pathway

This policy pathway tackles the primary challenge that CDR faces, namely, to create a stream of revenue for CDR. By pricing emissions – and thus letting polluters pay for climate mitigation – this model primarily aims to reduce CO_2 emissions. Whenever emissions cannot be avoided at a price lower than the carbon price, emitters pay the price of their emissions, and revenue is generated.

How Does it Work?

This pathway operates either through a CO_2 levy or an emission trading scheme, or a combination of both, as in the current Swiss setup. In order to incentivize CDR deployment, the economic price of emissions has to overshoot that of CDR. Polluters that cannot avoid emissions either via direct abatement or via point-source CCS pay a price for emissions, generating streams of revenues for CDR. While in the current set-up of the CO_2 levy, the revenues are redistributed to citizens, revenues of the CO_2 levy could be partially redirected towards CDR projects e.g., via public procurement on a competitive basis. However, there are legal constraints to the amount of levy that can be redirected since levies (unlike taxes) need to be redistributed to citizens.

Alternatively, in an emission trading scheme, the flow of finance towards CDR would happen via carbon removal credits, to be traded at the price of emissions credits.

Initially, pricing emissions is likely to mobilize only small volumes of CDR, while acting as an incentive for the decarbonization of the economy. Yet, once cheaper emissions reduction options will be exhausted (e.g., due to the limited availability of biomass or land), a broad range of CDR methods – with higher durability – could be mobilized. Moreover, revenues from emission pricing mechanisms can be deployed to finance public investments in the CO_2 transport and storage infrastructure.

Who Pays?

Polluters carry the price for their emissions. Yet, the design of this policy pathway largely influences which polluters exactly are subject to the pricing mechanism, leading to different distributional outcomes. If CDR is integrated into the emission pricing system, polluters affected by this system will contribute to bearing the cost of CDR deployment and will ultimately pass the costs on to the consumers of the services and products they provide. As shown in a recent UK case study (Owen et al., 2022), applying the polluters-pay principle to all emissions leads to a relatively small percentage of the income spent for CDR, yet it is regressively distributed among households (i.e., the relative contribution of low-income households is larger). Consumers of emission-intensive goods are, in fact, not necessarily the most high-income ones, with the exception of the aviation sector.

What Decisions Are Made and By Whom?

Depending on whether CDR is purchased directly or through the proceeds of a CO_2 levy, ultimate decisions fall on different actors i.e., on polluters or on the government respectively.

If not complemented with technology-specific supply-side policies, this approach remains largely technology agnostic, i.e., it does not explicitly pick winners but allows CDR methods to compete with each other and with other emissions reduction options. If emitters directly purchase CDR credits in an emission trading system, then they will not directly decide where the credit comes from, and which CDR method has generated it. Conversely, in a CO_2 levy, the purchase of CDR would likely be contract-based, and not market-based, and thus decisions must be made. If the policy allows for emitters to avoid paying the CO_2 levy if they counterbalance their emissions with CDR, it will be left up to emitters to purchase CDR directly. In this case, emitters can decide which emission reductions to substitute with removals and what specific type of CDR to deploy. Nonetheless, the government will clearly set out regulatory framework conditions under which CDR can be accounted to elude the CO_2 levy. Alternatively, if CDR is purchased centrally with the revenue of the levy, these decisions will be taken directly by the government, which could engage in reverse auctions to stimulate competition among CDR providers.

In both cases, the government will be involved in decisions on the number of emissions allowed or on the price of emissions. The amount of emission credits ultimately also affects the price at which emission allowances are sold in an emission trading scheme, while the price of a CO_2 levy ultimately affects the number of emissions that are avoided. The amount of demand for CDR under these policies is determined by a theoretical economic equilibrium point between emissions reductions and removals, which is difficult to exactly know ex-ante and control (for further explanation, see Betz et al., 2022). Since the Swiss emission trading scheme is linked to the European one, decisions on reforms and consequently on the price mostly fall within the EU.

What Are the Advantages?

This kind of climate governance model is already established in Switzerland, since both a CO_2 levy and an emission trading scheme, covering part of the current emissions, exist. This policy pathway is attractive since it reflects the dominant climate policy paradigm and would only necessitate amendments to existing frameworks (e.g., dealing with legal constraints in redirecting the proceeds of the CO_2 levy). That would in principle increase its political feasibility, although a high (and thus, likely politically disputed) carbon price is needed to trigger early CDR deployment.

By creating a market for CDR, this pathway has a second, highly beneficial effect: providing a long-term policy signal to CDR project developers and investors, helping to de-risk investments, and creating a competitive environment where CDR suppliers have an incentive to quickly drive costs down.

While it is unlikely that in the pioneering phase – when absolute emissions reductions are a priority and cost-effective solutions abundant – this approach will incentivize the deployment of CDR, it could nonetheless catalyze the development of standards, third-party verification and monitoring practices, and framework regulations for CDR. Moreover, in the near term, this pathway can mobilize the deployment of point-capture utilization and storage, which has beneficial spillover effects for some CDR methods (i.e., BECCS and DACS). In some “hard-to-abate” sectors (e.g., steel and chemical industry), point-source emissions could, in fact, be captured at a lower price than that of a CO_2 levy or emission allowance.

Finally, part of the revenues of the carbon pricing mechanism could be used to finance RDD&D for immature CDR and domestic storage methods (e.g., enhanced weathering) as well as for CO_2 transport infrastructure. By extending the rewarding mechanism to removal certificates issued abroad, this pathway incentivizes the development of CDR abroad which could then be sold in Switzerland, creating an initial niche market from which they can grow and improve.

What Are the Risks?

Two risks can undermine the efficiency of this approach. In an emission trading scheme, price volatility of emission credits might not provide the necessary certainty on revenues that CDR project developers and investors need. On the other hand, a CO_2 levy high enough to incentivize a large range of CDR methods might not be politically feasible. As a result, in both pathways, a race to the bottom to ensure lower CDR certificate prices could crowd out more expensive, yet durable and thus essential, CDR methods. Numerous supply-side policies have been proposed to deal with these risks, yet they do not strictly belong to the *Polluter Pays* governance model and are thus discussed below.

Moreover, this pathway leaves it up to the market to determine the volumes of CDR deployed and to allow CDR to substitute absolute emissions reductions. By basing this substitution solely on cost, it neglects the positive and negative externalities of some CDR methods, such as impacts on the environment and local communities, and could thus lead to non-optimal levels of CDR.

Finally, if CDR is under-supplied, not only CDR costs will be higher, but also emissions that were supposed to be counterbalanced by CDR will ultimately be net positive. This could exacerbate temporary overshoots of climate targets.

The *Only Carrots and No Sticks* Pathway

2.3.2 The Only Carrots and No Sticks Pathway

This policy pathway largely focuses on technology innovation and support, based on a policymaking model that resembles that of the United States, with a goal of advancing the CDR supply domestically and thus establishing an international leadership role. The focus of this policy pathway is mainly on CDR solutions that are currently at a low degree of technological and commercial maturity and that need improvement in order to be scalable. The goal of the policy is not to *pull* demand, but rather to *push* technology. Yet, by pushing technology and making it capable of competing in existing (voluntary) markets, it indirectly affects demand.

How Does it Work?

This pathway consists of technology-supporting, supply-side policies to mitigate market-access barriers faced by CDR project developers and increase investment security[21]. These include for example 1) contracts schemes whereby the government and project developers enter a public-law contract for the provision of negative emissions at a guaranteed price; 2) tax breaks to financially incentivize project developers to produce negative emissions; 3) direct government funding for initial demonstration of CDR, awarded through competitions or reverse auctions.

In the pioneering phase, this type of instrument should first be deployed to remove barriers to the development of CCS and especially BiCRS/BECCS, and to de-risk financing the infrastructure for CO_2 transport and storage. An instrument typically used to finance large-scale infrastructure assets is a Regulated Asset Base. Thereby, the government would grant a license to CO_2 transport and storage developers to charge a regulated price to consumers (i.e., industries with "hard-to-abate" point-source emissions) in exchange for providing essential infrastructure. This enables investors to share some of the project's construction and

[21] For a more in-depth discussion of different supply-side instruments to support CDR, please refer to https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1087918/greenhouse-gas-removals-business-models-consultation.pdf

operating risks with consumers, helping to lower the cost of capital.

This pathway is also capable of creating protected market niches for the early deployment of CDR methods. Direct government funding can initially pilot and demonstrate CDR methods that are not yet at commercial maturity or experiment with different integrated designs and intersectoral linkages. For more commercially mature methods, contracts-for-difference can mitigate the initial investment uncertainty.

At the same time, an array of RDD&D policies is deployed to advance immature CDR methods, such as RDD&D grants and loans, subsidies for pilot and demonstration projects, and public provision of pilot and demonstration plants e.g., through reverse auctions for selected technologies. RDD&D policies also foster the development of domestic storage methods, with grants, loans, and subsidies for research, exploration, piloting, and demonstration.

In the short-term, when infrastructures enabling cheap CO_2 storage abroad are still lacking and domestic geological CO_2 storage potential limited, this pathway should also tackle, through grants for public procurements and subsidies, the development of CDR methods that do not rely on geological storage (e.g., enhanced rock weathering, CO_2 storage in concrete, biochar) and of CDR technology components that can produce CO_2 and other byproducts (e.g., DAC). Contracts-for-difference, tax breaks, and other types of subsidies are especially useful for the latter since there are niche markets for CO_2 usage (e.g., synthetic fuels, fizzy drinks, and in greenhouses) that they could access – if helped to overcome market access barriers. While not enabling negative emissions per se, this approach would advance the maturity, energy, and cost efficiency of components of CDR methods (e.g., the direct air capture of CO_2).

In the scaling phase, technology support instruments could be further deployed to stabilize the price of CDR and share risks. Yet, the volumes of government direct support need to decrease with increasing capacity installed. Since the cost of some CDR methodologies will decrease due to technological learning and economies of scale as their deployment rates increase, the conditionality of government support of their survival in markets should decrease.

Who Pays?

The government, and hence taxpayers, bear the burden of technology support policies. This approach has been found in a study conducted in the UK (Owen et al., 2022). In order to share the cost of CDR, most equitably is financed through progressive revenue taxes.

What Decisions Are Made and by Whom?

The government takes decisions on the support that is given to technologies, especially on which technologies to support, under which circumstances, and how (e.g., via subsidies, tax credits, contracts for differences).

What Are the Advantages?

This policy pathway specifically tackles the near-term barriers faced by CDR developers and investors, such as price volatility, large initial investments, risky investments in infrastructures, and lack of funding for testing and demonstrating different approaches. Moreover, it offers the government the chance to steer the deployment of CDR towards promising techniques, and not just the cheapest ones, by leveling out the playing field with other cheaper carbon removal techniques and driving fair competition.

Finally, the pathway has the potential of being largely supported by the public and hence accepted by politicians, as subsidies usually enjoy broad public acceptance (Bellamy et al., 2021). Subsidies are in fact the most supported policy instruments since they provide positive incentives rather than restricting actions (negative incentives) (Huber et al., 2020). As long as the financial burden to taxpayers remains low (i.e., by phasing out subsidies when installed CDR capacity increases), it is likely that this scenario would cause less public backlash compared to the *Polluter Pays* pathway or even the *Command and Control* pathway.

What Are the Risks?

This policy approach does not offer a solution to the long-term lack of revenues for CDR. On its own, this pathway thus fails to expand the demand for CDR, leaving it to companies to voluntarily offset their emissions. Voluntary markets are yet unlikely to scale to the CDR volumes necessary to meet the multi-megaton scale, i.e., several million tons of CO_2 per year (Höglund & Mitchell-Larson, 2022). The effects of the policy pathway in complying with strict climate targets are hence uncertain and the subsidies will likely need to be gradually substituted with mandates and clear CDR targets.

Moreover, the degree of governmental spending on CDR technology development and deployment would heavily weigh on the national budget, and hence burden taxpayers. As a likely consequence, the degree of public support for this policy pathway can decrease if the magnitude of the subsidies is substantial, and thus the perceived burden on taxpayers is high.

The *Command and Control* Pathway

2.3.3 The Command and Control Pathway

The last pathway foresees a strategy to ensure that CDR is deployed independently from its cost efficiency relative to other mitigation strategies, making projections of demand more reliable and thus increasing the attractiveness of investments. Moreover, through clear mandates of emissions reductions and removals, substitutions between the two should not happen and thus climate goals are less at risk.

How Does it Work?

This pathway operates through stringent and enforced emissions targets, tailored by sector and with measurable in-between milestones to track progress.

In the pioneering phase, ambitious emissions standards tailored to different sectors could be set so that they can only be met with the help of CCS or small amounts of CDR. In sectors with point-source emissions, such as the waste, biogas, chemical, steel, and cement industry, these standards would catalyze the deployment of CCS as well as the development of infrastructure for CO_2 transport and storage. In the cement industry, moreover, emissions standards should be set so that they catalyze the CO_2-curation of concrete and thus CO_2 storage in buildings and roads – without de-incentivizing other reduction efforts. For sectors that cannot capture emissions at the point source, such as agriculture and aviation, emission standards could act as initial niche markets for the development and deployment of more mature and domestically available CDR methods.

In the scaling phase, emissions standards are progressively accompanied by mandates, such as carbon take-back obligations. Take-back obligations are a novel instrument proposed by some scholars (Allen et al., 2009; Jenkins et al., 2021) mandating a share of emissions to be taken back by polluters via CDR. Take-back obligations require suppliers of fossil carbon to recapture and store an increasing fraction of the carbon in their products. By allowing the carbon to be taken back within a few decades, overshoots of the carbon budget would be remediated within this time frame. To comply with the mandates to take back emissions, governments should facilitate initial investments to set up the CDR infrastructures.

Who Pays?

Like the *Polluter Pays* pathway, the economic burden of CDR is left on emitters, which pass it on to consumers.

What Decisions Are Made and by Whom?

Emitters directly purchase CDR certificates or directly engage in contracts with CDR developers. The portfolio of take-back obligations is defined by government guidelines e.g., to comply with a minimum share of CDR domestically and to support less developed CDR methods. Moreover, the government has the final word on the share of emissions to be taken back and thus can exert control on the pace of emissions abatement, especially if this policy is complemented by rigorous monitoring, reporting, and verification practice.

What Are the Advantages?

This pathway can effectively enable the early adoption of CDR by mandating a share of emissions to be taken back. The fraction of emissions to be taken back could be derived in a physically based manner from the residual carbon budget, offering advantages of simple governance, speed, and controllability, as it prevents carbon costs from exceeding the cost of the most expensive CDR technique. Moreover, the characteristics of take-back obligations can be shaped to catalyze sufficient experience with a wide array of CDR methods and to test their relative merits and flaws before their large-scale deployment is needed. In the short-term, the horizon of needing, eventually, 100% compensation for residual emissions could guarantee investments in less mature technologies that are needed at the margin, such as direct air capture and storage. This certainty in the need for CDR would also de-risk investments, lowering the financing cost for the costly CDR capital and CO_2 transport and storage infrastructure. In the long-term, if take-back obligations were to remove 100% of residual emissions once the carbon budget is exhausted, the burden of repairing overshoots would not be placed on future generations, thus avoiding threats to intergenerational equity.

What Are the Risks?

Take-back obligations risk shaping the technological mitigation portfolio towards CDR, impeding the development of other technologies. In fact, to comply with stringent take-back obligations, companies will be forced to invest heavily in CDR. By doing so, CDR cost could potentially sink below the costly mitigation options needed to curb the minimum residual emissions. This means that no more investments would flow into these technologies, at risk of locking-in long-term into a fossil fuels economy made climate-compatible by CDR. Due to the many adverse effects of CDR on land use, the environment, and local communities, and due to the urgency to phase out fossil fuels altogether, this is often not a desirable outcome. Unlike in most sectors, where high costs of carbon take-backs can be avoided thanks to readily available alternatives (e.g., in the electricity sector, renewable energy sources), hard-to-abate sectors will initially be burdened with the cost of CDR. While this sounds fair, it might sacrifice resources that the sector should invest in developing and deploying alternative decarbonization solutions e.g., methane inhibitors for livestock production and sustainable aviation fuels.

Moreover, as for most strict regulatory instruments, we hypothesize that such a mandate would receive mild political and public acceptance: to our knowledge, no government or company has yet implemented such a policy, suggesting that political feasibility and alignment with overall strategies may be low.

Finally, with carbon take-backs, the financing of CDR solely relies on the permanence of fossil fuels. However, if non-CO_2 emissions such as methane continue growing, the carbon budget will shrink, and solely offsetting CO_2 emissions will not be sufficient. The scope of takebacks should thus be progressively expanded from CO_2 to also non-CO_2 emissions (e.g., using CO_2-equivalent (CO_2e) emissions or relating the amount of carbon removal not to the stoichiometric carbon in the fossil fuels extracted, but to what is needed to comply with the carbon budget).

2.4 Policy Mixes and Sequences

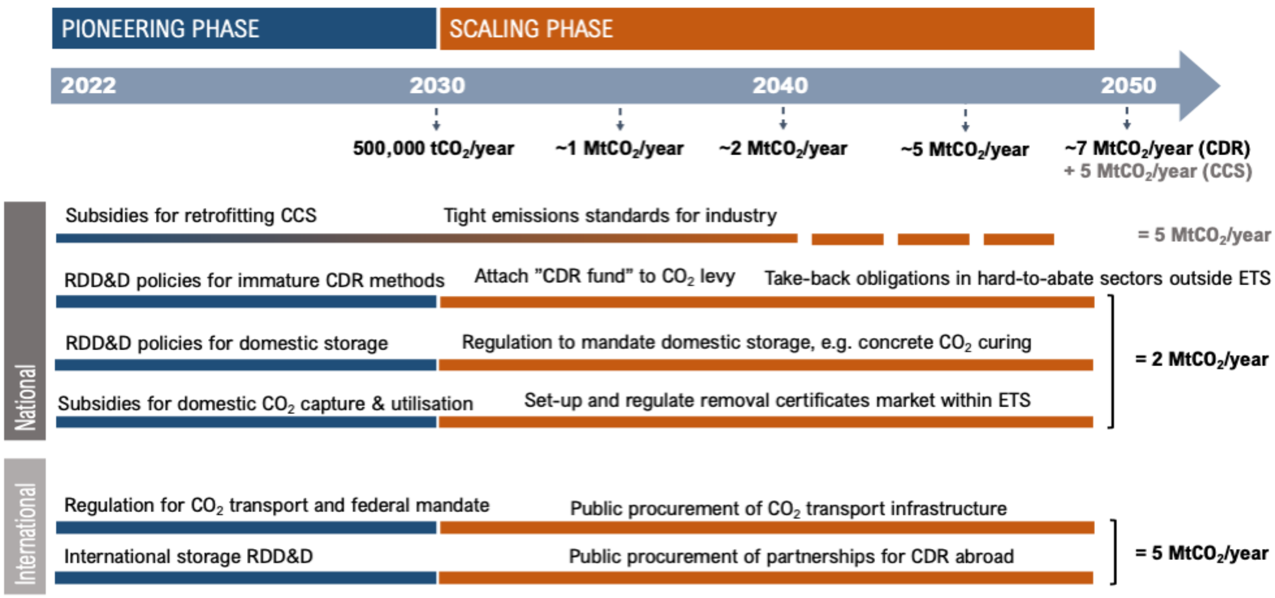
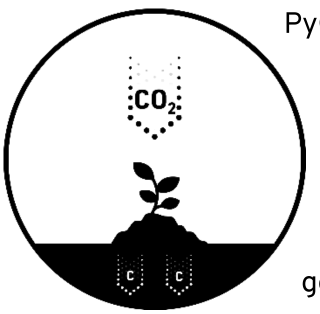


Figure 5: Policy mix and sequencing in the pioneering phase and scaling phase for both national CCS and domestic and international CDR deployment.

Policies of each pathway should be mixed and temporally sequenced to achieve the goal of pioneering different CDR methods, let them fairly compete and develop, as well as enable a rapid scale-up of mature methods to achieve scale in overall carbon removal rates. Importantly, mixing and temporally sequencing policies should be the result of thorough considerations of the function that policies need to have for each technology and socio-political context. Moreover, policy mixes should be mindful of the differences entailed by different paradigms and leverage them to increment public support and ratchet-up ambition. Based on the identified trade-offs and strengths of each pathway, we identify an example of how to sequence and mix different approaches to optimize their output (Figure 5). This policy sequencing follows the rationale of first going for *Only Carrots and No Sticks*, de-risking investments in early CDR deployment while promoting R&D and subsidizing immature technologies to let them develop and improve. Then, in the second phase, the focus is the integration of CDR into existing climate policy structures, such as the Swiss CO_2 levy and ETS (Polluter Pays pathway). At the same, auxiliary policies and regulations should enable storage and transport, domestically as well as abroad. Finally, as CDR methods get cheaper, the strategy could switch towards mandating CDR through both tight emission standards and take-back obligations (Command and Control pathway).

2.4.1 Pyrogenic Carbon Capture and Storage (PyCCS) / Biochar – Policy Mix Example



PyCCS is currently the most mature technical CDR methods solution. There are regulations in place from the Swiss government for compensation projects[22] and a proposal for an EU certification framework for CDR (European Commission, 2022). Most of the biochar projects are currently traded on the voluntary carbon removal market, where they have the largest market share and achieve average prices of ca. 160 \$/t-CO_2 (as of February 2023[23]). A number of programs (e.g., by CarbonFuture or First Climate[24]) and standards (i.e., the Verra biochar methodology) offer biochar-based CDR products on the voluntary carbon market, and new institutions are developing carbon standards that only focus on CDR (i.e., Puro and Carbon Standards International).

Under the current Swiss CO_2 regulation, only a max. of 8 t/ha is allowed in soil, projects must comply with the "Swiss Fertiliser Regulation" (Annex 3 of the regulation), the land has to be formally registered in the land register (Para 8a) and permanence is defined at a minimum duration of 30 years (Para 5.2). Those requirements and also the published fact sheet[25] show that albeit supporting biochar projects, the Swiss government is currently cautious with its application in soils. However, recent research found that risks related to CDR utilization in Switzerland can be controlled and that consequent use of pyrolysis for organic residues would offer a carbon sink of up to 4 million t CO_2eq until 2050 while significantly reducing net agricultural emissions and nitrogen losses (Schmidt et al., 2021).

However, today biochar utilization is not yet economical, even when accounting for the trading of resulting carbon removal certificates.

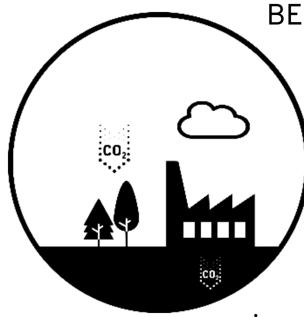
[22] Ordinance SR 641.711 of 30 November 2012 for the Reduction of CO_2 Emissions (CO_2 Ordinance), https://www.fedlex.admin.ch/eli/cc/2012/856/de
[23] Price per method taken from https://www.cdr.fyi
[24] First Climate PyCCS projects: https://www.firstclimate.com/co2-speicherung-durch-pflanzenkohle?lang=en
[25] https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/faktenblatt-pflanzenkohle-2022.pdf.download.pdf/D_Faktenblatt_Pflanzenkohle.pdf

In fact, 1 ton of biochar costs around 1,000 CHF today and removes up to 3 tons of CO_2, leading to a revenue of only 450-500 CHF from carbon removal certificates. Only if all benefits of biochar (i.e., reduced nitrogen losses, improved animal husbandry, and soil fertility) and its production process are accounted for (e.g., heat and electricity of the pyrolysis production) the application for farmers in soil may be attractive. Well-designed funding for further technical development and the integration of PyCCS in agriculture is thus necessary to enable PyCCS in Switzerland, such as a price on nitrous oxide emissions from agriculture (Brazzola et al., 2021). Furthermore, business cases would profit from accounting for agricultural co-benefits of biochar usage, including emission reductions (e.g., of methane), i.e. by "insetting projects".

Given the current administrative restrictions of biochar applications mentioned above, it is questionable if there will be any biochar compensation projects in Switzerland, as the price differences between compliance and voluntary market are negligible today. Biochar projects may therefore be more attractive for the voluntary market – which would not allow the Swiss government to account for those removals in their inventory – or biochar use in building materials, which is a new application area included in the current proposal for the revised CO_2 ordinance.

Finally, trade-offs with regard to sustainable sourcing of biomass for biochar production require attention, as also the accounting of the above-mentioned co-benefits. Higher quality wood needs to be used in a cascade first as construction material and only pyrolyzed later. Incentives need to be set by regulation or by market mechanisms in a way such as to enable cascading and that the co-benefits are all accounted for, thus that biomass ends up in the place where it will provide the highest social benefit for Switzerland and not where the willingness to pay is the highest or subsidies provide distortions (e.g., due to renewable energy support for wood incineration plants).

2.4.2 Bioenergy Carbon Capture and Storage (BECCS) – Policy Mix Example



BECCS has the potential to create more than 2 million tons of negative emissions in Switzerland, using a CO_2 capture process that is already technologically mature. The Swiss government acknowledged the importance of BECCS through its agreement[26] with the association for waste-to-energy plants (VBSA) in March 2022, committing to capture and store at least 100,000 tCO_2/year by 2030. However, further steps are needed to provide confidence to emitters such as biomass incineration plants, biogas plants, or waste-to-energy plants to act now. Two major challenges currently prevent the industry from kick-starting: 1) a lack of viable revenue models and 2) high cost mainly due to limited transport options.

Whereas countries like Denmark, the Netherlands, Norway, Sweden, or the US reward first-movers mainly through subsidy schemes, Switzerland currently does not provide any dedicated support. In the short-term, several levers could help improve overall market conditions. While the voluntary carbon market can be a helpful catalyst, it is unlikely to lead to the necessary scale. Furthermore, de-risking mechanisms like demand guarantees or guarantees for storage contracts could improve the confidence of emitters to implement BECCS projects. Finally, the Swiss government could take a more active role in initiating and coordinating efforts to implement a CO_2 pipeline within Switzerland and connect it to international pipelines. The latter will not only motivate BECCS players but also CCS players for hard-to-abate sectors.

To achieve the scale required in the Swiss climate strategy in the mid- and long-term, policy mechanisms need to be enabled by the Swiss climate law. These can be demand- or supply-side interventions: demand-side interventions stimulate the demand for negative emissions from the public and private sector, securing revenue models for BECCS projects, either through a voluntary or a compliance approach. The challenge in a limited-scale voluntary market is to get long-term large-scale commitments to provide investment security for projects. The government could introduce obligation schemes, which require corporations to compensate for part of their remaining emissions with technical carbon removal certificates. Furthermore, for the specific case of waste-to-energy plants, revenue streams could come from higher direct prices to consumers (e.g., increased fees for waste rubbish bags). Supply-side interventions provide government support to project developers. This could build on the aforementioned short-term measures, such as revenue guarantees. Another option is tax credits relating to the invested capital or the profit per tCO_2. A similar financial vehicle to the recently approved USD 1.16 billion Danish CCS

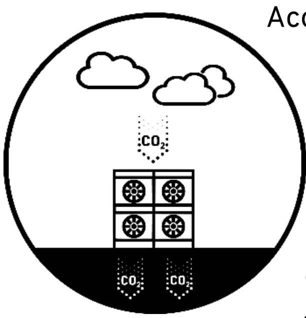
[26] https://www.bafu.admin.ch/bafu/de/home/themen/klima/fachinformationen/verminderungsmassnahmen/branchenvereinbarungen/vereinbarung-kehrichtverwertungsanlagen.html

project fund could invest in the first large-scale plants. Other options inspired by other countries include reverse auctions in Sweden, SDE++ in the Netherlands, or the European Innovation Fund.

Becoming a leader in BECCS could offer economic opportunities for Switzerland. In the mid-term, a large industry will emerge around CCS and CDR (incl. BECCS). So far, however, Switzerland has not placed itself in the pole position as an industry leader.

A White Paper by Airfix/Southpole provides detailed recommendations on how to address prominent barriers to scaling BECCS in Switzerland, with a focus on market incentives and CO_2 transport networks (Airfix, 2023)

2.4.3 Direct Air Capture and Storage (DACS) – Policy Mix Example



According to the Swiss CDR roadmap, Switzerland will likely rely on a relatively limited volume of DACS deployed abroad to meet its Net Zero emissions target, possibly reaching up to a few million tons of CO_2 removed per year. While this amount of DACS is far from the climate-relevant scale, Switzerland can have a significant role in initially pushing the technology and improving the performance of DACS and thus enable it to eventually scale up to the gigaton scale globally.

DACS faces three main challenges in the short- to mid-term: its low level of commercial maturity and its high costs and energy intensity, and the lack of financially viable business models. In the short-term, the focus is to develop and demonstrate the least mature component of DACS (namely, the direct air capture module) and buy down its cost. One potential policy option is direct government support for capture technology, such as government grants for R&D, pilot, and demonstration projects. Other options include government purchases of DAC credits or indirect support through the creation of additional niche markets. A potential niche market for DAC would be synthetic fuels produced from captured CO_2 from the air, direct use of CO_2 in the food and fertilizer production industries, or carbonization of cement (carbon capture and use with or without storage). Although most of these niches do not lead to Net Negative emissions, they already offer an established market to the DAC end products and thus can be leveraged for the short-term deployment of DAC.

To achieve long-term and large-scale deployment of DAC, several policy mechanisms could be implemented that mobilize reliable revenue streams for removing CO_2. These can be differentiated into market-based policies, contract-based policies, and government interventions. While niche markets for CO_2 use and voluntary markets can play an important role in testing the technology in the near term, comprehensive and sustained policy support is needed in the longer term to scale DACS. This is particularly challenging since DACS does not offer co-benefits but only delivers removed CO_2 (McCormick, 2021). The primary role of policies is to guarantee a source of revenue to DACS. This can be either from companies and polluters who need to counterbalance their residual emissions under either a voluntary or the compliance carbon market, stringent emissions standards, or a take-back obligation. Yet, even under these framework policies creating a "raison d'être" for carbon removal, policy incentives for DACS are needed to level out its competitive disadvantage relative to other CDR methods. These could include subsidies for DACS (e.g., feed-in tariffs for carbon credits issued by DACS) or regulations that mandate a certain amount of DACS, e.g., under a take-back obligation or government procurement.

Finally, to enable the scale-up of DACS, the regulatory and legal framework to enable underground storage and clarify long-term liability needs to be in place. These issues are, however, being clarified with the increasing deployment of carbon capture and storage, thus paving the way for DACS.

3. Long-Term CDR Policy Visions for a Net Negative Switzerland

3.1 Paradigm Shifts for Sustaining Long-Term CDR

The climate governance models discussed in Chapter 2 ("Polluter Pays", "Only Carrots and No Sticks", and "Command and Control") are implicitly or explicitly rooted in certain socio-economic paradigms. Seriously pursuing a Net Zero GHG goal or even a Net Negative GHG goal may require a change in the predominant climate policy paradigm. In the following, we outline four paradigms, sustainable CDR strategies could draw from:

The *Toxic Waste Removal* Paradigm

The removal of CO_2 from the atmosphere for remediation purposes can be considered under the paradigm of environmental restoration, similarly to how toxic waste is widely treated. Following this, governments would be in charge to contract CDR suppliers to remove the CO_2 overshooting their budget. The obligation per country should be defined under the principles of equity and fairness, balancing historical contributions to global temperature overshoots with the country's economic capacity for its remediation (Fyson et al., 2020). The cost for CDR would entirely fall on the governments and thus on taxpayers. Yet, by adjusting tax progression, the cost of CDR can be tailored to weigh more heavily on large historical polluters.

The *Carbon Debt* Paradigm

The responsibility for historical emissions overshooting the Swiss fair and equitable carbon budget could be alternatively borne by historical emitters. By allowing carbon emissions to be taken-back within a few decades, overshoots of the carbon budget would be remediated within this time frame. This could take the form of "carbon debts" (Bednar et al., 2021). Carbon debts are an extension of carbon pricing in the intertemporal space that caps emissions and enables paying back for overshoots of the cap. Polluters issuing a carbon debt are obliged to remove their emissions in the future at an "interest rate" of carbon debt. The accumulation of the interest rate for all overshooting carbon emissions would ensure that the proceeds from the pricing mechanism are high enough to enable net negative emissions in the second half of the century. Yet, the carbon debt also reduces the risks of relying too heavily on large-scale net negative emissions and deterring mitigation in the short-term, since repaying the carbon debt in the future is more expensive than avoiding it now. An advantage compared to the take-back obligation is that the interest on carbon debt, as for any financial debt, reduces inherent risks, such as the risk of default by carbon debtors.

The *Non-CO_2 Pricing* Paradigm

Another possibility to finance CDR is to require the sectors with residual emissions to directly affect removals. Yet, to enable this, the scope of emissions has to be expanded beyond CO_2 to all climate pollutants. A major source of non-CO_2 pollutants in the future will likely be agriculture, which emits large amounts of methane and nitrous oxide. Aviation too is likely to still have non-CO_2 climate impacts, even if a switch to CO_2-neutral sustainable aviation fuels rapidly happens. The rates of CO_2 removal needed to counterbalance these sectors' emissions are possibly going to be very large (Brazzola et al., 2021, 2022). This can justify their contribution towards the financing of CDR – or the contribution of CDR within the respective sector. A way to operationalize this contribution is to internalize the cost of the needed CDR, better earlier than later, on all residual CO_2 and non-CO_2 emissions via an emission levy. Proceeds of the levy would then flow to CDR providers.

The *Hybrid Governance* Paradigm

In the hybrid governance paradigm, both public regulation and private governance play an important role. Both types of regulation are linked via certification. Previous examples include measures to initiate and support private biofuel certification schemes and to then incorporate them in public regulatory frameworks. This has allowed for altering market behaviors through the hybrid regime in which public and private approaches are closely intertwined (Schleifer, 2013), and involve a wider range of actors. Such a paradigm already appears to develop in the area of biochar, where quality certification by the European Biochar Initiative has created a basis for voluntary carbon market developments and other voluntary uptake of biochar as a soil enhancement with productivity gains in agriculture. Adopting a regulatory basis for direct payments to farmers could further fund scale-up, however, additionality is to be avoided in hybrid policy frameworks.

3.2 Why Think About “Net Negative” Switzerland

Policy decisions to date aim at Net Zero emissions. “Net Negative“ anthropogenic GHG emissions describe a situation where the total amount of CO_2-equivalent (CO_2e) emitted to the atmosphere through human activity is less than the total CO_2e removed.

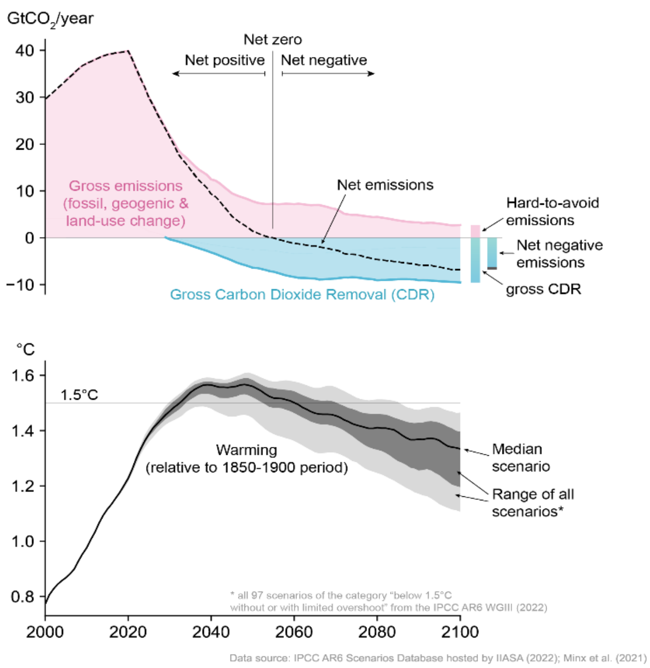


Figure 6: Illustration of net positive, net zero, and net negative CO_2 emissions (top) and the resulting global temperature increase (bottom). Data source: IPCC AR6 Scenario Database hosted by IIASA (Byers et al., 2022) and historical emissions from Minx et al. (2021).

A transition pathway of CO_2 emissions from net-positive (today) to Net Negative post 2050 is illustrated in Figure 6. The transition to global Net Negative CO_2 emissions (Figure 6, top) is a prerequisite for a stabilization or even decline in global mean temperatures (Figure 6, bottom).

For Switzerland, Article 3.2 of the federal climate law (KIG) requires net negative emissions after 2050[27]. In the following, we provide five reasons for Switzerland to aim for net negative anthropogenic GHG emissions:

1. **Net Zero emissions are a point target.** At the latest when this milestone is reached, climate policy needs to move beyond the point target and define a forward-looking strategy to effectively cap global warming in the long run.

2. Due to the unfortunate likelihood of overshooting 1.5°C on a global level, emissions budgets and according GHG concentrations, which imply that, to limit warming to 1.5°C, long-term GHG concentrations need to be lowered through **excess removals**. Some argue that GHG concentrations should even be returned to pre-industrial levels of CO_2e.

3. The final reason why Switzerland may need to pursue Net Negative emissions after Net Zero is due to the **possibility of accelerating climate system breakdown**. Net Negative anthropogenic GHG emissions may need to neutralize an acceleration in the release of GHG

[27] “After 2050, the amount of CO_2 removed and stored through the application of negative emission technologies must exceed the remaining greenhouse gas emissions.” translated from Article 3.2 of KIG, https://www.fedlex.admin.ch/eli/fga/2022/2403/de

from natural reservoirs or help fight other disruptive earth system changes, due to the warming and other disturbances already induced by humans. For example, the thawing of permafrost releases methane into the atmosphere and the melting of polar ice coverage can induce accelerating regional warming or even a disruption in life-sustaining ocean currents. In fact, the North Atlantic meridional overturning circulation, which shapes most of the European climate, is already measurably slowing.

4. **Some countries will struggle more with reaching Net Zero within decades than Switzerland.** Some might even have legitimate reasons to not fully reach Net Zero, such as fair share considerations or emissions related to natural hazards. Certainly, within the 21st century, it will be important – if not a moral obligation considering global equity principles – for some countries to achieve Net Negative emissions in order to allow for others to take more time (Lenzi et al., 2021). This could for example be due to differentiated historical responsibility or capabilities. Further reasons are the responsibility associated with embedded emissions related to import of consumption goods[28], international investments and international flights (McKinsey & Company, 2022).

5. Thinking and acting beyond Net Zero at this early stage is an **opportunity for Switzerland** to strengthen its international leadership role and further its reputation as a pioneer in terms of progressive climate diplomacy, as it has done acting upon Article 6 of the Paris Agreement.

In order to avoid getting stuck in a Net Zero paradigm and planning process, it thus seems important for a climate diplomacy leader such as Switzerland to anticipate and act on the need for a Net Negative economy, built on decarbonization, a reduced consumption of resources as well as CDR.

Net Negative challenges existing paradigms. One reason why a Net Negative policy paradigm may require different solutions to Net Zero is that some policy instruments might no longer work; for example, if the polluter-pays principle is fully utilized to achieve Net Zero, then there may be insufficient funds for achieving Net Negative (an excess in removals): For the

[28] In 2022, McKinsey estimated that imported goods would add another 69 $MtCO_2e$ per year to the Swiss carbon footprint: https://www.mckinsey.com/ch/~/media/mckinsey/locations/europe%20and%20middle%20east/switzerland/our%20insights/klimastandort%20schweiz/klimastandort-schweiz.pdf Klima-Allianz in 2016 estimated the CO_2 footprint of imported goods to amount to 110Mt: https://www.klima-allianz.ch/wp-content/uploads/Climate_Masterplan_Switzerland_EN.pdf

removal of GHGs that were either emitted in past decades, are being released from degrading ecosystems, or are being released by less developed countries, it is more difficult to assign responsibility. Perhaps, the most straightforward approach would be through direct government funding.

The scope matters. Differentiating between Net Negative emissions on a global scale and on a country-level is relevant: If one country achieves Net Negative emissions in a world that still has excess net-emissions of GHG, the negative emissions from the country contribute to mitigation by neutralizing the excess emissions of other countries. In the case of globally Net Negative emissions, global GHG concentrations are expected to fall – unless the release of GHG from natural reservoirs exceeds the Net Negative emissions. Research suggests that, due to natural buffers, net-removals have a lower impact on atmospheric CO_2 concentrations than CO_2 emissions of the same magnitude (Zickfeld et al., 2021). Hence, policymaking and certification frameworks need to account for this – also in comparison to reduction certificates – as the climate system moves into a phase of Net Negative emissions.

4. Welcome to 2065! A Speculative Excursion to a "Net Negative" Future

With this excursion into the future, we invite the reader to speculate with us on how the path to Net Zero and beyond could play out for Switzerland, and how different policies and efforts could interact over the coming decades to reach the milestone of effectively removing more CO_2e from the atmosphere than what is emitted.

Paris+50 – Celebrating a Success Story

In the year 2065, the world celebrates "Paris+50". The host country of the global festivities, Switzerland, is proud to celebrate 15 years since reaching the historic Net Zero milestone in 2050. In 2065, for the first time, Switzerland is estimated to have removed a total of 5 million tons of CO_2 more from the atmosphere than the CO_2e of its remaining annual GHG emissions. Here is a speculative retrospective on the path from 2023 until reaching this goal in 2065:

"Do Your Best, …"

Over the first half of the 21st century, societies had to learn to adapt not only to the changing climate, but also to the uncompromising necessity of emission reductions. In 2065, it is common knowledge and guideline that the costs of internalizing environmental impacts are the lower price to pay. Reductions are the backbone of any mitigation success story. While many sectors achieved market- and regulation-driven decarbonization – thanks for example to rapid electrification of transport and heating – others did require more deliberate government interventions and combined forces of civil society, public and pioneering private entities. This perpetual transformative process has been accompanied by a revolving societal debate on the costs of decarbonization, changing value-systems, and essentially the question which emissions count as hard to abate (and till when) and which must be reduced. Accompanying the phase-out of fossil fuels, profound transformations in the interlinked systems of production and consumption, including an increased circularity of goods and materials, allowed for a reduction of domestic GHG emissions by more than 90% in 2050 compared to 1990. We did our best.

"… Remove the Rest"

With this fundamental milestone achieved, carbon dioxide removal (CDR) has stepped up since the mid-2020s, to fulfill its crucial role for neutralizing the remaining hard-to-abate emissions, thus enabling true climate neutrality.

In 2025, Switzerland pioneered in defining a tight and legally binding target for removals – complementary to emission reduction. What followed was an open deliberation on the CDR methods that would best contribute to that end. At the same time, Switzerland mobilized funding to accelerate the sustainable scale-up of a wide portfolio of promising CDR methods: For example, the first international purchase of DACS credits advanced the scale-up of this approach. Regulatory frameworks designed in close cooperation with innovative practitioners were set to steadily transform key sectors like agriculture and construction from net GHG sources to CO_2-sinks.

The Laws that Saved the Carbon Markets

Until 2027, modular methodologies were developed in the context of voluntary carbon markets as well as for Article 6 transactions under the Paris Agreement. The regulation for measuring, reporting and verification of removals set by Switzerland in close cooperation with the EU set the standards for compliance-related removals and Article 6 transactions – but more than that: A series of forest fires and scandals in cheap afforestation offset markets led to an increase in scrutiny in forestry credits. As a consequence, a set of new standards emerged, combining biodiversity with a concept of "social permanence" with regard to the social and ecological impact of nature-based solutions. Another consequence of the disappearance of underpriced afforestation credits was a push toward CDR methods with inherently durable storage. In this process, the voluntary markets, riddled by a quality and reputation crisis in the early 2020s, happily adopted most of the public sector standards – managing to move beyond the deadlock of lacking transparency, diffusion and "green-hushing" – effectively opening opportunities both for project developers and CSR-managers alike. The methodologies developed in Switzerland and Europe were then also utilized by other governments across the world as a means for credibly tracking achievements in results-based climate finance transactions, for piloting during the late stages of research, and for the development of various novel CDR methods to get ready for participation in mainstream carbon markets.

Infrastructure on the Move

A national referendum in 2026 granted the Federal government sweeping authority for national licensing of a CO_2-pipeline infrastructure. A public long-term offtake guarantee incentivized the provision of CO_2-transportation services, connecting major domestic CO_2-sources with the Rhine port in Basel (and later a German northbound pipeline). The first sectoral agreement in the waste incineration sector which lead to the removal of 100,000 tons with storage in Northern Europe in 2030 triggered numerous countries to copy this approach for an entire sector to take the first steps to decarbonize and achieve removals using a growing infrastructure for Carbon Capture, Transport and Storage (CCTS). The planning and implementation of the required CO_2 infrastructures included citizen participation and elements of public deliberation from the beginning, contributing to procedural justice and public acceptance. Upon approaching the 2030 milestone, a new agreement was devised, which required the entire sector to be equipped with carbon capture installations (or face the arguably higher costs of purchasing domestic CDR credits). The waste-treatment sector, among others, chose to leverage their influential position to follow the "Polluter Pays" principle by raising the levy on trash bags as well as industrial waste. Internalization of reduction and removal costs in the prices of public services and basic products were accompanied by socially just redistribution measures.

Switzerland's Success Is Also a European Story

The EU put in place a rigorous regulatory system for the preferential installment of Carbon Capture, Use and Storage (CCUS) hubs and clusters along with the requisite pipeline infrastructure. Switzerland managed to negotiate access to pipelines in southern Germany, thus finally eliminating the bottleneck of transporting on the Rhine (regularly halted due to low water levels and overheating) and rail. The pipeline network finally came online in 2036 after EU member states agreed on an accelerated licensing process (which was controversial in countries with strong civil society hearing processes). While simplified approval processes were key for overcoming hurdles, it took a dramatic tightening of the EU ETS market (through the market stability reserve) to give a sufficiently clear signal of sustained demand for CCS and CDR services. Industries that did not on their own manage to remain within their allowances purchased CDR certificates, which rapidly became a predictable long-term commitment thanks to the now unambiguously trajectory towards Net Zero built into the EU ETS. Switzerland in short order adopted the same ETS refinements, which had the same incentivizing effect for industrial CDR.

No Silver Bullet, But a Broad and Innovative Removal Portfolio Across Sectors

Until 2030, Swiss production of high-quality biochar through pyrolysis increased from roughly 700 tons per year in 2022 to several tens of thousand tons by 2030. With regulatory obstacles reduced and import regulated, several competitors emerged, combining biochar production (for use in agriculture and beyond) and heat for regional heating and electricity generation with additional carbon removal. Recognizing a large growth market, new fertilizer products including high-quality biochar have emerged. Manufactures of (partly autonomous) tractor equipment were quick to also develop equipment for biochar distribution, carbon-optimized soil-treatment and monitoring of soil carbon content that boosted both the measurability, trust, and scaling of carbon farming. While this development was initially driven by rising demand on voluntary carbon markets, policies led to greater quality control and comparability. Thus, trust and long-term demand increased, as the land-use sector became subject to its own increasingly stringent emission cap gradually approaching zero net-emissions. Additional sector agreements resulted in rapidly growing demand for domestic wood biomass. To ensure a sustainable use of biomass, a well-coordinated portfolio of incentives was put in place. This ensured a meaningful cascading use of biomass from higher order (e.g., construction with wood also lowering requirements for cement) to lower order uses (e.g., production of biochar with energy use and CCS or waste incineration with energy use and CCS). The cascading use of biomass with CDR was gradually integrated in an efficient multi-criteria management of this precious resource, ensuring biodiversity benefits and other ecosystem services next to climate mitigation.

Article 6 as a Vehicle for Increased International Cooperation

Swiss pioneering of Article 6-based CDR across the world starting in the mid-2020s and continuing to scale beyond the 2030s, had a large effect well beyond its imminent outcome of CO_2-removal: Article 6 transactions by ambitious parties copying Switzerland's approach allowed international cooperation and overcoming the demand-pull gap (that would have meant a very deep valley of death) and paving the way to riding down cost-curves. Like this, Article 6 transactions became the global default approach to scaling CDR globally by the late 2030s. This allowed more and more countries to include their domestic CDR potentials as part of their Nationally Determined Contributions (NDCs). Initially, critical voices among heavily-emitting industries in Switzerland quickly realized that they would face much greater costs and regulatory uncertainty if they did not support a mixed approach which included the possibility of high-quality offsetting.

Net Negative Emissions: Reparation and Recovery

By the 2040s, Net Zero emissions in Switzerland were slowly but steadily approached, as regulatory and market processes had established decarbonization trajectories across all sectors. At the same time, the international debates towards taking responsibility for historical and indirect emissions heated up. This put a fair international distribution of burdens and costs higher up on the international agenda. A series of devastating heatwaves with hitherto unseen numbers of excess mortality and destruction of livelihoods further stressed the necessity for international solidarity. In this context, it became an inevitable next step for Switzerland and many other countries, to set a Net Negative GHG emissions objective for 2065. Excess removals have been realized by (1) successfully decarbonizing formerly hard-to-abate sectors with innovative approaches, (2) expanding existing CDR infrastructures and international partnerships where sustainably sensible, (3) incentivizing the restoration of ecosystems and (4) further adaptive transformation of soil management, with a focus on biodiversity, food security and the long-term carbon sink capacities of ecosystems and soils.

5. Conclusion

Mobilizing CDR in Switzerland is an indispensable yet challenging task that requires the formulation and implementation of policies. As elaborated in Chapter 1 of this White Paper, policies are necessary to achieve several objectives, including providing public benefits, reducing economic costs and uncertainties, and promoting desirable outcomes for climate mitigation, as well as social, environmental, and economic sustainability. One of the major challenges in developing such policies is the still limited public awareness of CDR in Switzerland, which highlights the importance of policies that clearly define its intended role. The planning process launched with the Swiss Federal Council's communication (referred to as the CDR roadmap) represents the beginning rather than the end point of the Swiss CDR deliberations and policy development on the municipal, cantonal and federal level. International policy developments in the US, Sweden, the Netherlands, the UK, and Denmark offer insights for possible policy designs in Switzerland. Furthermore, developments in the EU regarding direct funding, certification and ETS reform could be mirrored in Switzerland. Finally, ethical concerns must also be addressed including the tensions between moral pressure, moral hazard, and justice implications of implementation to enable fair, sustainable, and politically viable CDR scale-up.

Chapter 2 explored policy needs and opportunities for CDR towards Net Zero on year-to-decade timescales. In this context, it was outlined that policy designs should consider how socio-political and environmental factors intersect with the profiles of technologies including cost, resource requirements and social impacts. Furthermore, CDR policies may follow one of three policy pathways ("*Polluter Pays*", "*Only Carrots and No Sticks*", and "*Command and Control*"), associated with distinct policy paradigms, advantages, and problems. For CDR to play an effective role in the decarbonization of Switzerland, the definition of which areas are considered "hard-to-abate" at what stage need careful attention and recurring technical assessment and public debate, as well as a consistent mapping in effective policies. Switzerland needs to incentivize the scale-up of emissions-reducing measures (including CCS) and CDR methods across the board and avoid creating undue excuses and delays for some sectors.

With Chapter 2.4, we acknowledge that different CDR methods differ in their technical readiness, need for investment, costs, and ease of regulatory integration – as illustrated with three policy-mix examples on PyCCS/biochar, BECCS/BiCRS and DACS (Chapters 2.4.1 to 2.4.3). Feasibility and scaling potential over time differs between CDR methods. PyCCS, as one example, is already applied today at relatively low costs and traded on voluntary markets. The decentral characteristics of PyCCS allow for the development of creative storage and utilizations of biochar. For a scale-up in the mid-term, regulatory hurdles and open questions regarding side effects and the role of PyCCS in biomass flows need urgent attention. In contrast, the implementation of BECCS/BiCRS is focused on large point sources of CO_2 emissions with a biogenic input, i.e., waste-to-energy, waste-water treatment, biogas, and potentially cement plants using biomass as fuel. Here, major hurdles are currently the high investment costs for the capture unit as well as transport and storage. In the case of DACS, policy instruments and innovation need to focus on building long-term reliable revenue streams for CDR in an international context, while at the same time pushing for innovation with a focus on efficiency gains in costs and energy demand. These case studies illustrate well that a meaningful way forward must involve a policy mix, utilizing advantages of each paradigm, while also attenuating its problems. Policy mixes need to be adaptable over time and tailored to each CDR method's opportunities and challenges – and thus its role within the ensemble of measures toward Net Zero.

Chapter 3 took a step forward by offering a vision of Switzerland in the future having achieved a Net Negative GHG balance, that is, removing more CO_2e from the atmosphere than is emitted. We offer this vision to break with the limitations of not thinking beyond net zero and to clarify why pursuing such an ambitious goal might be our moral duty.

Chapter 4 shows the resulting storyline of how many of the currently moving parts in policy, markets, and technology development could come together to achieve a truly ground-shifting long-term outcome and unlock the new paradigms that may also be necessary to sustaining removals in the long term.

The challenges at hand require perhaps more than ever the constructive cooperation of diverse actors both in Switzerland and internationally – to pull their weight in restoring balance in the shared climate system. There is much work ahead at virtually all levels of society and in all sectors – including an informed public debate. With this White Paper, we hope that the concepts and case studies presented here can pave the way for concrete method-specific roadmaps and policy designs in the Swiss context – in the short-, mid- and long-term – while at the same time ensuring comparability and compatibility in measurement, reporting and verification (MRV) between the CDR methods and between Switzerland and the EU.

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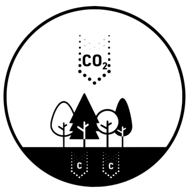
7. Annex

7.1 Table A1: List of CDR Methods With Potential for Switzerland

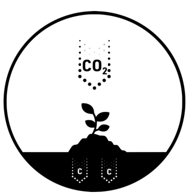
Carbon Dioxide Removal (CDR) methods are human activities that remove CO_2 from the atmosphere and store the carbon permanently outside the atmosphere. Storage can be realized in geological, terrestrial or oceanic reservoirs – or in long-lasting products. The following CDR methods are currently implemented or discussed for application in Switzerland:



Forest Management and Wood Use

Carbon is stored first in the forest ecosystem and timber. Through active and sustainable forest management, the CO_2 uptake of forests can be stabilized or increased slightly. The storage capacity of Swiss forests amounts to approximately 2.5 million tons of CO_2 per year. If harvested wood is used for durable products, the carbon remains sequestered.

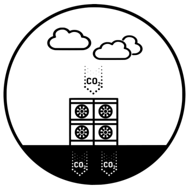
Forests play an important role for the mitigation of climate change, but the potential for scale-up is limited and the impact of climate change itself puts pressure on existing forests.



Soil Management and PyCCS/Biochar

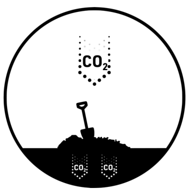
Various approaches can increase the carbon content in agricultural soils, effectively storing CO_2 in the long term. So-called carbon farming methods include high-carbon biochar produced through pyrolysis (PyCCS), agroforestry systems and approaches of regenerative agriculture, such as reduced tillage and crop rotations. Some of these approaches have been in practice for centuries or decades and biochar projects are marketed in the voluntary carbon markets. However, a number of environmental, regulatory, and financial issues need to be clarified before carbon farming can provide CDR at a large scale[29]. See also Chapter 2.4.1.

[29] https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/faktenblatt-pflanzenkohle-2022.pdf.download.pdf/D_Faktenblatt_Pflanzenkohle.pdf



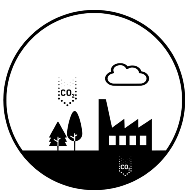
Direct Air Capture and Storage (DACS / DACCS)

Direct capture of CO_2 from the atmosphere is accomplished using chemical or processes that are powered by residual heat or renewable energy. Captured CO_2 is stored in geological formations or durable products. In the short term, direct air capture is unlikely to play a major role in Switzerland, as renewable energies are scarce and geological storage sites are not yet available. However, Switzerland could directly or indirectly co-finance DAC+S projects abroad – and domestic storage could still become feasible in the long term. See also Chapter 2.4.3.



Enhanced Silicate Rock Weathering and Carbon Absorption in Cement

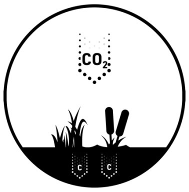
Through weathering, certain rocks naturally absorb CO_2. These processes can be technically accelerated both underground and above ground. Similar processes enable long-term carbon storage in structures: for example, through special processes of concrete recycling with CO_2 absorption. Suitable rock for enhanced weathering is scarce in the Alps. Storage in concrete is already being implemented in Switzerland.



Bioenergy With Carbon Capture and Storage (BECCS)

Carbon Capture and Storage (CCS) describes the activity of capturing CO_2 (of fossil or biogenic origin) at a point source (e.g., cement plant) and storing it permanently underground or in building materials. If this activity uses CO_2 of biogenic origin it is called BECCS or Biomass Carbon Removal and Storage (BiCRS) and carbon removal is achieved: Plants remove CO_2 from the atmosphere as they grow. When biomass is burned or fermented, CO_2 is released again. By integrating CCS into such industrial combustion processes, it is possible to maintain the plant's natural CO_2 removal. In Switzerland, CO_2 capture is planned and tested for example at biogas plants and waste-to-energy plants – with storage of the CO_2 abroad or in concrete. About half of the incinerated municipal waste comes from plant sources (biomass), the other half of the waste is of fossil origin (e.g., plastic). Only the biogenic part contributes to CDR in the form of BECCS, while capturing of fossil CO_2 counts as avoided emissions. See also Chapter 2.4.2. The term ***Biomass Carbon***

Removal and Storage (BiCRS) is used as an alternative term describing BECCS implementation build with a focus on CDR rather than bioenergy (ICEF, 2021).



Maintenance & Renaturation of Wetlands

Peatlands and other wetlands store large amounts of carbon. In Switzerland, there are not many preserved wetlands left. These valuable ecosystems should be conserved for species protection and renatured where possible. The climate change mitigation potential of renaturation consists largely of emissions reductions and to a small, as yet unquantified part in the long-term peat build-up.

7.2 Table A2: Glossary of Policy Instruments

Cap-and-Trade: In a cap-and-trade framework, companies must comply with an emissions limit (cap). If they do not manage to cut emissions sufficiently, they can purchase certificates from CDR providers to comply (trade). This is a hybrid market solution.

Carbon pricing: Mechanisms that place a fee on emitting actors. Carbon pricing includes emissions trading systems (ETS) and taxes/levies on GHG emissions (See Chapter 2.3.1). But CDR certificates will be traded under the EU ETS starting in 2031(in which Switzerland participates).

Contract for difference: Contract between the public administration and a company, where a carbon price is fixed over a given period. If the price is lower than the set price, the company receives the difference. If the price is higher than the set price, the company returns the additional revenue to the government. This reduces the investment risk for companies and shares the CO_2 costs between public and private entities.

Sustainable public procurement: Integrating standards targeting sustainability into the process by which public authorities, such as government departments or local authorities, purchase work, goods or services from companies. For example, public procurement can target CDR when it comes to construction materials or energy production. Many European cities have pursued sustainable procurement actions[30].

[30] Procura+ European Sustainable Procurement Network, https://procuraplus.org/achievements/

RDD&D policies: Policies regarding research, design and development that would lead to the creation and scale up of CDR systems. This includes, for example, research on improved mechanisms for the monitoring of soil carbon sinks, innovation in wood construction, or funding for critical infrastructure like geologic carbon storage and carbon dioxide transportation (See Chapter 2.2).

Legal Obligations: mandates that require the deployment of CDR. For instance, by targeting sectors to reach ambitious emission targets that might require the use of CDR.

Removal certificate markets: Voluntary or compliance markets for certificates that prove CDR as a neutralization of emissions (e.g., used for Net Zero claims). Compliance markets rely on public regulation that obliges consumers or operators to pay for CDR. For social acceptance and fairness, this may require accompanying socio-political measures. Switzerland has one of the first compliance markets that includes sinks/CDR. Voluntary markets have since a long time included afforestation projects and are including biochar projects. Cap-and-Trade frameworks can be considered a form of hybrid market.

Reverse auctions: Type of auction where there is one buyer and many sellers. In a reverse auction of CDR, the buyer places a request on the amount and conditions of CDR, and suppliers submit bids for selling their CDR services. Reverse auctions have been proposed in Sweden to incentivize BECCS.

Subsidies: Financial support for the implementation and operation of methods, given according to the expected or achieved amount of CO_2 removed. They may be provided, for instance, as direct grants (provision of funds for a project with no requirement for repayment), contracts for difference or tax deductions/breaks (See Chapter 2.3.2).

7.3 Table A3: Policy Design Risks

Risks associated with policy designs and best practices to address them, based on Florin, M.-V. (2022):

Risk	Best Practice
Technology-agnostic policies risk leading to perverse incentives and misuses, if generalizations or blanket decisions about "CDR" lead to wrong, inaccurate, or misleading incentives.	Policies need to be designed and formulated in precise regard to the technology they address. Even the main categories of "nature-based", "hybrid", or "engineered" should be avoided, as they contained largely diverse methods.
Policy decisions are complicated by the frequent **inadequacy or imperfection of current technical instruments** for identifying, assessing, and managing potential risk, for example in the context of environmental impact assessment, or life cycle assessment.	Policy analysis and a priori assessment methods including evaluations of risks should be a priority of research and governmental agendas. Methods, assumptions, and simplifications used when assessing a policy should be transparently communicated.
The presence of scientific uncertainty, which requires using evidence-based methods of governing uncertainty and making decisions under uncertainty, can lead to **postponing policy decisions** "until more evidence" is available.	Two principles can help in taking decisions under uncertainty: 1. Robustness: the ability of decisions to display good enough – though not optimal – performances for various possible futures, such as those that could unfold after the adoption of emerging CDR technologies. Robustness in decision-making thus reflects the willingness of decision-makers to abandon the advantages of optimization to gain a higher ability to cope with subjective probabilities (that are revised in light of new information) and generally uncertain futures.

	2. Adaptive governance and regulation: pursuing a pathway of flexible regulation that can be modified within pre-arranged limits. This is particularly needed for emerging and systemic risks presented by CDR, whereby policymakers and regulators will be able to benefit from new knowledge when it becomes available and adapt requirements and incentives to avoid adverse unintended consequences and maximize opportunities presented by CDR. Prerequisites for planned adaptive regulation include: engaging in multi-stakeholder consultations to determine shared goals; planning for future review and revision of governance arrangements; monitoring of performance and impact of existing arrangements; and funding of targeted research organized in a way that is credibly overseen for quality and relevance and that explicitly feeds into the reassessment of the evidence base.
There is ambiguity about the present **underlying value systems**, which may evolve further in the future. In other words, a CDR technique that may present large risks today may be seen as less risky in the future, or vice-versa. This depends on risk comparison: as climate changes, its risks will be perceived differently from how they are perceived now. Therefore, risks from CDR will also be perceived differently in the future.	Riskier CDR methods should be left for the "last bite" of the CDR portfolio to develop. They might still be valuable last resort options, but priority and resources should flow, in the short-term, in less risky options.

Risk of **irreversible damage on the environment** or the climate from promising (yet uncertain) applications.	Governments are confronted with the need to **balance innovation and precaution**, both for the short term (present) and the long term (future), with particular attention to assessing irreversible damage to the environment or the climate, after which interventions will no longer be possible or effective. When little is known about a threat but there could be severe negative consequences, precaution-based and resilience-focused strategies can ensure the reversibility of critical decisions and increase the system's coping capacity so it can withstand shocks or adapt to new contextual conditions. Prior to making decisions, policymakers must clearly understand the thresholds of, for example, acceptability or irreversibility. How far can we go before it is too late to act?

7.4 Table A4: Differences Between CDR Policy Instruments – Guiding Questions

Guiding Question	Differences Between Policies
Who bears the cost of CDR?	Policies come with different distributions of where and to which actors costs accrue. Subsidies, R&D policies, and other technology-supporting instruments often rely on governmental budgets, so that tax-payers bear the cost. Policies that penalize CO_2 emissions, such as carbon pricing, largely result in costs imposed on consumers of CO_2-heavy goods or on company shareholders.
How do CDR policies relate to the dominant climate policy framework?	Some established policies can enable CDR under new arising conditions e.g., the cost-competitiveness of CDR methods within a carbon market, while some existing policies need some adjustments to adapt to the needs of CDR methods e.g., introducing a certification procedure to enable the integration of removal credits in emission trading systems. Finally, some policies can be created ad hoc with the sole intent of mobilizing CDR.
Are policies incentivizing or regulating CDR?	CDR policies can be based on monetary incentives, both to subsidize the cost of technologies or to attract demand, or on regulations that make their deployment necessary. These policies can both directly or indirectly target CDR e.g., by explicitly subsidizing, mandating, or deploying via government purchasing policies a CDR method (direct) or by introducing standards and targets that are unreachable without the deployment of CDR (indirect).
How much control over climate targets do policies enable?	While some policies are agnostic of how much CDR they will enable (e.g., subsidies), others can directly relate targets to incentives: for example, sectoral emissions targets can be only technologically feasible with the deployment of CDR, or regulations might oblige polluters to offset (part of) their emissions via CDR to comply with an emissions budget.

How much competition with other CDR methods do they entail?	Policies can also be technology-neutral – meaning that they apply the same rules to all CDR methods, thus fostering competition between different methods – or technology-specific, tailored to the needs of different CDR methods. These differences translate in various levels of effectiveness for different technology maturities.
Are policies acceptable and politically feasible?	Many of the above-mentioned factors can affect the public acceptance and political feasibility of policies. These factors are e.g., the visibility and distribution of costs to support CDR, whether policies lead to unfortunate resource-competitions between CDR and other clean technologies, and the degree of alignment with the incumbent climate policy regime.
What trade-offs does the policy generate?	Some policies may create undue competition between solutions including measures that would reduce emissions. Policies need to ensure that CDR complements rather than displaces other mitigation actions. Policies also need to avoid creating undue conflicts over limited resources such as land, energy or water in order to avoid incentivizing ensembles of measures that cannot scale up.

7.5 Abbreviations

BECCS: Bioenergy with CCS

BECCTS: Bioenergy with CCTS

BECCUS: Bioenergy with CCUS

BiCRS: Biomass Carbon Removal and Storage

CCS: Carbon Capture and Storage/Sequestration

CCTS: Carbon Capture, Transport and Storage/Sequestration

CCU: Carbon Capture and Utilization

CCUS: Carbon Capture and Utilization with Sequestration/Storage

CDR: Carbon Dioxide Removal

CO_2: Carbon Dioxide

CO_2e: Carbon Dioxide Equivalent (unit to make different greenhouse gases commensurable)

COP 26: United Nations Climate Change Conference Glasgow 2021

CRCF: Carbon Removal Certification Mechanism

DAC: Direct Air Capture (of CO_2)

DACS: Direct Air Capture and Storage (also known as DACCS)

DeCIRRA: DEcarbonisation of Cities and Regions with Renewable GAses

DemoUpCARMA: Demonstration and Upscaling of CARbon dioxide MAnagement solutions for a Net Zero Switzerland

EBC: European Biochar Certification

ETS: Emissions Trading System

EU: European Union

EU ETS: European Union Emissions Trading System

FOEN: (Swiss) Federal Office for the Environment

GHG: Greenhouse Gas

IPCC: Intergovernmental Panel on Climate Change

LULUCF: Land Use, Land-Use Change and Forestry

KIG: Bundesgesetzes über die Ziele im Klimaschutz, die Innovation und die Stärkung der Energiesicherheit

MRV: Monitoring, Reporting and Verification

$MtCO_2$: Megatons (million tons) of CO_2

NDCs: Nationally Determined Contributions

NET: Negative Emissions Technology (=CDR method)

PyCCS: Pyrogenic Carbon Capture and Storage

RDD&D: Research, Development, Deployment and Diffusion

REDD+: Reducing Emissions from Deforestation and Forest Degradation

R&D: Research and Developments

SDE++: Stimulation of Sustainable Energy Production and Climate Transition

SFOE: Swiss Federal Office of Energy

SWEET: Swiss Energy research for the Energy Transition

VBSA: Verband der Betreiber Schweizerischer Abfallverwertungsanlagen

Swiss Carbon Removal Platform

RISK_DIALOGUE
CREATING A BETTER FUTURE. TOGETHER.