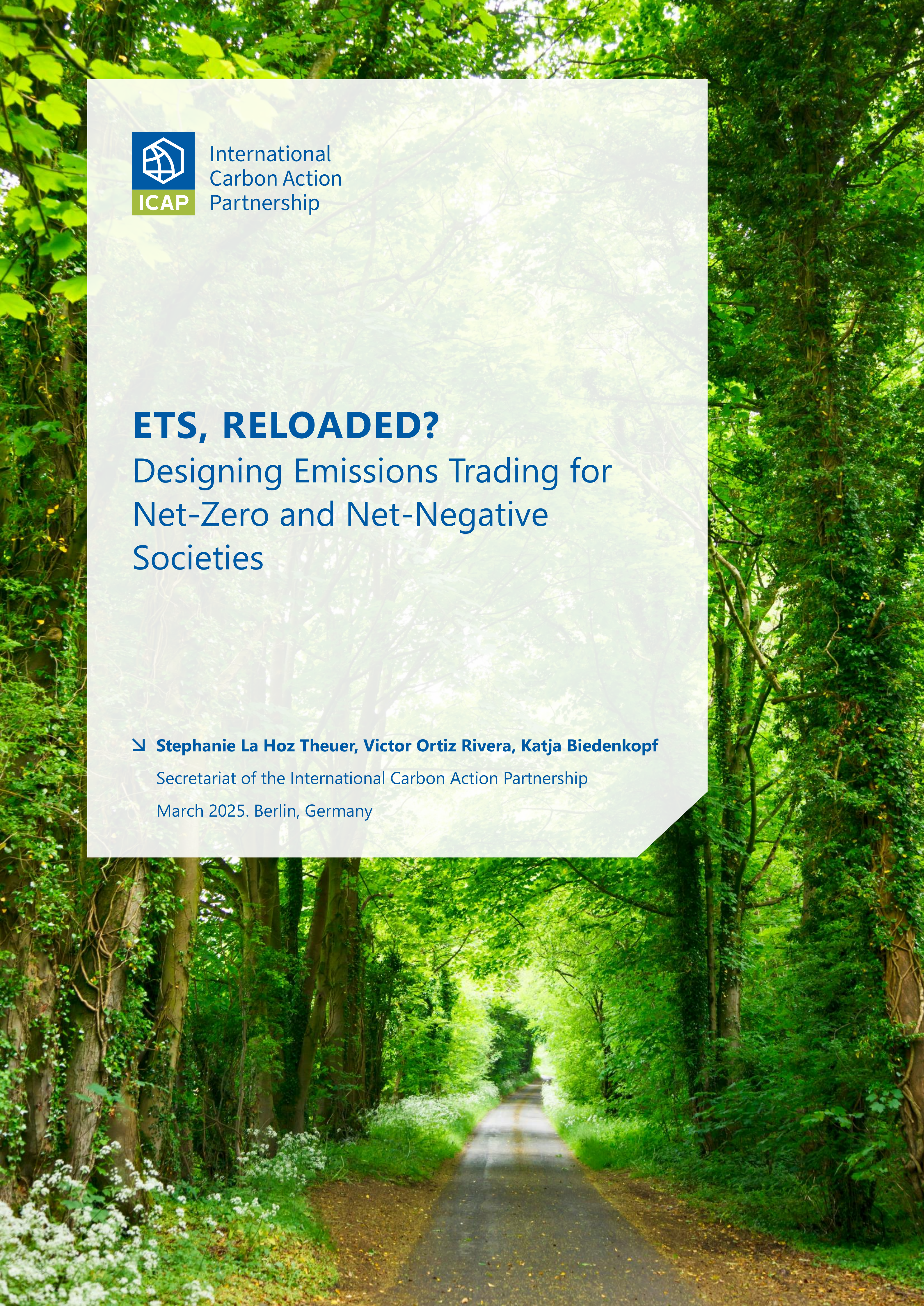

International Carbon Action Partnership

ETS, RELOADED?
Designing Emissions Trading for Net-Zero and Net-Negative Societies

↘ **Stephanie La Hoz Theuer, Victor Ortiz Rivera, Katja Biedenkopf**

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Authors:
Stephanie La Hoz Theuer (ICAP Secretariat)
Victor Alejandro Ortiz Rivera (ICAP Secretariat)
Katja Biedenkopf (ICAP Secretariat)

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EXECUTIVE SUMMARY

All emissions trading systems (ETSs) to date deliver net-positive greenhouse gas (GHG) emissions, but recently jurisdictions have begun to ponder how ETSs should look in the future as jurisdictional net GHG emissions need to reach zero or even become negative. This discussion is very alive in the European Union, where the EU ETS would be on a path to an absolute zero system in the early 2040s under the assumption of no fundamental changes to it. In 2024, the United Kingdom conducted a public consultation on integrating engineered GHG removals into the UK ETS and the government is currently exploring design options. California has a net-zero target for 2045, which requires swift policy adjustments to ensure attaining the target. In many other jurisdictions, however, conversations are less advanced, and academic literature is yet to catch up.

ETS emission levels may mirror broader jurisdictional goals (e.g., a jurisdiction with an economy-wide net zero target and a net zero ETS), but that need not be the case. California, for example, has a target to reduce anthropogenic GHG emissions by 85% and achieve net zero by 2045. To achieve these goals, it is planning for a net-positive ETS, complemented by removal units outside the trading system's scope. The role of the ETS in each jurisdiction will heavily depend on the jurisdiction's emissions profile, planned mitigation pathway, access to carbon dioxide removals (CDR) and storage, as well as its broader policy mix. In all cases, ETSs can play an important role in reducing GHG emissions on the pathway towards net zero. Regulators must then decide what role, if any, their ETS could play in driving down residual emissions, balancing emissions with removals, and delivering a net negative outcome.

Five options for ETSs' emissions outcome in the years to come

The future trajectory of ETSs is an open question with multiple possibilities. While current policy debates often imply that the only reasonable option for ETSs is to deliver net-zero emissions, this paper shows that other options are possible: they could deliver net-positive, net-zero, net-negative, or even absolute zero emissions. While each of these four options could be a step in the evolution of an ETS over time, they are also steady states in and of themselves. An ETS could, moreover, also be phased out in favor of other policies. For each of these states, ETSs can take slightly different functions compared to current designs, prioritizing different aspects of GHG mitigation pathways. These five options are explored in the report and are summarized in Table 1 and Figure 1 below.

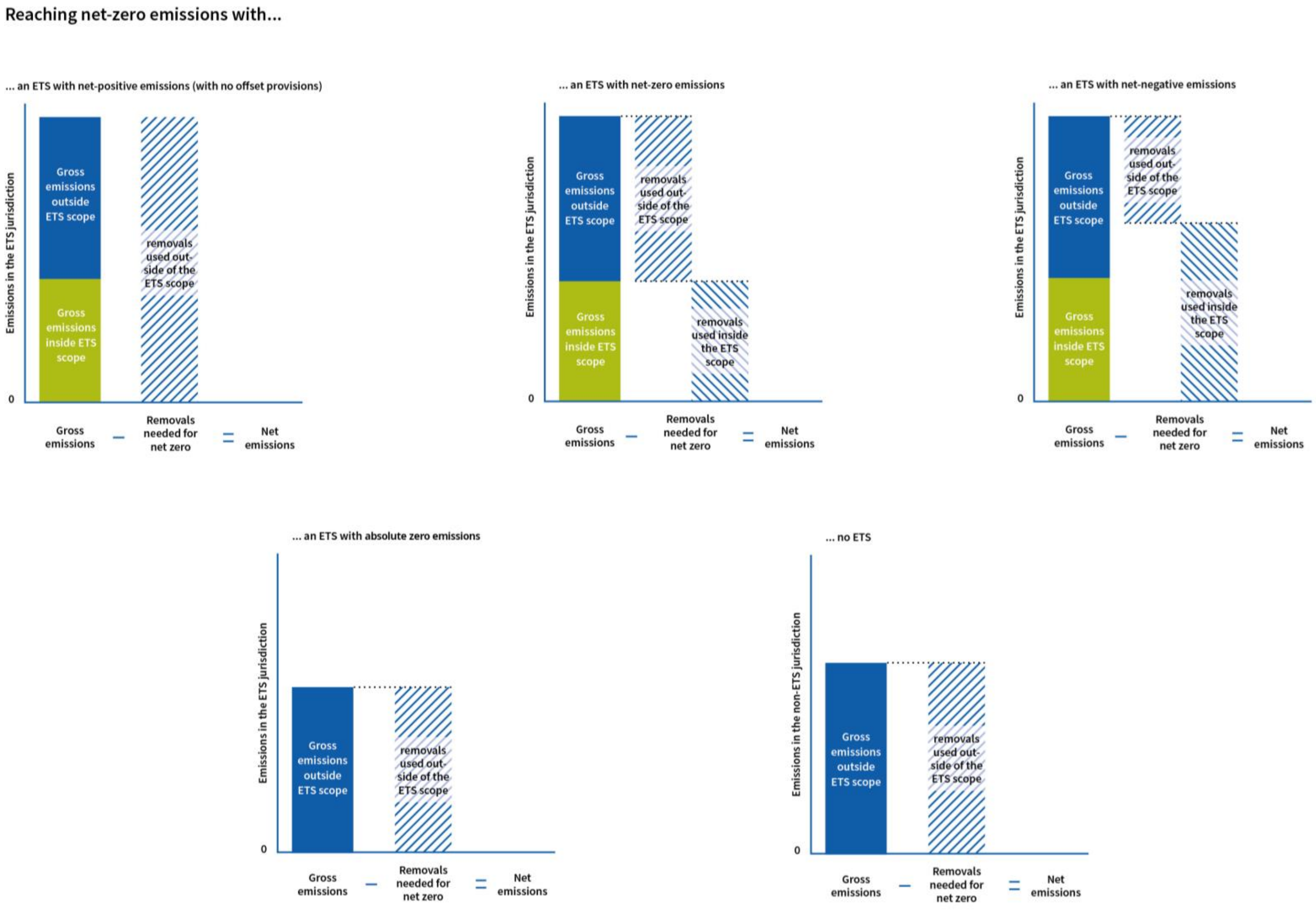
Table 1: Five options for ETSs' emissions outcome in the years to come

Net-positive ETS	• The ETS results in net-positive emissions. • Conventional ('fiat') allowances continue to be issued, and the system may or may not allow for the use of removal units. • GHG reduction and removal targets can be kept separate and thus help address abatement deterrence concerns. • The regulator must define the volume of compliance units available in the system (which, in turn, determines the amount of permissible residual emissions). • If the jurisdiction has a net-zero or net-negative target, other policies will need to balance for net-positive ETS emissions with CDR outside of the scope of the ETS.
Net-zero ETS	• Gross emissions are positive, but net emissions are zero.[1] • The regulator ceases to issue fiat allowances, but emissions are still possible if they are balanced by removal units. • Does away with the need for additional policy instruments to balance for ETS residual emissions to achieve a jurisdictional net zero target. • Could allow for a cost-effective mix of abatement and removal. • The use of removal units in the ETS could be subject to limits. • Risk of abatement deterrence. • To the extent that the ETS trades exclusively in removal units, a net-zero ETS could be said to have transitioned into a 'removals trading system'. • An increase in gross residual emissions (e.g., if the volume of compliance units increases vis-à-vis the baseline scenario) could make it harder to achieve net-negative in the jurisdiction if removals are scarce.
Net-negative ETS	• Gross emissions under the ETS are positive, but net emissions are negative. • The regulator ceases to issue fiat allowances. • Remaining emitters in the ETS surrender more than one removal unit per tCO_2e emitted. • Can deliver negative emissions for as long as there are gross emissions in the ETS. • Could overburden already-strained residual emitters.
Absolute zero ETS	• Fiat allowances decline to zero. There are no provisions for removals. • The ETS pushes gross emissions covered by it to zero. • The ETS functions as a ban on emissions and no longer as a "trading" system. • Feasible only in sectors where full decarbonization is technologically and economically feasible. • An emissions ban might be seen as a draconian form of climate policy, especially in the presence of relatively lower removal costs. • More prone to carbon leakage than systems which allow for gross emissions.
ETS phase-out	• The ETS ceases to exist.

[1] Gross ETS emissions are the sum of all GHG emissions in the ETS' scope that reach the atmosphere, before accounting for the effect of, for example, CDR activities. In an ETS that allows for removal units, net emissions are the gross emissions minus the removed emissions that are accounted for under the ETS.

	• Could make sense, for example, where the ETS is too small to provide effective price discovery, or where other policies are considered more effective in achieving mitigation goals. • A phase-out could entail the ETS morphing into a carbon tax by eliminating make-good provisions and instituting a fixed fine per tCO_2e. • Requires the establishment of a cost-efficient package of other policy instruments.

Figure 1: Illustrations of the five options for ETSs' emissions outcome



Cross-cutting design considerations

Policymakers' decisions on what constitutes 'residual' and 'hard-to-abate'[2] emissions will be crucial in most scenarios. To the extent that gross emissions are allowed for ETS regulated entities (i.e., in the net-positive, net-zero, and net-negative emissions scenarios), such gross emissions would themselves be a product of societal/political decisions about which emissions are considered hard-to-abate. Any classification of hard-to-abate emissions will carry a strong aspect of value judgement, for example, determining what constitutes an acceptable cost, and how to prioritize policy goals. It is also a moving target, among others due to technological progress and society's willingness to bear costs and change practices.

Issues of 'small markets' are relevant to all ETS options that retain trading elements. Tightening emission limits create significant challenges, including increased banking behavior, price volatility, market friction, potential illiquidity and manipulation risks – all of which can erode political support. Governments may address these through various strategies: expanding sectoral coverage, lowering participation thresholds, incorporating removal units, enhancing market stability mechanisms, strengthening competitiveness protections, linking with other systems, improving price discovery, and developing alternative revenue sources. Expanding ETS coverage requires careful consideration of administrative burdens for smaller participants, with threshold adjustments becoming necessary as installations' emission levels naturally decrease. In jurisdictions targeting net-zero emissions, expanding the scope of the ETS could either increase pressure on non-ETS sectors to deliver negative emissions (if the ETS remains net-positive) or provide additional support for necessary CDR (if the ETS requires net-zero or net-negative outcomes).

Abatement deterrence is a major concern for all options that involve the inclusion of removal units in the ETS. At the core of abatement deterrence is the concern that CDR comes at the expense of emissions reduction, such that gross emissions remain higher than they would otherwise be. Strategies to address abatement deterrence differ for short-term and long-term effects. Concerns over a short-term increase in ETS gross emissions can be addressed by maintaining a limit on gross emissions – for example through a 'one in, one out' approach, whereby for each removal unit entering the system, one fewer fiat allowance would be issued. Longer term effects stem from the high long-term uncertainty on the volume and cost of removal units: there is value for regulated entities to delay abatement investments until there is more information about the costs of available measures. This creates the risk of being locked in a higher-emissions pathway, which is detrimental to climate mitigation and could lead to steep carbon price rises, especially if the CDR supply fails to materialize, and lead to political pressure to reduce the ambition of the system. A stepwise evolution of the ETS could allow for technology and policy learning, and sector-specific complementary policies could help maintain levels of abatement.

Jurisdictions looking to include removal units in their ETS have several options in terms of legal tender and route to market. Removal units can be generated outside or inside the ETS. This pertains to two design considerations: whether CDR providers receive fully fungible allowances or distinct credits (legal tender), and whether regulated entities purchase removal units directly from suppliers or through government intermediation (route to market). These choices impact market dynamics, pricing transparency, regulatory control, and transaction costs. Fully fungible allowances and a direct route to market can provide for a single market with direct price

[2] In this paper, 'residual emissions' means any emissions that reach the atmosphere after the net-zero point; and 'hard-to-abate' emissions to mean those with a limited abatement feasibility because of technological, economic, social or political considerations. See section 4.1 for a discussion.

discovery but lead to the regulator losing control of the balance between abatement and removal. Fully fungible allowances and a government-mediated route to market could lead to higher control by the regulator and enable the regulator to bridge cost gaps between abatement and removal but could lead to a market that is less responsive to market changes. Allocating non-fungible credits to CDR suppliers creates market fragmentation but with more control by the regulator, with similar dynamics across the routes to market as for fungible units.

Issues of linking are relevant across all ETS options, as jurisdictions with connected systems face coordination challenges when caps decrease. Net flows of compliance units between linked systems reflect differences in abatement costs, with units typically flowing from lower-cost to higher-cost jurisdictions. As caps tighten and prices rise, these flows may change based on the planned steady states of the linked systems. Various scenarios present distinct challenges: when both systems target positive emissions, traditional linking dynamics apply; when systems have different targets (positive vs. net-zero/negative), cost differentials between abatement and removals determine unit flows, potentially requiring de-linking if compliance unit compatibility issues arise; links between net-zero and net-negative systems would create larger markets for removal units with potential for administrative efficiencies; systems targeting absolute zero emissions would likely need to de-link from positive emissions systems to achieve their goals; and any system planning to phase out would require careful de-linking regardless of its partner's steady state. In systems where at least one partner accepts removal units, jurisdictions must address eligibility divergences to maintain system stringency, potentially through "restricted linking" options.

Discussion and conclusions

The future trajectory of ETSs is an open question with multiple possibilities. While current policy debates often imply that the only reasonable option for ETSs is to deliver net-zero emissions, this paper shows that other options are possible: ETSs could deliver net-positive, net-zero, net-negative, or even absolute zero emissions. The ETS could, moreover, also be phased out in favor of other policies. For each of these options, ETSs can take slightly different functions compared to current designs, prioritizing different aspects of GHG mitigation pathways. Interestingly, interviews indicated wide divergence among experts on which ETS design is more likely or beneficial.

Expanding ETS coverage to encompass more, or even all, economic sectors could fundamentally alter the feasibility and desirability of different end states. A jurisdiction with an economy-wide ETS, for example, might need to incorporate removal units to accommodate sectors with limited abatement potential and achieve jurisdictional net zero targets, whereas a jurisdiction with a narrower ETS might more easily maintain a focus on emissions reductions without CDR. Expanding the scope can help mitigate some of the small-market challenges and generate efficiencies and ensure better market functioning.

Differentiating between gross and net emissions in ETS design is helpful but so far not often done. This distinction is likely to become more important as jurisdictions fine-tune their emissions and CDR in their pathway towards net-zero and net-negative economies. Clarity on gross and net emissions limits in ETS-regulated sectors will influence how the systems will evolve, what role removal units will play in compliance, and how emissions and CDR will be managed across the economy. Higher gross emissions inside the ETS, for example, can make it harder to achieve jurisdictional net-negative targets if CDR is scarce. The potential use of removal units from other jurisdictions in lieu of domestic removals presents additional considerations, among others reducing costs and increasing flexibility, but introducing risks related to environmental integrity, permanence and governance, including potential dependency on external carbon removal markets.

While ETSs could drive demand for removal units and provide support to the development and deployment of CDR, they are unlikely to be sufficient. In systems with limits on the use of removal units, support will be constrained by these limits. In systems without such limits, support for CDR will be determined by where gross emissions settle based on the relative marginal costs of abatement versus removal. The net-negative ETS option provides the most substantial support for CDR deployment by requiring emitters to overcompensate for their emissions. However, even in that scenario, ETSs alone are unlikely to drive adequate CDR deployment. A back-of-the-envelope calculation suggests that requiring ETS residual emitters to remove 2 tCO_2 for every tCO_2e emitted in the second half of the century could contribute significantly to addressing the historical overshoot. However, in practice, such an obligation would likely face strong resistance as it would place a heavy burden on already-strained ETS residual emitters.

Some ETS designs may be vulnerable to the risk that certain removal technologies are not viable at scale. While most mitigation pathways assume that several gigatons of CDR capacity will be added before mid-century, policymakers must plan for the risk that certain CDR technologies are not viable at scale (Larkin et al. 2018). Jurisdictions must therefore understand the consequences of CDR supply uncertainty, and design ETSs so that they can operate effectively in multiple CDR supply scenarios. This is an area for further research.

Understanding the policy mix for net-negative emissions can be crucial for defining the role of ETSs in long-term climate strategies. Policymakers have the challenging task of designing policy mixes that drive ambition and achieve net-negative emissions. While jurisdictions' current focus is to achieve global net-zero emissions by mid-century, post-net-zero strategies can have implications for current policies. For example, a jurisdiction that puts in place a comprehensive and dedicated basket of policy measures for CDR may prefer to keep removals outside its ETS, using the ETS to drive abatement only. To the extent that policymakers recognize the need for dedicated policies to cost-effectively drive CDR and net-negative emissions, early consideration of these issues can help clarify the potential role of instruments such as ETSs.

Speaking about the future of ETSs requires clarifying what we mean by "an ETS". Among others, ETSs could evolve into fundamentally different mechanisms such as 'removal trading systems' or carbon taxes. Moreover, terminology differences can complicate policy debates, particularly when discussing the emissions outcomes of evolving systems.

Several areas remain for further research. A deeper understanding of market dynamics in both transition and steady states is needed, particularly addressing the challenges of small, potentially illiquid markets as emissions decline. More research would be valuable in developing and assessing policy options (such as quantitative limits on CDR use) for addressing abatement deterrence while maintaining cost efficiency. More research is also needed on policy packages for achieving net-negative emissions and the role of ETSs therein. Finally, considerations for intensity-based systems merit further investigation, understanding how the considerations explored here apply to systems without an absolute cap.

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Definitions

Emission limits	A term that encompasses limits to gross and/or net emissions.
Emissions Trading System	An ETS is a type of direct carbon pricing instrument in which a regulator limits GHG emissions of regulated entities, and where regulated entities surrender tradeable compliance units for tonnes of CO_2e emitted.
Fiat allowances	Fiat allowances are the predominant type of units traded in most ETSs today. These units are either auctioned, given for free or represent the overperformance against an emissions benchmark. They represent the right to emit one tCO_2e under the scope of application of an ETS. They enable a tCO_2e to reach the atmosphere unabated and therefore contribute to depleting the carbon budget.
Gross ETS emissions	Gross ETS emissions are the sum of all GHG emissions in the system's scope that reach the atmosphere, before accounting for the effect of, for example, CDR activities.
Hard-to-abate emissions	Hard-to-abate emissions are those whose abatement feasibility is limited because of technological, economic, social or political considerations.
Net ETS emissions	In an ETS that allows for removal units, net emissions are the gross emissions minus the removed emissions that are accounted for under the ETS.
Removals trading system	A removals trading system is a policy instrument that creates a market for trading removal units by requiring certain sectors to comply with an obligation to surrender removal units. Several design options exist, and compliance obligations could be assigned based on GHG emissions or on other metrics.
Removal units	Removal units represent one tCO_2e permanently removed from the atmosphere. Removal units could be generated outside the ETS' scope (as a 'removal credit') or as part of the ETS, when CDR operators are directly covered by the ETS. The latter option could see the issuance of a 'removal-based allowance'.
Residual emissions	Residual emissions mean any emissions that reach the atmosphere after the net-zero point.

Acronyms

CBAM	Carbon Border Adjustment Mechanism
CDR	Carbon dioxide removals
CO_2	Carbon dioxide
CCUS	Carbon capture, utilization and storage
EITE	Emission-intensive and trade-exposed
ETSs	Emissions trading systems
EU	European Union
GHG	Greenhouse gas
MRV	Monitoring, reporting and verification
OTC	Over-the-counter
RTS	Removals trading system
RUs	Removal units

1 INTRODUCTION

Emissions trading systems play an important part in many jurisdictions' mitigation strategies, but their role and design are likely to change over the decades to come. Achieving net-zero emissions by mid-century or soon thereafter is essential to keep global temperatures at safe levels. Consequently, multiple jurisdictions have adopted climate neutrality targets by around mid-century (van Soest et al. 2021). Emissions trading systems (ETSs) can play a central role in this process (Haites et al. 2023) and have been an important part of policy mixes aiming to reduce greenhouse gas (GHG) emissions by 2020 and 2030. They are very likely to remain important after 2030, but their role and design will need to evolve and change in the context of net-zero and net-negative targets and economies. Jurisdictions can consider several ETS options, depending on their circumstances and preferences. Although a net-zero emissions design dominates much of the debate on the future of emissions trading, net-positive or net-negative ETSs can be other viable options, depending on the respective jurisdiction and its overall climate policy mix.

This report aims to contribute to jurisdictions' process of contemplating the role of emissions trading in their trajectory towards net-zero and net-negative emissions. Some jurisdictions, such as the United Kingdom, the European Union (EU), and California, have launched discussions and public consultations on how their respective ETSs could be updated in light of their mid-century net-zero targets, by for example including carbon dioxide (CO_2) removal units (RUs). More jurisdictions are expected to follow suit as they chart their pathways to decarbonization post-2030.

Theoretical and practical thinking on the role of ETSs in a net-zero or net-negative economy is still in its infancy. Academic research so far has focused on specific aspects of the discussion such as the inclusion of CO_2 removal (CDR) technologies in ETSs (for example Burke and Gambhir 2022; La Hoz Theuer et al. 2024) or on specific jurisdictions – particularly the EU (for example Rickels et al. 2021).This report adds to this research agenda by differentiating and analyzing five distinct options for ETS designs.

ETS designs can vary with regard to their intended effect on the net emissions result within the system's scope. For instance, an ETS can, in the long term, result in net positive emissions, even as part of an overall policy mix that cumulatively results in net-zero or net-negative emissions. An ETS can also result in net-zero emissions, by allowing for emissions as long as they are balanced with removals. An ETS can also be designed in a way that results in net-negative emissions by requiring more removals than it allows for emissions. Theoretically, an ETS could also result in absolute zero emissions, by acting as a ban on emissions after a certain point in time. As a fifth option, this paper discusses the phasing out of an ETS as a jurisdiction nears net-zero emissions and concludes that other policy instruments are more suitable at that stage. While the focus is on the overall net emissions result, the ETS options can moreover achieve additional intermediate goals on the way to net-zero and net-negative emissions such as supporting the development and deployment of CDR technologies.

The discussion of the different ETS options aims to explore what an ETS in a net-zero or net-negative economy could look like. It elaborates each of them in turn, structured along the same criteria: relevance in achieving jurisdictional priorities, ETS functioning, and feasibility. This paper identifies the upsides and downsides of each option to inform the debate on the various roles an ETS can play.

This report differentiates two types of compliance units: fiat allowances and removal units. Fiat (or 'conventional') allowances are the predominant type of units traded in most ETSs today. These units are either auctioned, given for free or represent the overperformance against an emissions benchmark. They represent the right to emit one tCO_2e under the scope of application of an ETS. They enable a tCO_2e to reach the atmosphere unabated and therefore contribute to depleting the carbon budget. Unless specifically stated, this paper refers to fiat allowance when using the term 'allowance'. Fiat allowances are not to be confused with removal units, which represent one tCO_2e permanently removed from the atmosphere.[3] Removal units could be generated outside the ETS's scope (as a 'removal credit') or as part of the ETS, when CDR operators are directly covered by the ETS. The latter option could see the issuance of a 'removal-based allowance' (the New Zealand ETS, for example, covers removals and emissions from forestry, issuing allowances to forestry owners when removals take place).[4] This report distinguishes fiat allowances from 'units' that represent the removal of a tCO_2e from the atmosphere, regardless of whether CDR activities are assigned 'allowances' in some systems. For simplicity's sake, these are referred to as "removal units". Covering both fiat allowances and removal units, this report uses the term compliance units.[5]

This report differentiates gross and net emissions of an ETS. Gross emissions are the sum of all GHG emissions in the ETS' scope that reach the atmosphere before accounting for the effect of CDR. Net emissions are the gross emissions minus the removed emissions that are accounted for under the ETS. This includes removal units generated inside and outside the ETS.

An ETS cap represents the sum of all fiat allowances (excluding removal units) and thus determines the volume of net emissions resulting from the ETS. The gross emissions can be higher than the cap, e.g., in a system that allows for the use of removal units. Depending on its design, an ETS can set further requirements such as a maximum number of emissions that can be balanced with removal units.

This paper is structured as follows: Section 2 presents the methodology on which this report's analysis is based. Section 3 details the five options to achieve the different emission results from ETSs and Section 4 explores the design considerations of these different options in more detail. This includes defining residual and hard-to-abate emissions and the volume of removal units permitted, and addressing abatement deterrence, among other issues. Section 5 provides a conclusion and key messages.

[3] Noting the risk of reversals and the need for appropriate measures to address them.

[4] Similarly, the United Kingdom is considering whether to incorporate CDR in its ETS through allowances. See also La Hoz Theuer and Olarte 2023 for a discussion generating removal units inside and outside the ETS scope.

[5] In this report, we only discuss the role that removal units could play in ETSs. We do not consider the use of emission reduction credits (such as reduced landfill gas emissions). While emission reduction credits would in some situations have the same or similar effect as removal units, the space for generating such credits is expected to be very limited as economies approach net-zero emissions.

2 METHODOLOGY

This report describes and differentiates options for ETS design to inform the policy debate on future trajectories of emissions trading. Any ETS will be embedded in a broader policy mix with which it interacts. It focuses specifically on ETS design; the broader policy landscape is beyond the scope of this report. Each of the five options is discussed according to the same criteria – relevance, ETS functioning, and feasibility – to ensure comparability and a systematic discussion. This study is based on a review of relevant academic and policy-oriented literature as well as exploratory expert interviews.

The ETS options should not be equated with a jurisdiction's overall emissions target. A jurisdiction can pursue a net-zero emissions target with a net-positive ETS as long as it adopts ancillary policies that achieve negative emissions so that the overall sum of the policy mix's outcome is net-zero (see Haites et al. 2023). Equally, a net-zero ETS can be implemented in a jurisdiction that does not have a net-zero emissions target. The role of an ETS in a jurisdiction's policy mix depends on the entire portfolio of policies with which the jurisdiction seeks to achieve its climate target, the sectoral coverage of the ETS, and the level of ambition. Nevertheless, the broader the scope of the ETS, the fewer the options for ancillary policies to adjust the jurisdiction's overall emissions result.

Jurisdictions that have adopted an ETS differ widely with regard to their policy mix, economic structure, emissions profile, capabilities, natural endowments, and other key parameters. For this reason, the differentiation of five options in this paper provides insights for varying contexts: an option can be appropriate for one jurisdiction and unsuitable for another. Policymakers need to tailor their ETS solution to their specific needs. This analysis aims to contribute to and support this process by systematically evaluating each of the options and raising pertinent design questions that arise from them.

ETSs have been evaluated with various criteria including environmental, economic, political, and procedural aspects (Clo et al. 2013). While several studies narrowly focus on the environmental dimension of GHG emission reductions, several others take a broader perspective. Environmental effectiveness, cost effectiveness, and relevance are commonly used criteria for *ex ante* and *ex post* policy evaluations. This report, however, takes a slightly different approach, because the options assessed are generalized options for future ETS implementation, rather than specific ETS designs whose effects could be observed today, or even in the near future. This report also does not conduct an *ex-ante* evaluation, since it does not focus on one specific jurisdiction.

The discussion of each of the ETS options is guided by three criteria: relevance, ETS functioning, and feasibility. These criteria were derived from guidance for policy evaluation provided by the OECD (2021) and adapted to explore and systematically discuss the five ETS options. The purpose of the analysis is not to weigh or score the different options, but rather to highlight the benefits and challenges associated with each of them. The paper also describes the process of transitioning an existing ETS to each option.

- **Relevance**: The extent to which the ETS option corresponds with the jurisdiction's needs and priorities (Fallmann et al. 2015; OECD 2021) with regard to its mitigation pathway, and creating incentives for abatement and deep decarbonization (Fallmann et al. 2015).

- **ETS functioning**: How each respective option would function and what challenges can be expected. ETS functioning includes effective price discovery, liquidity, and market integrity.
- **Feasibility**: Administrative and legal factors that could facilitate or hamper the ETS option's implementation as well as social acceptability and distributional consequences. These aspects are central considerations when policymakers ponder an option, but they also are highly context-specific and can therefore only be discussed in general terms.

This report systematically discusses the five ETS options guided by these three criteria.

Data for the discussion of the options was collected from existing literature and expert interviews. First, the authors reviewed the existing literature on the future of emissions trading. No other study has conducted a systematic breakdown of all the options included in this report, but different aspects of the options have been elaborated in earlier studies (Burke and Gambhir 2022; Burke, J., Byrnes, R., & Fankhauser, S. 2019; Fankhauser et al. 2022; Haites et al. 2023; La Hoz Theuer et al. 2024; Pahle et al. 2023; Rickels et al. 2022; Rickels et al. 2021; Sultani et al. 2024; Tvinnereim and Mehling 2018)These ideas and proposals were used for the discussion of the options. Second, 21 exploratory interviews were conducted with scholars, policymakers from jurisdictions that have an ETS in place, and industry and NGO representatives. The interviewees were identified based on the literature review, ICAP membership, and by asking interviewees to recommend further experts with whom we should talk (snowballing). The interviews were used to collect ideas and insights to complement the literature review. The conversation was guided by a small set of open questions that aimed at gathering the interviewees' views and ideas pertaining to each of the five ETS options. Through this approach, earlier identified insights could be validated, and additional perspectives collected. Each interviewee gave their informed consent and agreed to the pseudonymized use of the information that they shared. For this reason, generic interview identifiers are used. Third, the authors used logical reasoning and their own experience to develop and detail the ETS options. Drafts of the report were reviewed by two academic experts, who validated the options and suggested additional insights.

3 OPTIONS TO ACHIEVE DIFFERENT EMISSIONS RESULT FROM AN ETS

While there might be a plethora of different possible ETS designs in a net-zero emissions jurisdictions, this report makes clear distinctions based on the emissions result that they generate. The purpose of this categorization is to highlight the key considerations for each of these designs and also the option of no longer using an ETS in a jurisdiction's climate policy mix. The authors do not advocate for one option over another and this section rather provides arguments in favor and against each of the options, while remaining agnostic on their desirability. Through highlighting both positive and negative considerations, this paper aims to contribute to jurisdiction-specific policy debates.

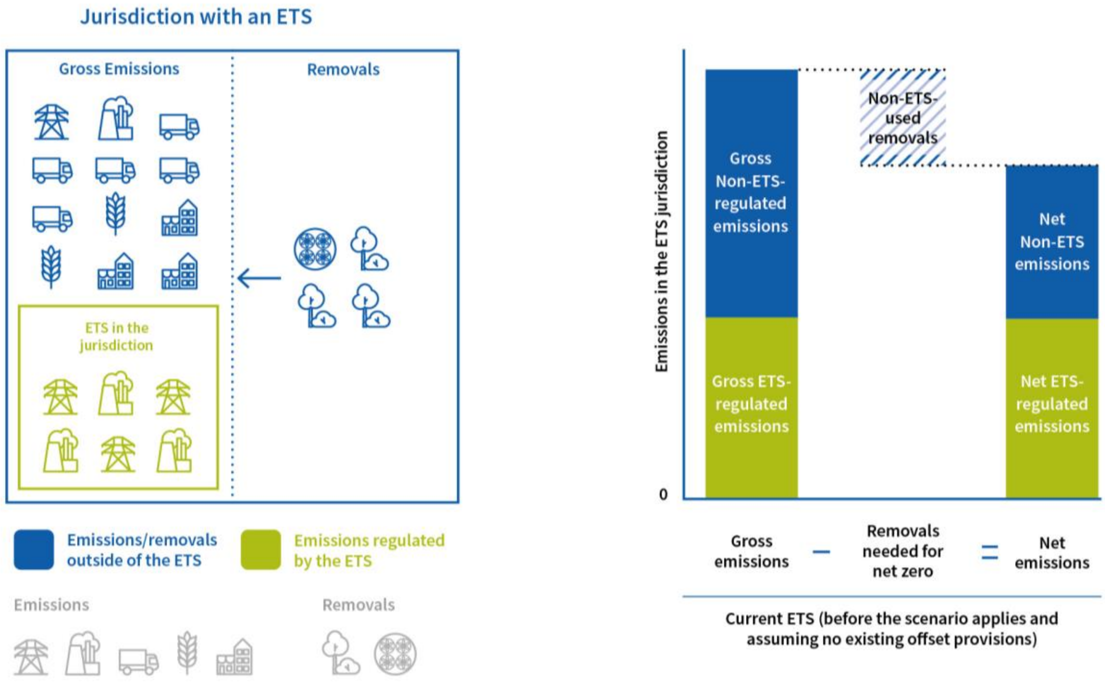
An ETS is a type of direct carbon pricing instrument in which a regulator limits GHG emissions of regulated entities, and where regulated entities surrender tradeable compliance units for tonnes of CO_2e emitted.[6] In this paper, it is assumed that regulated entities comply with their obligations by abating their emissions, surrendering fiat allowances and/or by using removal units.[7] As such, the net GHG impact of the ETS equals regulated entities' gross emissions, minus any emissions removed (through the use of removal units within the ETS).

For simplicity of depiction, throughout the five options, the generation and use of removal units is discussed as if they were produced outside of the scope of the ETS' application. In practice, this simplification may not hold, for e.g., electricity and heat generators using sustainable biomass with carbon capture and storage. This simplification does not prejudice the analysis presented here. Section 4.5 discusses the possibility of generating removal units inside the ETS scope. It is also assumed that removal units stem from domestic CDR suppliers, although loosening this assumption does not contradict the arguments presented. Figure 2 illustrates the base scenario of an ETS in which no removal units are used. The ETS' net emissions result equals its gross result. The jurisdiction can still reduce its overall emissions through CDR, but this is done outside the ETS.

[6] In particular, this paper distinguishes an ETS from other instruments that establish an obligation for regulated entities to purchase removal units based on something other than gross GHG emissions (e.g., an obligation to purchase removal units on the basis of energy use, irrespective of the carbon content of such energy). Such an approach, which could resemble an ETS in certain design features, would nevertheless be a different instrument from an *emissions* trading system. It is noted, however, that an ETS could be said to morph into a "removals trading system" if the only units available for compliance are removal units; see section 3.3 .

[7] For simplicity, this paper does not consider the use of carbon credits (e.g., from emission reductions outside the scope of the ETS). Their use does not contradict the findings presented in this paper.

Figure 2: Base scenario of gross and net emissions in a jurisdiction with an ETS and with no offset provisions in the ETS.



In Figure 2, the oval shape on the left side represents a jurisdiction with an ETS. Emissions are presented to the left of the dotted line, and removals to the right. The rectangle represents the ETS in the jurisdiction. Emissions and removals generated outside the scope of the ETS are presented in green. The right panel of the figure is a stylized waterfall graph that represents the emissions balance of the jurisdiction as a whole (inside and outside the ETS scope).

This section assesses four ETS design options that lead to different mitigation contributions of the scheme, in terms of the net emissions result from the actions (and purchases) of ETS-regulated entities: net positive, net zero, and net negative. An absolute zero ETS could enforce a ban on emissions, albeit without a trading function. Moreover, recognizing that jurisdictions may decide to phase-out the ETS in favor of other mitigation policies, it also analyzes a "no ETS" option.

While each of the options presented here could be a steppingstone into another of the options (e.g., an ETS with net positive emissions can transform into a net zero one), each of them could also constitute a valid "steady state" for an ETS. The discussion in this section focuses on each of the options as a steady state of the ETS, with brief considerations on the transition towards that state.

It is worth noting that this section is agnostic on *how* removal units enter the ETS – e.g., whether through a government agency (such as a central carbon bank) or through direct purchases between ETS regulated entities and CDR suppliers. For more on this, see section 4.5 and La Hoz Theuer et al. 2024.

3.1 Net-positive emissions

In a net-positive ETS, regulated entities can continue to emit net GHGs to the atmosphere, even after the point where the jurisdiction has achieved its net-zero target. This means that fiat allowances would still be issued and the infrastructure and the processes of the ETS, such as auctions, monitoring, reporting and verification (MRV), and compliance cycles would continue to exist. The volume of gross and net emissions permissible in the system will likely be determined by: i) the long-term role that ETS-regulated sectors play in the achievement of the jurisdiction's climate goals, (for example, these sectors could be those that the jurisdiction defines as "hard-to-abate", see section 4.1), and ii) the level of allowed removal units under the ETS. A net-positive ETS may or may not allow for the use of removal units. Gross emissions will be determined by the volume of compliance units (e.g., fiat allowances plus removal units), with net emissions determined by the volume of fiat allowances. In principle, gross and net emissions could remain stable, although amendments may be required to respond to economic and technological conditions, as elaborated further below.

For jurisdictions with net-zero targets, any net positive emissions from inside the ETS would need to be balanced with an at least equivalent CDR effort *outside the ETS*, e.g. through removal purchase mandates and through public procurement of removal units (potentially (co-)financed by ETS allowance auctions), among others. These units, however, would *not* flow inside the ETS. In this case, the *jurisdiction* would be net-zero, but the *ETS* would not.[8] Figure 3 provides an example of a jurisdiction that achieves net-zero emissions and has an ETS with net-positive emissions, and where the ETS does not contain provisions for the use of removal units. In Figure 4, the jurisdiction achieves net-zero emissions and has an ETS with net-positive emissions, but with provisions for the use of removal units by ETS-covered entities.

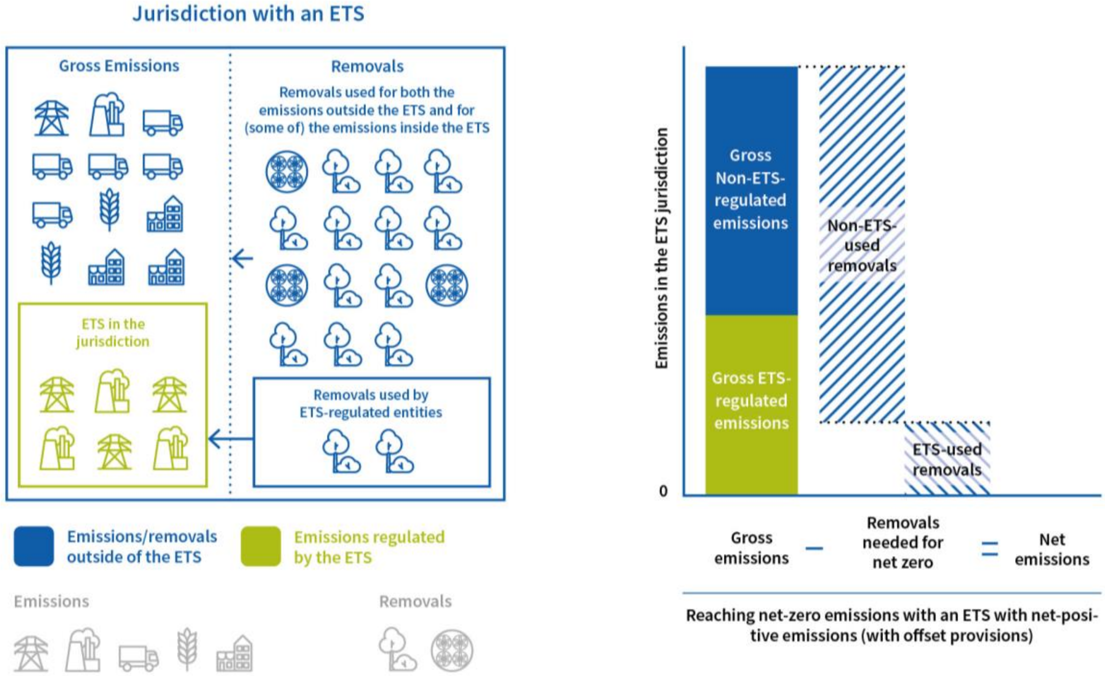
Several jurisdictions are currently planning for ETSs with net positive emissions in the longer term. The implementing regulations of the ETSs in some jurisdictions part of the Regional Greenhouse Gas Initiative, for example, currently foresee the volume of fiat allowances to stabilize at a positive level in the early 2030s. In California, options currently under discussion would see the Cap-and-Trade Program have a positive number of fiat allowances (and thus allowing positive net emissions) in 2045. The jurisdiction is planning to reach aggregate net-zero emissions through removal units outside the ETS.

[8] Assuming the ETS does not cover all emissions in the jurisdiction.

Figure 3: Reaching net-zero emissions in a jurisdiction with an ETS that results in positive emissions and has no offset provisions.

In Figure 3, the oval shape on the left side represents a jurisdiction with an ETS. Emissions are presented to the left of the dotted line, and removals to the right. The rectangle represents the ETS in the jurisdiction. Emissions and removals generated outside the scope of the ETS are presented in green, whereas emissions generated inside the scope of the ETS are presented in blue. The right panel of the figure is a stylized waterfall graph that represents the emissions balance inside and outside the ETS scope: by not accepting removals for use in compliance of the ETS, all of the emissions of both the scope of the ETS and outside of the scope of the ETS are balanced by removals from outside of the scope of the ETS. Implications for allowing removals in the ETS are discussed in section 4.5 .

Figure 4: Reaching net-zero emissions in a jurisdiction with an ETS that results in positive emissions and that allows removals.



In Figure 4, the oval shape on the left side represents a jurisdiction with an ETS. Emissions are presented to the left of the dotted line, and removals to the right. The rectangle represents the ETS in the jurisdiction. Emissions and removals generated outside the scope of the ETS are presented in green, whereas emissions generated inside the scope of the ETS are presented in blue. The right panel of the figure is a stylized waterfall graph that represents the emissions balance inside and outside the ETS scope: the first green striped block represents all the removals that are used to balance the emissions outside of the scope of the ETS, as well as the emissions inside the scope of the ETS that are themselves not balanced by removals. The second green striped block of the waterfall graph are the removals that are used by ETS-regulated entities for compliance. They contribute to reaching net-zero in the jurisdiction. Implications for allowing removals in the ETS are discussed in section 4.5 .

Relevance

- The limit on gross emissions in the ETS will be determined by the volume of compliance units available in the system, and net emissions will depend on the volume of fiat allowances.
- If removal units are not permitted in the ETS, that results in net positive emissions, or if they are permitted to a limited extent, the ETS can enable a situation where emissions and removal targets are kept separate, thus helping address concerns of abatement deterrence within the ETS (see section 4.2).
- An ETS with net positive emissions allows for long-term gross emissions in the jurisdiction, e.g., from hard-to-abate sectors. Defining the level of acceptable residual emissions, however, could be politically challenging, as discussed in section 4.1 . Because the definition of “hard-to-abate” sectors is likely to be a political one, and to change over time, it may be a definition subject to debate and at risk of being used by stakeholders interested in keeping the ETS compliance costs low (see, for instance, discussion in Buck et al. 2022; Lund et al. 2023)
- For jurisdictions with net-zero targets, any net positive emissions from inside the ETS would need to be balanced with an-at least equivalent CDR effort outside the ETS.

- Technological advances, reduction in costs of abatement options and changes in policy priorities may reduce the aggregate emissions of ETS-regulated entities over time. In such a situation, the number of compliance units may have to be adjusted downwards (or complemented by other policies) to avoid the re-entry of carbon-intensive participants that could otherwise use the now available space under the emissions limit in the system.[9]
- Jurisdictions could have different mechanisms to control the level of gross emissions over time, for example by focusing on economic and technological developments in specific sectors to enable a bottom-up approach, or by having a dynamic approach to the supply of compliance units that responds to the price, such as the one proposed by Burtraw et al. 2022, that could also prevent emissions rebound.
- The ETS could serve as an incentive for emission reductions and CDR in sectors outside of its scope, although this depends on a number of factors. High allowance prices, for example, could support demand for high-quality removals, but the inclusion of removals can also lead to abatement deterrence (see section 4.2).

ETS functioning

- For the ETS to continue operating as a functional market, the conditions must be set for the system to result in effective price discovery – such as having sufficient trading between regulated entities, participation of market makers, and having publicly available pricing information via exchanges or auctions. A small market (which could be a result of the ETS decreasing its emissions limits until the steady state) faces several challenges (see section 4.3). With a constant and positive emissions limit, scarcity in the system would come from expected increases in production levels and, consequently, demand for compliance units.
- One of these challenges is that a small market for allowances could also lead to decreased liquidity and/or increased market power for some participants. If the market for allowances becomes too small, random noise in trading might lead to higher volatility and more difficult price discovery (see Pahle et al. 2023, also discussed in sections 3.4 and 4.3). Systems with a large number of participants, with very high heterogeneity in their abatement costs and sufficient trading, however, may be more likely to maintain effective price discovery.

Feasibility

- Allowing net positive emissions to continue and to regulate them under the ETS could contribute to policy credibility and give market participants certainty about the continuity of the system and the validity of allowances – especially when accompanied by credible long-term climate targets and implementing policies.
- For the systems that use auctioning as an allocation method, allowing net positive emissions to continue could facilitate the continuation of a revenue stream for the regulator, which can facilitate political support. Among others, resources could be used to continue current financing initiatives, and/or to finance the acquisition of removals to balance the emissions inside the scope of the ETS.
- Jurisdictions can, by controlling the supply of compliance units, exercise control over the allowance price level and costs faced by emitters. This could be designed to avoid, or

[9] Conversely, a positive (but very tight) supply of compliance units could lead to very high carbon prices, undermining the social acceptability of the system. As ever, careful cap-setting remains critical in balancing the various jurisdictional policy priorities.

react to, socially unacceptable carbon prices.[10] This includes periodic adjustments to emissions limits (e.g., considering indicators such as economic growth, observed impacts on consumer prices, and changes in availability and cost of abatement technologies in setting the volumes of fiat allowances and removal units admitted in the system), as well as market stability instruments that allow for the issuance of additional allowances if prices exceed pre-determined thresholds. Such adjustments would have to take into account the detrimental effects of loss of policy credibility and predictability.

- However, an ETS that allows net-positive emissions means that those emissions are allowed to continue unabated by the ETS. A jurisdiction seeking to achieve a net zero target would have to balance those emissions outside the scope of the ETS.

Transition

- It seems likely that many of the challenges faced by regulators and market participants will relate to the managing of a shrinking market (see section 4.3). Measures such as expanding the scope of the ETS, including removal units, refining market stability and competitiveness-protection measures, establishing links to other jurisdictions, and facilitating price discovery, among others, may become increasingly relevant.
- High allowance prices may also require the establishment or refinement of market stability measures.
- If the jurisdiction auctions allowances, the decreasing size of net positive emissions allowed in the ETS might translate into lower auction revenues – unless higher prices compensate for the decreasing emissions budget. Jurisdictions faced with lower auction revenues may have to find alternative revenue sources.

ETSs with net-positive emissions: summary

<table>
<tr><td>Concept</td><td colspan="2">• Gross and net emissions inside the ETS are positive.
• The system continues to issue fiat allowances.
• The volume of compliance units at the steady state will likely be defined by the future perception of which emissions remain hard to abate.
• May or may not allow the use of removal units, which in turn could influence the volume of fiat allowances.
• For a jurisdiction to achieve net zero, net positive emissions from the ETS must be balanced with removals outside the realm of the ETS.
• Examples: California Cap-and-Trade Program; several RGGI jurisdictions</td></tr>
<tr><td></td><td>Pros</td><td>Cons</td></tr>
<tr><td>Relevance</td><td>• Allows for hard-to-abate emissions to continue in the ETS.
• GHG reduction and removal targets can be kept separate and thus help address abatement</td><td>• Balancing for ETS residual emissions must happen outside of the ETS.
• Political challenge of defining the level of acceptable residual</td></tr>
</table>

[10] This level of control is also higher than in options that involve extensive use of removal units (e.g., net zero or net negative ETSs). In those cases, the price level and cost for emitters will be determined to a greater extent by the cost and availability of removals. Governments will be able to control which removal units are allowed, but will not be able to directly control marginal removal costs.

	deterrence concerns within the ETS (if zero or very few removals are allowed into the ETS). • Jurisdictions could react to downward pressures on the carbon price (e.g., due to technological developments) through regular emissions limit adjustments	emissions within and outside the ETS, as well as how to allocate responsibilities over the financing of removals. • Emission limits may require adjustments to reflect changing circumstances.
ETS functioning	• The ETS can continue to be a market that realizes the most cost-effective abatement options, provided that the conditions for effective price discovery are met.	• Small markets will likely face low liquidity, low trading activity, high volatility, and greater potential for market manipulation, undermining price discovery.
Feasibility	• Clarity on the continued functioning of the system. • Allows for a continued revenue stream through allowance auctions, which can facilitate political support. • Emission limits could be designed to avoid unacceptably high carbon costs.	• Other policies supporting the delivery of CDR will be necessary to balance ETS emissions. • Adjustments to emissions limits could erode policy credibility and predictability. • Potentially very high allowance prices and volatility, which could erode political support for the system.
Transition	• Jurisdictions may face the choice of modifying different design elements in the ETS, such as inclusion thresholds or sectoral scope rules as entities decarbonize, the market diminishes, and prices increase. • Governments may need to identify alternative sources of revenue if falling covered emissions translates to lower revenues.	

3.2 Net-zero emissions

In a net-zero emissions ETS, the regulator ceases to issue fiat allowances, but emissions are still possible if they are balanced by removal units. There will be a transition phase but in a steady-state net-zero ETS, only removal units can be traded. Removal units are used to balance any gross emissions (e.g., from hard-to-abate sectors) such that the ETS results in net zero emissions.

There can be limits on the use of removal units. Decisions on the volume of removal units allowed into the system are tightly connected to jurisdictional decarbonization trajectories and regulators' definition of residual emissions (see section 4.1), as well as to measures to address abatement deterrence (see section 4.2). Limits could be operationalized, for example, by having the regulator control the volume of removal units that can enter the system through centralized auctions, or through a 'one in, one out' approach, whereby the use of a removal unit in the system leads to one fewer fiat allowance being made available in the market.

By trading exclusively in removal units, a net-zero ETS could be said to have transitioned into a removals trading system (RTS). This paper understands an RTS to be a policy instrument that creates a market for removal units by requiring certain sectors to comply with an obligation to surrender them. RTSs could in theory take several shapes. Compliance obligations, for example, could be established on the basis of emissions or of other metrics, e.g., energy use, addressing fossil CO_2 at the source, or simply as a cost of doing business (see e.g., Carbon Gap and CONCITO 2025). The market structure could involve multiple covered entities purchasing removal units from multiple CDR suppliers and/or from the government, and/or the government purchasing removal units from multiple CDR suppliers. To the extent that non-governmental entities are engaged in purchasing removal units, a key question is how this purchase obligation is assigned. In the scenario discussed here, obligations to purchase removal units would apply to RTS-covered entities on the basis of their gross emissions. Several removal obligation instruments have been proposed in the literature (see Box 1).

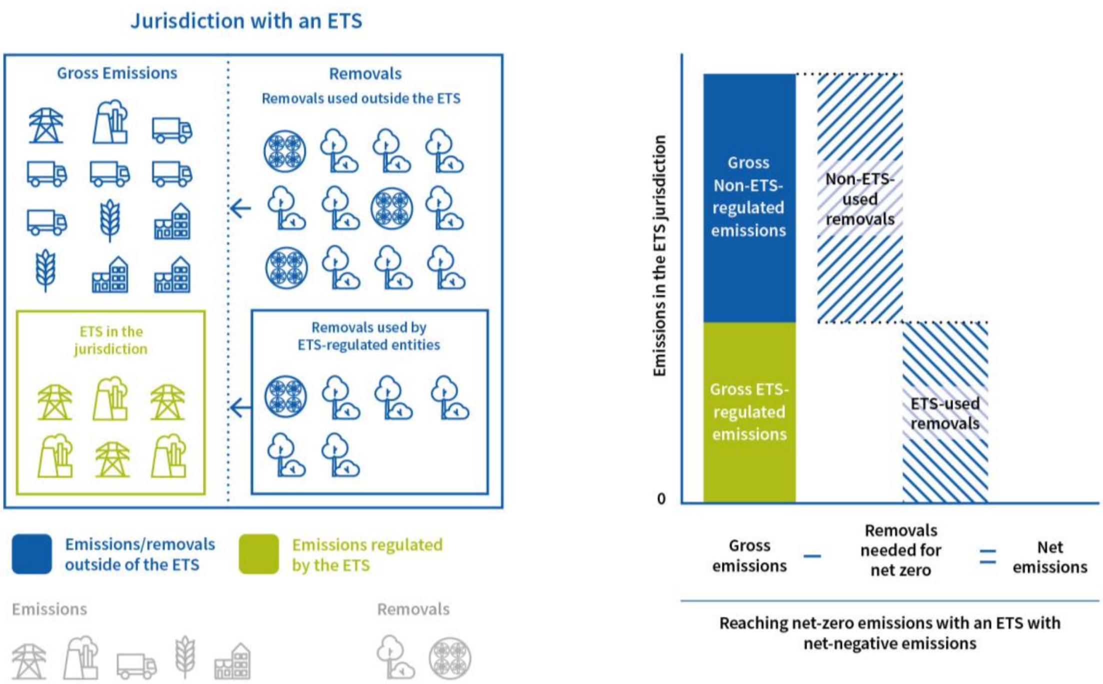
Box 1: Removal and storage obligation instruments

Various options have been proposed in the literature to impose upon GHG emitters and/or fuel producers and suppliers the responsibility to remove (or store) emissions from the atmosphere (see, e.g., Allen et al. 2009; Bednar et al. 2024; Jenkins et al. 2023; Lemoine 2020; Lyngfelt et al. 2024; Zakkour et al. 2024) – also referred to as extended emitter responsibility instruments (European Scientific Advisory Board on Climate Change 2025, sections 11.3 and 12.2). A legislative proposal for a removal obligation instrument was also discussed in California in 2023 (California Legislature legislative proposal for a Carbon Dioxide Removal Market Development Act (SB 308)), but ultimately failed to pass. Generally speaking, under these instruments, fossil fuel producers and/or entities that emit GHGs into the atmosphere could have the obligation to surrender a carbon removal unit (or a carbon storage unit) for each tCO_2e that they cause. The compliance obligation can be phased in in terms of quantity (that is, less than one such unit per tCO_2e) and over time (that is, a unit has to be surrendered years after the emission took place), and can use various instruments (e.g., tradeable certificates, carbon debt instruments).

By and large, the literature so far has treated ETSs and such removal/storage obligation instruments as distinct mechanisms, potentially operating in parallel, or with removal/storage obligation instruments replacing ETSs. These instruments as currently proposed are thus a *related but distinct* type of instrument as compared to ETSs. Both instruments aim to mitigate GHG emissions, establish compliance obligations on the basis of positive emissions, and can be market-based instruments that allow for trade in compliance units. Yet differences exist. The first one is their aims: while ETSs typically aim to *reduce* GHG emissions, removal/storage obligation instruments proposed in the literature aim to *neutralize* (at least part of) them, typically over several years, and often have the explicit objective of facilitating the development and deployment of negative emission technologies and/or storage capabilities. The traded units also differ. ETSs have mainly traded fiat allowances, with some use of offset credits and removal units. Removal/storage obligation instruments would primarily trade in removal or storage units, potentially backed by instruments to anchor the carbon debt.

One recent study proposes to incorporate carbon debt in ETSs, such that fiat allowances be replaced by 'clean-up certificates', which would allow a regulated entity to emit CO_2 albeit with an obligation for its future removal (Lessmann et al. 2024). If all fiat allowances are replaced with obligations to remove such that one emission requires one removal unit, then the emissions result (after the removal) would be net-zero. Such a system could feature a limit on the number of available clean-up certificates.

Figure 5: Reaching net-zero emissions in a jurisdiction with an ETS that results in net-zero emissions



In Figure 5, the oval shape on the left side represents a jurisdiction with an ETS. Emissions are presented to the left of the dotted line, and removals to the right. The rectangle represents the ETS in the jurisdiction. Emissions and removals generated outside the scope of the ETS are presented in green, whereas emissions generated inside the scope of the ETS are presented in blue. There is the same number of emissions under the scope of the ETS as there are removals being used by ETS-covered entities to balance their emissions. The right panel of the figure is a stylized waterfall graph that represents the emissions balance inside and outside the ETS scope: the first green striped block represents all the removals that are used to balance the emissions outside of the scope of the ETS. The second green striped block are the removals that are used by ETS-covered entities for compliance. They fully balance the gross emissions of ETS entities and contribute to reaching net-zero in the jurisdiction. Implications for allowing removals in the ETS are discussed in section 4.5 .

Relevance

- While gross emissions in the ETS are positive, the ETS delivers net-zero emissions, doing away with the need for additional policy instruments to balance for ETS residual emissions in order to achieve a jurisdictional net zero target.
- By allowing for the use of removals in the ETS, the system encourages both abatement and removals.
- Could provide for a cost-effective balance between abatement and removals inside the ETS, although abatement deterrence (see below) can result in economic inefficiencies.
- Different jurisdictions have different removal and storage capacities. A net zero ETS could include international trade of removal units where this would provide cost efficiency.
- The volume of gross emissions in the ETS depends on the volume and quality requirements of removal units permitted into the system (limited or unlimited;[11] engineered and/or nature-based, etc), as well as on the associated marginal removal costs compared to the marginal abatement costs. Given cost-competitive removal units, an unlimited inclusion of CDR in the ETS would likely lead to higher gross emissions.

[11] Note that this is not about 'quantitative limits' in the sense of a proportion of an entity's compliance obligation, but rather an absolute quantitative limit on use of removal units that can enter the system.

- Allowance price impacts are also influenced by removal unit volume and cost.
  - An unlimited use of removals would effectively establish a (dynamic) price ceiling in the ETS, as determined by the CDR technology costs. Gross emissions inside the ETS will thus depend largely on the volume of abatement available up to the cost of eligible removal units in the system. Allowing unlimited forestry units, for example, is likely to result in higher gross emissions under the ETS than the unlimited use of engineered removals, as the latter are typically much more expensive.[12] An unlimited use of removals would lead to a higher risk of abatement deterrence (see further below).
  - A limited use of removal units would likely result in ETS compliance costs somewhere between those resulting from the absolute zero ETS and the net zero ETS with unlimited use of removal units. If the government or a governmental agency buys such units and auctions them in the ETS, acting as a gatekeeper limiting the removal unit quantity, then the auction price is likely higher than in a no-limits scenario but lower than compliance costs in an absolute zero scenario. The number of fiat allowances that are still in the system also influences the price development in an ETS with limited removal units being released.
- Allowing removal units in an ETS can lead to the risk of abatement deterrence. Since emissions are still possible, covered entities can decide whether to reduce their emissions or to buy removal units. This can send the signal that investments in emission abatement are not necessary or urgent because emissions can be balanced by removal units. This can slow down the necessary structural transformation of certain industries, delay investments to a later point in time, and lock carbon in the economy. Abatement investments' payoff could be rendered uncertain, delaying abatement decisions. Limiting the volume of available removal units as well as implementing complementary policies that drive abatement may help address the risk of abatement deterrence. For more on abatement deterrence, see section 4.2 . On the upside, removal units could help address carbon leakage if their use reduces compliance costs.
- An increase in gross residual emissions could make it harder to achieve jurisdictional net-negative targets if removals are scarce.
- The ETS could play an important role in accelerating the development, deployment, and commercial viability of removal activities, by providing a source of demand for such units. It is important to note, however, that the incentive would be limited to the level of gross emissions in the ETS. If jurisdictions need to scale up CDR supply to address residual emissions outside the ETS and/or historical overshoot emissions, other policy instruments, including a net-negative ETS, would be required to incentivize such investments.
- A net-zero emissions ETS must address the issue of equivalence and fungibility between GHG emissions and removals, as well as among different types of removal units.
- Ensuring the quality of removal units requires well-designed regulations and procedures.

ETS functioning

- To the extent that removal units are cost-competitive *vis-à-vis* abatement costs inside the ETS, the inclusion of removals can provide for a reduction in compliance costs compared to the absolute-zero and net-positive scenarios.
- Compliance costs will be determined not only by abatement costs inside the ETS, but also by the cost of removal units, mediated by any limits on the use of such removal units.

[12] The former would also be problematic due to performance concerns. Quality requirements (e.g., on permanence) have a significant impact on removal unit price.

Moreover, liquidity, transparency, and transaction costs will also be influenced by the means through which removal units enter the ETS (see section 4.5).

- A few aspects indicate that a net-zero ETS could be more liquid than a net-positive one, assuming that the former is less restrictive on the use of removal units (although this may not mean that the market be able to sustain effective price discovery – see section 4.3). First, where CDR suppliers participate in the ETS directly, this can increase the number of participants or compensate for the decline in conventional traders and help prevent an illiquid market where participants refrain from trading. Second, it seems possible that gross emissions can be higher in a net-zero ETS scenario as compared to the net-positive one. This is especially plausible if the integration of removals is unlimited in a net-zero ETS compared to a tight cap in a net-positive ETS. Higher gross emissions could mean higher trade volumes as compared to the net-positive ETS.
- If the ETS and removal markets are connected directly (that is, covered entities procure units directly in the primary removals market), and if the regulator wishes to impose a limit on the use of removals, the regulator must either set a limit on CDR supply or on demand. A limit on supply requires that the regulator act as a gateway for the inclusion of removal units in the system, and can be established for example by defining a maximum volume in auctions or in unit reserves. Limits on demand for removal units could require the establishment of product-specific benchmarks (see also section 4.1). Complementary policies such as product standards could help drive abatement action and avoid abatement deterrence. It would be important to design such standards carefully to avoid distortionary effects within the ETS.
- A limit on the number of removal units that can be used in the ETS implies a decision on the level of acceptable residual emissions within the system (see section 4.1). This also requires determining which limit is needed to avoid abatement deterrence if prices for removals are low.
- Certain CDR technologies are not viable at scale (yet). This can create uncertainties for designing a net-zero ETS with sizeable removal use.

Feasibility

- Ensuring and managing the environmental integrity of removal units can be challenging for the regulator.
- CDR could need to be scaled up rapidly to cater to the expected demand. The incentive provided by the ETS might not be sufficient and could require additional RD&D support, infrastructure investments etc.
- Abating an economy's last emissions is likely to be very expensive and removal units are likely to be cheaper. Compared to an absolute zero ETS, a net-zero ETS can give covered entities more time to find solutions or continue to emit and balance for as long as the ETS permits it.
- Since the price is likely lower than in an absolute-zero ETS, public acceptability of a net-zero ETS is likely higher.
- A net-zero ETS assumes that the regulator would no longer issue fiat allowances and, instead, use removal units from CDR suppliers. This means foregone allowance auction revenues for the regulator, albeit while also reducing the burden on the regulator to purchase removal units in order to achieve net zero.

Transition

- Transitioning to a net-zero ETS begs the question of when and how to integrate the removal units. This could happen at a single moment when the regulator ceases to issue fiat allowances and exclusively makes use of removal units inside the ETS as or through a phased approach, e.g., as detailed by Sultani et al. (2024). The options for the transition will also depend on how removal units flow into the ETS, whether through a government agency or whether covered entities purchase units directly from CDR suppliers.
- During a transition period, both fiat allowances and removal units can be traded. Clear rules on their fungibility and possibly the acceleration of using fiat allowances to get them out of the system are required.
- A net-zero ETS also needs to address the question of banked allowances and allowances in a market stability reserve. Covered entities could possibly still have significant numbers of banked allowances that remain in the market unless there are specific rules limiting or prohibiting banking.
- Calibrating the ETS rules to avoid abatement deterrence is an important challenge for the transition to a net-zero emissions ETS. Establishing limits on the use of removal units and employing a gradual, phased approach are some of the options available to policymakers (see section 4.2).

ETS with net-zero emissions: summary table

<table>
<tr><td>Concept</td><td colspan="2">• The regulator no longer issues fiat allowances, but the system includes provisions for removal units.
• Gross emissions under the ETS remain positive, but net emissions are zero.
• The use of removal units may be subject to limits.
• By trading exclusively in removal units, a net-zero ETS could be said to have transitioned into a ‘removals trading system’.</td></tr>
<tr><td></td><td>Pros</td><td>Cons</td></tr>
<tr><td>Relevance</td><td>• Does away with the need for additional policy instruments to balance for ETS residual emissions to achieve a jurisdictional net zero target
• The ETS incentivizes both reductions and removals.
• The ETS supports the development and deployment of CDR technologies.
• An unlimited use of removals would effectively establish a (dynamic) price ceiling in the ETS, as determined by the CDR technology costs.
• Could provide for a cost-effective balance between abatement and</td><td>• Complexity of ensuring quality of removals units.
• Can lead to an increase in gross emissions.
• Risk of abatement deterrence within the ETS, e.g., delaying investments and slowing down structural transformation.
• An increase in gross residual emissions within the ETS could make it harder to achieve jurisdictional net-negative targets if removal units are scarce.</td></tr>
</table>

	removals inside the ETS, barring abatement deterrence effects.	
ETS functioning	• Cost-competitive removal units can reduce compliance costs compared to the absolute-zero and net-positive scenarios. • An increase in gross emissions (e.g., where there is no quantitative limit on removal units) and in supply-side market actors may lead to a more liquid market than under a net-positive ETS with quantitative restrictions on removal units.	• An integration of removal units without limits would likely lead to an increase in gross emissions. • Challenge to establish the right removal unit limit. • Uncertainty of removals supply and costs. Some CDR technologies might not be viable at scale.
Feasibility	• Likely to have lower carbon prices and higher social acceptance than in the absolute zero emissions scenario.	• Foregone revenue for the regulator from the auction of fiat allowances.
Transition	Challenges in: • managing the phasing out of fiat allowances and phasing in of removal units • managing the bank of allowances during the transition, and • addressing abatement deterrence.	

3.3 Net-negative emissions

We define a net-negative ETS as a system where the sum of net emissions by *regulated entities* is negative. This can be achieved by requiring that ETS-regulated entities surrender more than one removal unit for each positive emission they cause. For example, a cement company that emits 1000 tCO_2e could have to surrender 2000 removal units, thus resulting in net -1000 tCO_2e for that entity. To our knowledge, no such system has been detailed in the literature,[13] neither has any jurisdiction yet announced to follow such a path. (See Box 2 below for a discussion on diverging views on what can constitute a net-negative ETS). Such an ETS could be described as a removals trading system (RTS), in the sense that only removal units would be traded. Market participants would be GHG emitting entities on the demand side, while the supply side could be composed of individual CDR suppliers, or only the government (e.g., where the regulator purchases removal units and re-sells them in the ETS, and/or sells them via consignment auctions on behalf of CDR suppliers). Gross emissions could be subject to a limit, e.g., where the supply of removal units into the ETS lies under government control and is limited. A similar possibility is a removal obligation instrument (see Box 1 in section 3.2 above) where regulated entities have the obligation to surrender, in the future, more than one removal per emission thereby resulting in net-negative emissions at the end of the compliance period. While removal obligation instruments are typically portrayed as a related but distinct type of instrument, an ETS can be morphed into a removal obligation instrument if ETS allowances are replaced with obligations to remove (e.g., through carbon debt), as proposed in Lessmann et al. (2024).

[13] Rickels et al. 2021 makes a brief mention of this possibility, noting that "a negative regulatory cap requires that [carbon removal certification credits] are demanded in excess of gross emissions, implying that either there is additional demand by the regulatory authority or a fewer than one exchange rate between CRCs and allowances".

Box 2: Diverging views on what constitutes a net-negative ETS

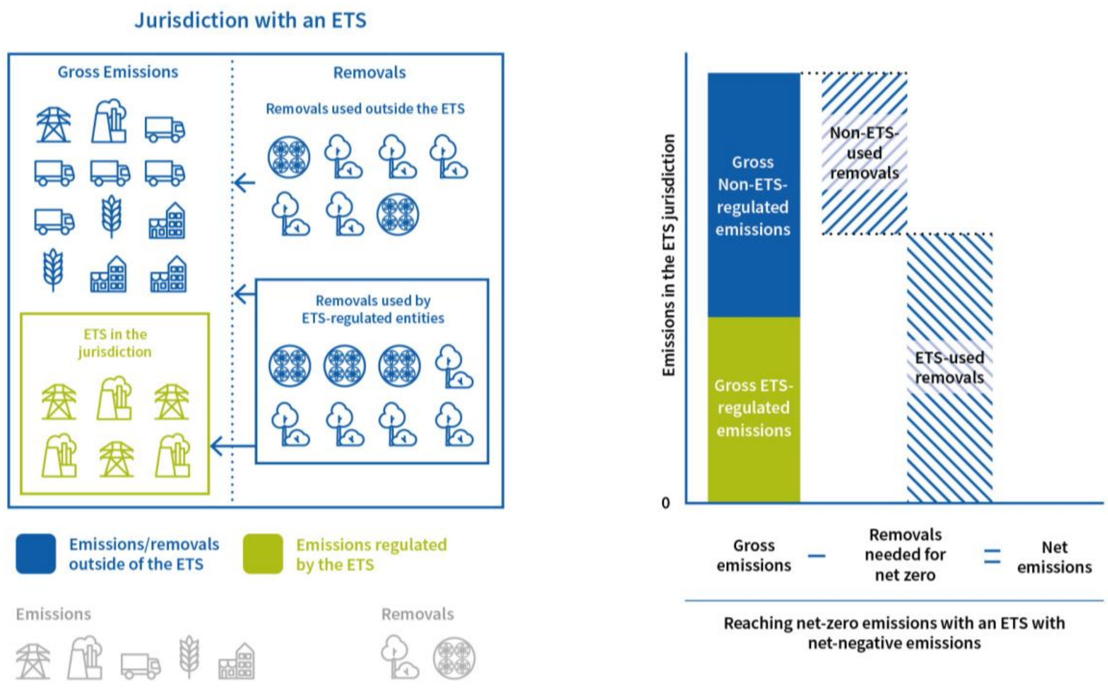
There can be a semantic discussion on what constitutes an ETS that delivers net-negative emissions. Interviews yielded many ideas, mainly involving extra purchases of units by the regulator.[14]

For example, one interviewee argued that a negative emissions outcome could be achieved by an ETS where regulated entities have a positive or zero allowance allocation, and where the government purchases large volumes of removals (perhaps using ETS auction revenues) on its own, without inserting such removal units into the ETS. Similarly, another interviewee suggested that the regulator could purchase removal units outside the ETS and replace allowances inside the ETS with these, with covered entities surrendering only one allowance per tCO_2e emitted. Yet neither of these options would constitute a net-negative ETS, as the emissions impact of the ETS (as defined by its cap) is commonly understood as the limit on "how much regulated entities can contribute to global emissions" (World Bank and International Carbon Action Partnership 2021, p. 79, emphasis added). Removal units purchased through other policy instruments would not accrue to the impact of the ETS, or of its cap. The second option, moreover, would at best yield a net zero (and not net-negative) result.

Another possibility is an ETS where the government not only ceases to issue any allowances and compliance units while maintaining the obligation to surrender them (absolute zero cap) but also buys back part of the allowances being banked by market participants. In such a situation, the ETS could be said to deliver negative emissions in that year, in the sense that the regulator is removing allowances from the market in that period. However, even in the year of the buy-back of allowances, *covered entities* would either still continue causing net GHG emissions (by consuming the bank of allowances), or, at best, reach absolute zero emissions (if the bank of allowances is entirely used up). This possibility would thus contribute to increasing abatement ambition but would not lead to net removal of CO_2 from the atmosphere.

[14] As described in the chapeau of this section, this paper understands the emissions result of an ETS as the net result of the gross emissions of regulated entities and of the compliance units they use. As such, it does not consider any options that would establish removal obligations on the basis of anything other than present GHG emissions.

Figure 6: Reaching net-zero emissions in a jurisdiction with an ETS that results in net-negative emissions.



In Figure 6, the oval shape on the left side represents a jurisdiction with an ETS. Emissions are presented to the left of the dotted line, and removals to the right. Emissions and removals generated outside the scope of the ETS are presented in green, whereas emissions generated inside the scope of the ETS are presented in blue. The right panel of the figure is a stylized waterfall graph that represents the emissions balance in the jurisdiction: the green striped block represents all the removals that are used to balance the emissions in the jurisdiction. In this figure, we have assumed that some of the emissions that used to be covered by the ETS remain after the ETS has been phased out. Note that, like the other figures, this one presents the achievement of a jurisdictional net-zero target. A net-negative ETS can be used as a tool to achieve net-negative jurisdictional emissions.

Relevance

- An ETS as described above can deliver net-negative emissions for as long as there are positive emissions in the ETS (because the number of negative emissions is a multiple of the number of positive emissions in the system).
- A back-of-the-envelope calculation suggests that requiring ETS residual emitters to remove 2 tCO_2 for every tCO_2e emitted in the second half of the century could contribute significantly to addressing the historical overshoot (see Box 3).
- In practice, such an obligation would likely face strong resistance as it would place a heavy burden on already-strained residual emitters. Nevertheless, the overall result in the long-term may trend to zero, as emitters decarbonize or cease to exist.
- Again in this option, regulators would have to address the difficult issue of equivalence/fungibility between emissions and (different types of) removals.
- Regulators would also need to address the risk of abatement deterrence, especially if the (relatively cheap) biogenic CDRs are included (Burke and Gambhir 2022).

Box 3: Back-of-the-envelope calculation on residual and overshoot emissions and net-negative ETS balances

In order to understand the extent to which residual ETS emissions can be used as a leverage to address overshoot emissions, this box provides quick estimates on each side of the equation.

Global residual emissions: Estimates of global residual emissions lie around 14 Gt/year (Buck et al. 2022).[*1] Fifty years of such residual emissions would amount to 700 Gt in the second half of the century.[*2]

Global overshoot emissions: The IPCC estimates that, for category C2 pathways,[*3] around 360 Gt (range of 60 to 680 Gt) net-negative emissions will be required in the second half of the century to address emissions overshoot for a 1.5°C temperature goal (Intergovernmental Panel on Climate Change 2023).

ETS coverage and net-negative contribution: If ETSs were still to cover around 20% of the world's residual emissions,[*4] and if <u>all</u> ETS residual emitters were required to submit two removals for each tCO2e emitted, then ETSs worldwide would not only balance their own residual emissions, but also contribute around 140 Gt of net-negative emissions in the second half of the century – or around one third of the ~360 Gt overshoot volume mentioned above.

(*1) This is in line with other estimates, e.g. , 9-15 Gt (Edelenbosch et al. 2022), and 16 GtCO2e/yr (with a range of 12-26 GtCO2e/yr) (Lamb 2024), with figures depending on temperature goals and on the point of net zero.

(*2) Given that emissions are likely to be higher in the early decades but lower in the later decades of the 50-year span considered here, we assume a constant 14 Gt/year.

(*3) From Intergovernmental Panel on Climate Change (2023): *Category C2 comprises modelled scenarios that limit warming to 1.5°C in 2100 with a likelihood of greater than 50%, and exceed warming of 1.5°C during the 21st century with a likelihood of greater than 67%. (...) [T]hese scenarios are also referred to as scenarios that return warming to 1.5°C (>50%) after a high overshoot. High overshoot refers to temporarily exceeding 1.5°C global warming by 0.1°C–0.3°C for up to several decades.*

(*4) This would likely require ETSs expanding in sectoral as well as in geographical coverage to address the changing emissions profile both in terms of sectors (as ETS-covered emissions tend to go down more steeply than non-covered sectors, e.g., agriculture and transport emissions) and in terms of geographical emissions sources (as high-income countries are expected to reduce emissions more quickly than low-income ones).

ETS functioning

- It seems possible that a net-negative ETS would have similar challenges to a net-zero ETS, with relatively few sources of demand and potentially relatively low volumes. Nevertheless, given a certain level of gross emissions, the net-negative scenario would likely see larger trade volume than a net-zero one, given the requirement to surrender more than one removal unit for each tCO_2e of gross emissions.
- As in the case of other scenarios that use removal units, the integrity of the system would rely crucially on the environmental integrity of the compliance units used in the system – with the attendant challenges related to measurement and permanence, among others.

Feasibility

- Such a system could be perceived to overburden already strained residual emitters within the ETS, especially if removal units are expensive.
- The purchase of removal units by covered entities will entail a financial flow towards suppliers of removal units. This may increase support for the system by widening the constituency that benefits financially from the ETS. Yet this may present a political challenge, in particular if suppliers are located outside jurisdictional borders.
- Compliance costs will depend on the type of obligation and on the type/quality requirements (and cost) of removal units allowed. High compliance costs are likely to undermine international competitiveness and political support for the system.
- This option assumes that the regulator would no longer issue fiat allowances and, instead, use removal units from CDR suppliers. This can mean foregone ETS auction revenues for the regulator.
- Ensuring and managing the environmental integrity of removal units can be challenging for the regulator.

Transition

- The transition to a net-negative ETS faces the same challenges as the transition to net-zero, e.g., managing a gradual phase out of fiat allowances and phasing in of removal units, managing the bank of allowances during the transition, and addressing abatement deterrence.
- The transition into a net-negative state could entail the regulator's gradual replacement of allowances for removal units (e.g., where the regulator purchases them and auctions them into the market), then slowly phasing in a requirement to surrender more than one unit for each tCO_2e emitted.

ETS with net-negative emissions: summary table

Concept	• The regulator ceases to issue fiat allowances. There are provisions for removals trading. • Remaining emitters in the ETS surrender more than one removal unit per tonne of emissions. • Gross emissions under the ETS are positive, but net emissions are negative.	
	Pros	**Cons**
Relevance	• Can deliver negative emissions for as long as there are gross emissions in the ETS. • Back-of-the-envelope calculation suggests that requiring ETS residual emitters to remove 2 tCO_2 for every tCO_2e emitted in the second half of the century could contribute significantly to addressing the historical overshoot.	• The overall result in the long-term likely trends to zero as emitters decarbonize or disappear. • Could overburden already-strained residual emitters. • Risk of abatement deterrence, especially if the (relatively cheap) biogenic CDRs are included.

ETS functioning	• May provide more liquidity through additional demand and supply-side market participants.	• The ETS could still suffer from low liquidity (depending on the structure of CDR supply).
Feasibility	• Financial flows to removal unit providers could increase political support for ETS by widening the benefitting constituency.	• Complexity of ensuring quality of removals units. • The ETS is likely to have high costs for emitters and, as a result, low social acceptance. • Financial flows to removal unit providers outside of the ETS could be politically challenging if suppliers lie outside jurisdictional borders.
Transition	• Many of the same challenges as the transition to net-zero, e.g., managing the phase out of fiat allowances and phasing in of removal units, managing the bank of allowances during the transition, and addressing abatement deterrence. • The transition to a net-negative state could entail the regulators' gradual swap of allowances for removal units, then slowly phasing in a requirement to surrender more than one removal unit for each tCO_2e.	

3.4 Absolute-zero emissions

Under an absolute zero emissions ETS, no new allowances are issued, and there are no provisions for removals. Covered entities can continue using banked allowances to cover their emissions and can continue to emit GHGs for as long as they have banked allowances, or can buy allowances that another entity previously has banked. There may also be some allowances in a market stability reserve, which could be released into the market after a transition from a positive to an absolute zero emissions ETS. There could thus still be some allowance trading and emissions during a transition phase, but only within the cumulative emissions limit of previous years. A stable-state absolute-zero emissions ETS does not have any allowance trading and therefore no longer is a "trading" system. Once the banked allowances are used, and assuming ETS obligations are enforced, gross emissions of all entities regulated by the ETS must reach zero[15] (see Figure 7). Covered entities can still use technologies such as carbon capture, utilization, and storage (CCUS) to avoid emissions reaching the atmosphere. At this stage, the ETS functions as a ban on uncaptured emissions rather than a trading system, since there are no allowed uncaptured emissions and no trading.

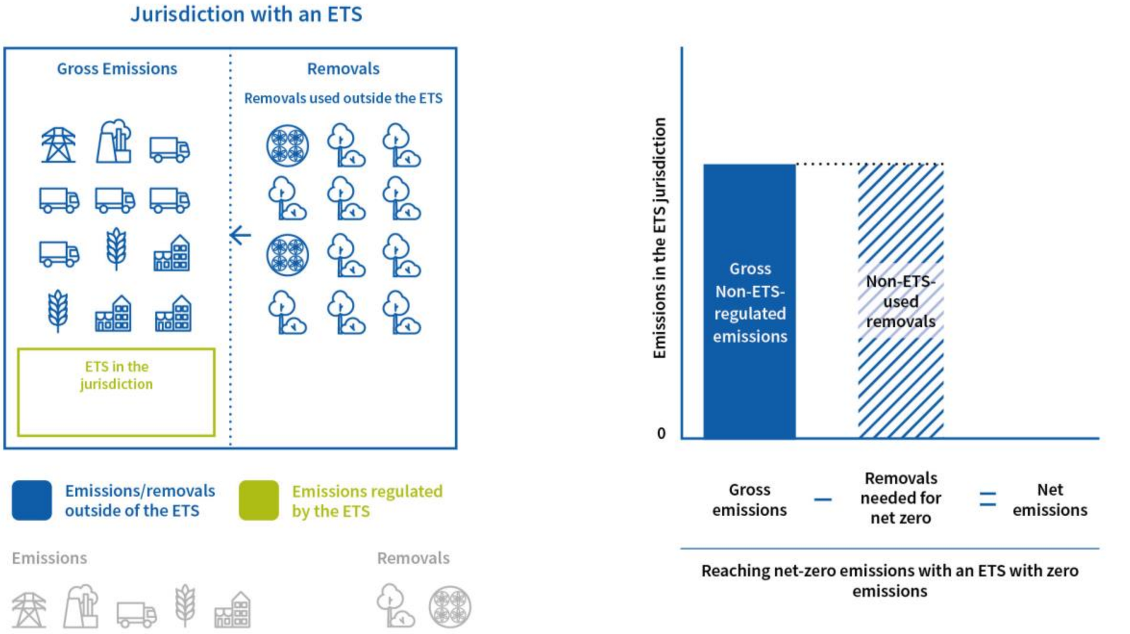
Mandatory make-good provisions are crucial to enforce a ban on emissions through the ETS. Make-good provisions require that an allowance always be surrendered when an emission takes place. If a system has make-good provisions, then no emissions are possible once there are no allowances left in the system. In the absence of make-good provisions, however, the non-compliance fine will act similarly to a carbon tax, and the system would result in net-positive emissions.

If unchanged, current provisions under some existing ETSs could make them become absolute zero emissions systems in the future. For example, until 2023 the EU ETS had a 2.2% linear reduction factor for its emissions limit (of the average total quantity of allowances issued annually from 2008 to 2012). Since 2024, the linear reduction factor has been 4.3% and from 2028 it will be 4.4%. If there are no future changes, this will bring the EU ETS 1 emissions limit down to zero in 2040 for stationary emitters plus maritime. Under the current provisions for aviation, there will be still some small positive cap left in 2040.

This option is hypothetical and includes several challenges. With currently available technologies and low societal acceptance for high mitigation costs, the viability of a ban on emissions is very low. An absolute-zero emissions ETS could be feasible for sectors in which *fully* eliminating emissions is technologically and economically feasible. Since carbon leakage could be a high risk, if the sectoral scope includes emission-intensive and trade-exposed (EITE) sectors, measures to protect from this risk would need to be designed. Since there will no longer be an allowance price, current carbon border adjustment mechanisms would need to be rethought. As a long-term steady state policy, it could be impractical compared to some alternative policy measures.

[15] Jurisdictions may decide to change the inclusion thresholds or sectoral scope as the market becomes smaller; see section 4.3 .

Figure 7: Reaching net-zero emissions in a jurisdiction with an ETS that results in zero-gross emissions.



In Figure 7, the oval shape on the left side represents a jurisdiction with an ETS that accepts no more emissions within its scope. Emissions are presented to the left of the dotted line, and removals to the right. The rectangle represents the ETS in the jurisdiction, and the lack of emissions therein represents the fact that no gross emissions are permitted in its scope anymore. Emissions and removals generated outside the scope of the ETS are presented in green. The right panel of the figure is a stylized waterfall graph that represents the emissions balance in the jurisdiction, with the green striped block representing all the removals that are used to balance the emissions in the jurisdiction.

Relevance

- The absolute-zero ETS design does not allow for any gross emissions under the scope of the ETS. However, virtually no sector can arrive at absolute zero emissions with current technology and at current societal willingness to pay. An absolute-zero emissions ETS could thus face major challenges.
- In an absolute-zero emissions ETS, covered entities are not permitted to release residual emissions once banked allowances are used, no other entity is selling allowances, and allowance reserves are depleted.
- A ban on emissions, if credible, can send a very strong decarbonization signal to market actors and encourage early and aggressive investment in abatement, zero-emission technologies, and RD&D. This can lead to overall higher cost effectiveness in achieving long-term mitigation goals (Vogt-Schilb et al. 2018) and create important societal benefits such as reduced climate damages, improved health, and innovation (Intergovernmental Panel on Climate Change 2023). The decarbonization signal of this option is likely to be stronger than in all other options considered in this paper.
- The system would provide incentives for developing abatement (including CCUS) rather than for removal solutions, as CDR would not be accounted for under the ETS.
- An absolute-zero emissions ETS sends a strong signal on where the system is heading well before no allowances are issued and fully used. Banked allowances can keep an ETS functioning for a significant period after the last allowance has been issued but the signal of their finality is sent long before.

- In most, if not all, sectors, residual emissions are likely to exist under current technological conditions. When banked and reserve-stored allowances are used, an absolute zero ETS cannot accommodate them. A ban on emissions is very likely to lead to carbon leakage, as entities in hard-to-abate sectors might choose to relocate to jurisdictions with a lower compliance burden. The risk of investment leakage is also high.
- To address carbon leakage, a complementary measure could be introduced to ban embedded emissions from imports. This could be a novel design of a carbon border adjustment mechanism (CBAM), not based on a carbon price as currently existing proposals, but on other to-be-developed criteria. Comparing, for example, a jurisdiction's absolute-zero emissions limit with another jurisdiction's net-zero emissions limit would be one of the challenges to be solved.

ETS functioning

- Without allowance trading and a carbon price, most of the features that characterize a typical ETS disappear. ETS structures (such as a registry to track allowances and trades, auctioning platforms, and compliance cycles) become unnecessary. However, provisions for monitoring (the absence of) emissions and enforcement of obligations would remain, and would be crucial in the application of the emissions ban through the ETS. An enforceable ban on emissions could also require new structures, such as remote sensing to detect emissions, as well as rules for liability.
- Mandatory make-good provisions that require that an allowance always be surrendered when an emission takes place would be necessary to ensure an emissions ban, as ETS compliance would become impossible once allowances are no longer available in the market. In the absence of make-good provisions, the penalty for non-compliance would be similar to a carbon tax, delivering net positive emissions. See section 3.4 for an exploration of this option.

Feasibility

- An ETS with a stable absolute-zero emissions limit has the advantage that it provides for the implementation of an emissions ban through the continuation of an established policy instrument. No new policy measure needs to go through a possibly controversial political process.
- An absolute-zero ETS might be seen as a draconian form of climate policy imposing a ban on what some may consider socially and economically justifiable emissions. Mitigation costs can be exorbitantly high, which would likely increase the costs of goods and services significantly, and which could be difficult to justify in the presence of relatively lower removal costs. Considering these aspects, policymakers could adjust the scope of an absolute-zero ETS to those sectors in which reaching absolute-zero emissions is feasible and not unreasonably expensive. An assessment of what these sectors are will vary according to a jurisdiction's geography, economic structure, wealth and related factors.
- Regulated entities unable to reduce their emissions to zero would have to either shut operations or relocate to other jurisdictions, which can lead to job and international competitiveness losses and carbon leakage. This can undermine political support for the system.[16]

[16] Complementary measures to ban embedded emissions from imports could help address this problem, but could be considered similarly draconian.

- The feasibility of an absolute-zero emissions ETS relates in parts to the timing of the gross emissions limit reaching zero and the availability of allowances that are banked or held in reserves. If the unavailability of allowances occurs at a point in time when it is economically and technically feasible to abate all covered emissions, the absolute-zero emissions ETS seems feasible. If it occurs too early, and in the absence of other tools to ban imported embedded emissions, carbon leakage is likely.
- An early – and credible – announcement of an emissions ban may send a strong signal for abatement action, encouraging investment in finding abatement solutions and accelerating their deployment. Climate policy that is viewed as draconian, however, would likely lack credibility.

Transition

- Transitioning to an absolute-zero emissions ETS does not only depend on the point in time when no new allowances are issued, but also on the number of banked and market stability reserve allowances that are still in the system. If previously issued but not yet used allowances are plentiful, an ETS with zero new allowances can continue to operate for a while (Pahle et al. 2023).
- Regulators can control the length of the transition period. To shorten it, they could limit or prohibit banking of allowances in earlier phases. Such a measure would, however, need to be balanced with market stability measures since the prospect of not being able to bank allowances could dampen market activities with uncertain effects on the carbon price. To lengthen the transition period, regulators could establish a bank in which all previously unused allowances are collected, and which releases them into the market when certain conditions are met.
- An ETS that is transitioning to an absolute zero emissions scenario can be expected to lead to higher banking behavior (Pahle et al. 2023) and less liquidity, if no provisions are adopted in this regard. Higher banking incentives will translate into higher prices than would otherwise be the case, with possible negative effects on the economy and the pathway to net-zero. Such a market is likely to be small, and may encounter several challenges to ensure proper price discovery (see section 4.3).
- Markets with a tight emissions limit may see higher speculation, and the price-finding mechanism might no longer be based on abatement costs. Excluding non-compliance entities from an ETS that approaches or has reached an absolute zero cap could help address this challenge. Yet, this would pose problems for market liquidity within the market. In the situation in which little heterogeneity or price discovery is left, the utility of the ETS's trading function will decline rapidly.

ETS with absolute-zero emissions: summary table

Concept	• The volume of fiat allowances declines to zero and no more allowances are issued. The ETS, however, remains in place. • There are no provisions for removal units. • Once all banked allowances and market stability reserve-stored allowances have been used, covered entities would no longer have compliance units for any residual emissions. • Gross emissions covered by the ETS reach zero. The ETS functions as a ban on emissions and no longer as a "trading" system. MRV and other non-trading requirements continue to apply.

	• Feasible only in sectors where *full* decarbonization is technologically and economically feasible. • Mandatory make-good provisions are crucial to enforce a ban on emissions through the ETS.	
	Pros	**Cons**
Relevance	• The ETS becomes an instrument to enforce a ban on emissions. • An early – and credible – announcement of an emissions ban may send a strong signal for abatement action, leading to early investment in RD&D and co-benefits. • No incentive for CDR, but incentive for CCUS and related technologies.	• Virtually no sector can achieve full decarbonization with current technologies and willingness to pay. • As it stands, a ban on emissions in any sector is unlikely to be credible. • More prone to carbon leakage than systems which allow for gross emissions to exist, as entities in hard-to-abate sectors may relocate to jurisdictions which allow for gross emissions. The investment leakage risk is high.
ETS functioning	• Emissions monitoring and sanction systems would continue.	• Without allowance trading or a carbon price, the features that characterize a typical ETS disappear.
Feasibility	• Emissions ban through the continuation of an established policy instrument.	• Imposing a ban on what some may consider as socially and economically justifiable emissions might be seen as a draconian form of climate policy, especially in the presence of relatively lower removal costs. • Potential for losses in jobs and international competitiveness can undermine political support for the system, which renders its adoption challenging.
Transition	• High risk of speculation and volatility as well as a very high carbon price in anticipation of the scarcity of allowances. • Depending on the number of banked allowances, emissions in an absolute net-zero ETS can continue for a significant time.	

3.5 No ETS

For some jurisdictions, maintaining an ETS may cease to make sense. This could be because the ETS can no longer provide for effective price discovery, or because policymakers consider that the ETS achieved its objective in driving down emissions within covered sectors, among other reasons.[17] Further incentives for abatement (e.g., to address any residual emissions and to prevent leakage and backsliding) would be driven by other instruments, such as carbon taxes and technology mandates. Incentives for CDR could be driven by e.g., a carbon removal obligation mechanism and government purchasing programs.

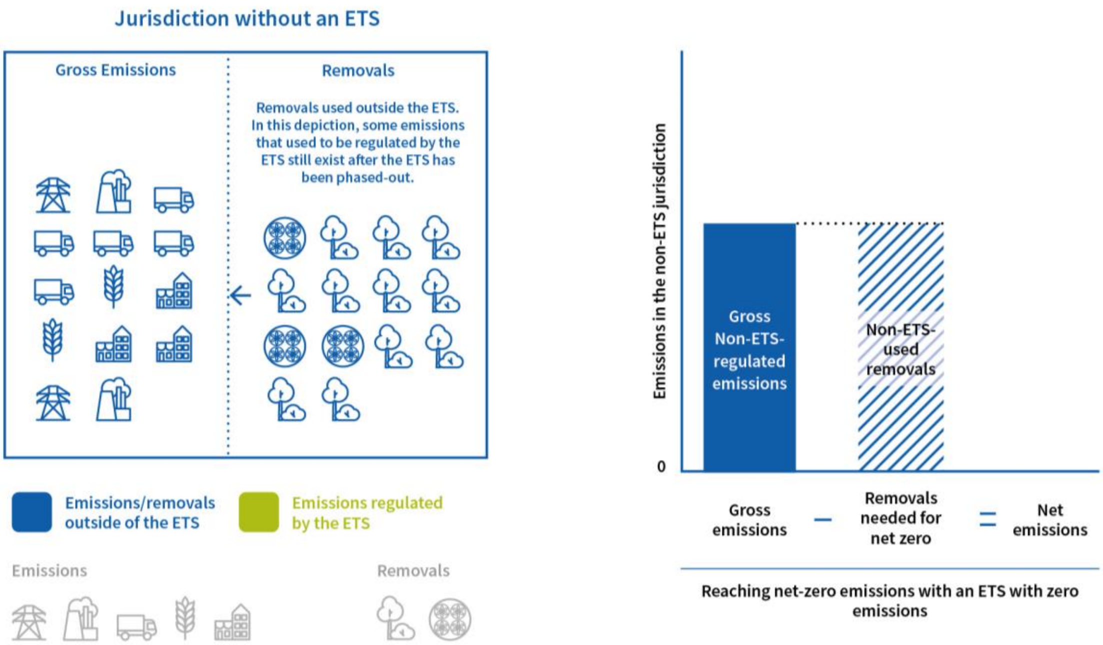
The phasing out of (some) ETSs may be implementable with relatively small changes. One relatively simple exit strategy entails the ETS morphing into a carbon tax, notably by eliminating make-good provisions and instituting a fixed fine per tCO_2e. In this case, part of the ETS 'skeleton' (MRV and compliance obligations) would still be maintained, but the cap-and-trade elements of the ETS would cease to exist. Alternatively, regulators could implement a price ceiling at which new allowances could be issued without limit. This would retain the usual ETS compliance mechanics and could be a transition measure towards the carbon tax model (which could be administratively simpler). Whether or not the remaining policy instrument is then titled an 'ETS' or a 'carbon tax' is less important than the underlying mechanics of how the policy functions, and whether key difficulties (such as price discovery in very small markets) are addressed.

While there are a few examples of phased-out ETSs, their relevance to this study is relatively limited. Some were replaced by other trading programs that also focused on emissions reductions. The US NOx Budget Trading Program, for example, was replaced by the Clean Air Interstate Rule, which was later replaced by the Cross-State Air Pollution Rule. This progression reflected an increase in scope (e.g., increasing coverage to SO2 emissions) and in stringency over time (driving steeper emission reductions) but retained the element of allowance trading. Another example is the wind down of the Nova Scotia cap-and-trade program, which was replaced by the Nova Scotia Output-based Pricing System for Industry in addition to the federal fuel charge, in order to comply with Federal carbon pricing regulations. Although the output-based pricing system does not feature an emissions cap, it also operates by trading emission units.[18]

[17] The focus here, thus, is on situations where the ETS becomes functionally irrelevant, rather than a situation in which political priorities change such that the ETS is scrapped without another instrument to drive mitigation action to replace it.

[18] Other ETSs were phased out following shifts in ruling governments and policy priorities, such as in Ontario, Virginia, and Australia; these experiences highlight the importance of a carefully planned phaseout, but do little to clarify how this could be best achieved.

Figure 8: Reaching net-zero emissions in a jurisdiction without an ETS.



In Figure 8, the oval shape on the left side represents a jurisdiction without an ETS. Emissions are presented to the left of the dotted line, and removals to the right. Emissions and removals, which are generated outside the scope of an ETS, are presented in green. The right panel of the figure is a stylized waterfall graph that represents the emissions balance in the jurisdiction: the green striped block represents all the removals that are used to balance the emissions in the jurisdiction. In this figure, we have assumed that some of the emissions that used to be covered by the ETS remain after the ETS has been phased-out.

Relevance

- As economies move towards net-zero, the potential for ETSs to support climate goals may change, and in some cases lead to ETSs having a (much) reduced role in the overall climate policy mix. The challenges in enabling effective price discovery in very small markets (see section 4.3), combined with the limited ability of ETSs in delivering net-negative emissions (see section 3.3), in addition to the many challenges in addressing land-use emissions, which may constitute an important part of residual emissions, suggests that the importance of ETSs in the climate policy mix may decline as emissions approach net-zero and dip into negative. To the extent that instruments other than an ETS are better placed to support sustainable and low (or zero, or negative) carbon development (e.g., due to lower administrative burden, or by better targeting particular emission sources), such instruments could be used to replace an ETS.
- If an ETS is phased out, other instruments (such as a carbon tax and/or command and control regulation) would be necessary to influence the mitigation pathways of residual emitters and to provide certainty on emissions levels. Sectoral policies should be carefully balanced to achieve a cost-efficient policy mix. Other instruments (such as public procurement for CDR) would also be necessary to incentivize emission removals. This could require a shift in regulatory culture, which can prove very challenging due to path-dependence effects (see e.g., Rosenbloom et al. 2019).
- Relying on other instruments may provide for administrative advantages, e.g., in terms of Paris Agreement accounting. An ETS is a policy that provides some degree of intertemporal flexibility in compliance, which may be difficult to reconcile with single-year

emissions targets that are used by the vast majority of countries (see Hynes and Schneider 2023).

ETS functioning

- Since the ETS ceases to exist, this section does not apply.

Feasibility

- ETSs provide a transparent price signal, which is usually regarded as beneficial. However, this can also pose challenges related to public acceptance. Research suggests that subsidies (such as tax credits) and command-and-control regulations (such as technology or product standards) tend to encounter less public opposition (Drews and van den Bergh 2016).[19] Public acceptance of new policy packages would likely hinge on the perceived fairness, economic impact, and the government's ability to clearly articulate the benefits and manage the transition smoothly.
- Nevertheless, there can be concerns about the feasibility of delivering abatement through other policies with the same environmental certainty as an ETS. A transition away from an ETS could require a complex mix of carbon budgets and sectoral regulation with effective performance monitoring to uphold jurisdictional climate targets. A too-early phaseout could mean that the ETS is replaced by policies which deliver net-zero or net-negative, but at a higher cost to society than the ETS would have been able to achieve.
- Morphing the ETS into a carbon tax could generate (or maintain) revenue stream.

Transition

- An orderly phaseout is important to minimize negative effects on ETS functioning before its sunset date. Starting from early discussions, it will be crucial to maintain the credibility of overarching decarbonization goals, as these have an important role in maintaining the drive for mitigation (Sitarz et al. 2023).
- Allowances can be used as a transitional feature if they remain valid for compliance against the succeeding regulations, thus helping retain their value within the ETS before the phaseout date.
- In the case of a conversion to tax, the announcement of a future carbon tax with a fixed price is likely to cause the ETS allowance price to converge with the tax price, especially if there are banking provisions. This is because market participants will seek to take advantage of the arbitrage opportunity by buying allowances at the lower market price and using them when the tax is in effect. The transition period and market confidence in the policy change will influence the speed and completeness of this price convergence.

[19] Subsidies, moreover, can also send a transparent price signal, albeit of a different kind.

No ETS: summary table

Concept	• Regulators choose to phase out the ETS. The ETS ceases to exist. • Abatement is driven by other instruments, e.g., carbon tax, technology mandates, etc. • Removals are driven by other instruments, e.g., public procurement. • May be implementable with relatively small changes, e.g., morphing into a carbon tax by eliminating make-good provisions and instituting a fixed fine per tCO_2e.Feasible only in sectors where *full* decarbonization is technologically and economically feasible.	
	Pros	**Cons**
Relevance	• Focus on the effective use of policy instruments.	• May require a shift in regulatory culture. • Requires the establishment of a cost-efficient package of other policy instruments.
ETS functioning	• n/a	• n/a
Feasibility	• Lower public resistance to e.g., product standards. • Revenue stream generated in case of replacement by carbon tax.	• A transition away from ETS could require a complex mix of carbon budgets and sectoral regulation with effective performance monitoring to uphold jurisdictional climate targets.
Transition	• Difficult to retain an ETS's credibility once phaseout is announced. • Allowances can be used as a transitional feature if they remain valid for compliance with the succeeding regulations. • In the case of a conversion to tax, the announcement of a future carbon tax with a fixed price is likely to cause the ETS allowance price to converge with the tax price.	

4 DESIGN CONSIDERATIONS

Several cross-cutting issues apply to many or most ETS options outlined in the previous sections: defining residual and hard-to-abate emissions and the volume of removal units permitted, addressing abatement deterrence, considering issues resulting from shrinking markets and related to linking systems, as well as generating removal units inside or outside the ETS. This section delves into those challenges. In addition, it also highlights the importance of policymakers interrogating the equivalence and fungibility between abatement and removals, alongside corresponding eligibility criteria for the use of CDR (if any) in the ETS, as well as the complex interactions between the volume of fiat allowances and the use of removal units. For more on these aspects, see La Hoz Theuer et al. (2024).

4.1 Defining 'residual' and 'hard-to-abate' emissions for the ETS and the volume of removal units permitted in the system

Different economic sectors will make different contributions to the achievement of jurisdictions' climate goals. In some instances, emissions might continue after the point of net-zero, at least in part driven by technological constraints, lack of alternatives, or because of economic, social or political considerations.

There are no established definitions for 'residual' and 'hard-to-abate' emissions. In this paper, 'residual emissions' is taken to mean any emissions that reach the atmosphere after the net-zero point (Schenuit et al. 2023; Smith et al. 2024); and "hard-to-abate" emissions to mean those whose abatement feasibility is limited because of technological, economic, social or political considerations (Edelenbosch et al. 2022; Lund et al. 2023; Schenuit et al. 2023; Smith et al. 2024).[20] It is thus a moving target, among others due to technological progress and society's willingness to bear costs and change practices. Any classification of hard-to-abate emissions will carry a strong aspect of value judgement, for example, to determine what constitutes an acceptable cost, and how to prioritize policy goals against each other (Lund et al. 2023). It therefore quickly becomes a political question.

Thus, to the extent that gross emissions are allowed for ETS regulated entities (e.g., in the net-positive, net-zero, and net-negative emissions scenarios), such gross emissions would reflect the residual emissions left in the system – themselves a product of societal decisions about which emissions are considered hard-to-abate. Several approaches could be employed to identify hard-to-abate emissions inside the ETS scope, such as:

a. Prescriptively, at system level. For example, a top-down decision on maximum emissions that ETS sectors may still emit (e.g., 10% of 1990 emissions), or a specific price threshold;
b. Implicitly, at system level. This would occur with an unlimited use of removal units in the ETS, which implies that abatement will only take place until marginal abatement costs equal marginal removals costs, subject to the eligibility of removal units for use in the system;

[20] Hard-to-abate emissions, thus, would not include those that can be abated through carbon capture and storage technologies.

c. Prescriptively, at product entity level. For example, a top-down decision on maximum emissions per unit of production, set by the regulator according to economic, technological, and societal considerations. This would be akin to an emissions standard;
d. Dynamically, at regulated entity (or product) level. For example, an entity would be allowed to emit only a certain percentage of emissions more than the best performer in their sector (or product).[21]

A definition of 'hard-to-abate' would then inform the volume of compliance units that are allowed into the system, noting that there could be hard-to-abate emissions both inside and outside the ETS. Similarly, definitions involving specific price thresholds could be implemented as price ceilings in the ETS.

4.2 Addressing abatement deterrence

At the core of abatement deterrence is the concern that carbon removal comes at the expense of emissions reduction, affecting gross emissions. McLaren (2020)identifies and models three types of abatement[22] deterrence: (1) Substitution and failure, highlighting the risk of relying on CDR technologies that may underperform or fail altogether; (2) Rebounds, related to unintended consequences of CDR deployment, such as using captured carbon for enhanced oil recovery, or releasing carbon stored in soils when converting land for biomass production; and (3) Mitigation foregone, where the promise of CDR could lead to actors delaying abatement action that would otherwise have occurred. Under ETSs, issues (1) and (3) seem the most relevant ones, in both cases relating to the concern that gross emissions in the ETS remain higher with the introduction of CDR than they would otherwise be. The effects could be different in the short vs long term.

Concerns over a short-term increase in ETS gross emissions can be addressed by maintaining a limit on gross emissions – for example through a 'one in, one out' approach whereby for each removal unit entering the system, one fewer fiat allowance would be released (CATF and CONCITO 2024).

Longer term effects are more delicate and stem from the high long-term uncertainty about the volume and cost of removal units. As highlighted by Sultani et al. (2024), regulated entities may delay abatement investments until there is more information about the costs of available measures. This creates the risk of being locked in a higher-emissions pathway, which could lead to steep price rises, especially if the CDR supply fails to materialize (Burke and Gambhir 2022). This in turn could lead to political pressure to reduce the ambition of the system (Sultani et al. 2024). Another failure mode stems from saturation, especially in the context of land-based removals: a jurisdiction with abundant access to land-based removals could lock itself into a high emissions pathway but then find itself unable to maintain net emissions due to forest carbon saturation in existing forests coupled with land scarcity, which prevents the establishment of new ones. Moreover, a concern has been raised that market actors could pressure the regulator to weaken removal unit quality criteria so as to reduce compliance costs (Carbon Market Watch 2023).

[21] An accurate definition of the point of comparison (sector/product, including alternatives) would be crucial.

[22] The literature typically refers to this effect as "mitigation deterrence". However, this can be a misleading term, as CDR is also a type of mitigation action (Honegger et al. 2021). This thus paper employs the term "abatement deterrence" instead.

Addressing short-term effects may be simpler than addressing long-term ones. One of the simplest approaches to addressing[23] abatement deterrence is to separate abatement and removal targets and actions (McLaren et al. 2019), but this can lead to overall economic welfare losses if CDR is cheaper than abatement.[24] Where regulators wish to introduce CDR into ETSs, short-term abatement deterrence effects may be dealt with by managing and limiting the influx of removal units. In the UK, for example, the UK ETS Authority proposes to swap fiat allowances for removal units, thus maintaining the same level of gross emissions under the system compared to a situation where removal units were not included (UK ETS Authority 2024). For long-term effects, the inherent uncertainty in terms of future economic, technological and political circumstances makes it very difficult to establish policy transparency and predictability while maintaining flexibility for the regulator to adapt to changing circumstances. Sultani et al. (2024) propose a stepwise inclusion of removals into the EU ETS in a way that allows for technology and policy learning, although ultimately arriving at unlimited integration of engineered and biotic removals in the future. Long-term effects could potentially also be managed by policies outside the ETS, such as technology mandates and product standards to drive abatement action. Whether or not such an approach would be effective at mitigating long-term abatement deterrence effects is a subject of further research.

4.3 Managing small markets

As the ETS emissions limits become tighter and regulated entities reduce or eliminate their emissions, market demand for ETS compliance units will decline. This shrinking market will represent new or added challenges for participants and regulators, which have been identified by different academic studies:

- A rapidly declining emissions limit may lead to more banking by regulated entities (Pahle et al. 2023) .
- High price uncertainty of marginal abatement costs could lead to more volatile pricing (Goodkind and Coggins 2015).
- Increase in market frictions may distort market outcomes (Baudry et al. 2021).
- The “extent of randomness or noise in the stochastic process that can originate from trading or the market itself” (Bouleau 2012, 2018) can increase allowance price volatility.
- Small markets can be illiquid with a potential for market manipulation and an increase in detrimental speculation (Quemin and Pahle 2023).
- Increased price volatility can result in decreased political support for the ETS (Pahle et al. 2023).
- Questions about the suitability of the ETS as a sole mechanism to prevent re-entry of positive emissions, as well as to remunerate negative emissions (Pahle et al. 2023).
- Since the complex trader ecosystem will probably continue to exist, greater market oversight and transparency may be required (Pahle et al. 2023).

As the number of ETS participants decreases, governments may try to manage some of the challenges outlined above by:

- Increasing the ETS scope in terms of sectors and/or GHGs;
- Reducing the threshold for mandatory participation in the system to add more participants;

[23] For an overview on possible solutions to abatement deterrence risks, see Höglund et al. 2023.

[24] Assuming that barriers to equivalence and fungibility between emissions and CDR are addressed.

- Including provisions for the use of removal units as compliance units in the ETS;
- Establishing or refining market stability and flexibility mechanisms;
- Establishing or refining competitiveness-protection measures (such as CBAMs) in case of high prices;
- Linking with other systems, which however creates a different set of challenges, particularly in coordinating the ambition levels in the linked jurisdictions. This is discussed in section 4.4 below;
- Facilitating price discovery through auctions and/or through requirements for exchange trading; or,
- Identifying alternative sources of revenue to compensate for lower auction revenues.

By expanding the ETS sectors or lowering the inclusion threshold for mandatory participants, regulators will need to consider the increased administrative and transaction costs that participants will face.[25] This requires particular attention to participants with low emissions because of a low output (as opposed to high output but carbon-efficient processes), and therefore low capacity to effectively participate in the system. Some adjustment to participation thresholds, however, will likely be necessary, as average emission levels per installation decrease over time.

In a context in which a jurisdiction aims to reach net zero emissions, increasing the sectoral scope of the ETS to increase liquidity could create an even higher pressure on sectors not covered by the ETS to deliver negative emissions if the ETS delivers net-positive emissions. In turn, if the ETS has a steady state that requires net zero or net negative emissions, increasing its sectoral scope could provide support for the necessary removals in the system, either within or outside of the scope of the ETS.

4.4 Issues related to linking

Jurisdictions that are already linked, or that consider linking, will face an additional set of coordination challenges as their caps decrease. In particular, the net flow of compliance units across jurisdictions will vary depending on the design of each of the linked ETSs.

A net flow of compliance units reflects differences in average abatement costs across linked ETSs (Schneider et al. 2018). The system with lower abatement costs tends to export units to the ETS with higher costs. If there is only a limited supply of cheaper abatement opportunities in the exporting jurisdiction, and as caps decrease and prices increase, more expensive abatement options for the system exporting compliance units should become increasingly cost-effective, reducing the gap in average abatement costs (and, therefore, the net flow of units) between the systems. However, what happens afterwards is conditional on the difference in expected steady states in the linked systems. For simplicity, the following bullet points assume a link between two systems:

- If **both systems have planned to have a net-positive emissions steady state**, the situation is similar to currently linked ETSs as described above. The net flow of compliance units from the exporting jurisdiction to the importing jurisdiction, however, means that the importing jurisdiction has higher GHG emissions in its territory compared to the situation where the systems are not linked. If linked ETSs are in different countries, regulators might need apply the rules under Article 6 of the Paris Agreement to the allowance flow in order to meet international targets (for more on this, see Hynes and Schneider 2023).

[25] The inclusion of fossil fuel producers and importers can help expand the coverage of the system with limited transaction costs.

Moreover, if both systems are of significantly different size, the smaller system will continue to be the price taker in the relationship.

- If one jurisdiction has planned a **net-positive emissions steady state and the other has planned a net-zero, or net-negative emissions steady state**, the cost differential between abatement in the net positive ETS and removal units in the other ETS would determine the flow of compliance units across the linked system. Coordination across systems would be key to ensure continued compatibility, especially with regards to acceptability of compliance units. For example, if the net-zero or net-negative ETS ceases to accept fiat allowances for compliance (which would be required in a steady zero or negative state), then a de-linking may be necessary. Coordination in ambition levels (also during the transition period) would be necessary to avoid perverse incentives, in particular for the net-positive ETS.
- A link between a **system that has planned a net-zero emissions steady state and a system that has planned a net-negative emissions steady state**: in a net zero emissions system, emissions must be balanced by removals, whereas a system with a negative emissions outcome requires emitting entities to overbalance for their emissions. In both instances, removal units become the compliance units under the system. A link between a system with a net-zero ETS and a net-negative ETS would mean that removal units accepted for compliance in one system would also be accepted in the other, and that the market for those removal units would be as large as the combined compliance obligation under the linked systems. If the regulators in the linked systems act as intermediaries in the procurement of and/or sell removal units, pooling resources between the regulators could reduce administrative costs. In such a linked system, policymakers might benefit from agreeing whether their role is only to decide which removal units are accepted under their systems, or also to procure and sell credits to cover the aggregate demand under the linked systems (in which case, they may benefit from procuring the units together). A similar situation as the one described here can be expected to occur if both systems have a net-zero emissions steady state or a net-negative emissions steady state.
- If one **system has planned an absolute zero emissions steady state**, it can be expected that this system will continue to be, or transition to become, the system importing allowances in the relationship. If the net flow of allowances continues, the jurisdiction would not achieve absolute zero emissions. In order to keep to absolute zero emissions, the de-linking of the systems would likely be required. However, the de-linking process would require careful planning and implementation, particularly if regulated entities use a large number of allowances issued by the other system (through, e.g., the gradual phase out of the validity of allowances from the linked jurisdiction for compliance).
- If **one jurisdiction has planned to phase out their system**, a de-linking process would be required regardless of the planned steady state of the emissions in the other system. As with the case of the de-linking process between a system with a positive emissions steady state and a zero emissions steady state, the de-linking process would require careful planning and execution.

As mentioned above, in linked systems in which at least one of the linked partners accepts removal units, jurisdictions may have to address divergences in the eligibility (quantitative or qualitative) of those removal units to keep the planned stringency of their systems. "Restricted linking" options, such as those discussed in Schneider et al. 2017 could serve as useful options to do so.

4.5 Generating removal units inside or outside the ETS and considerations on the acquisition of removal units

The simplified model described in section 3 above assumed that removal units are generated outside the scope of the ETS. The below discusses the consequences of lifting this simplifying assumption. This pertains to two important design considerations:

(a) **Legal tender: which units are allocated to CDR providers**, in particular whether such units are fully fungible with allowances. CDR suppliers can receive allowances or credits. In particular, issuing units to CDR suppliers that are indistinguishable from other allowances in the market would make it more difficult to implement limits on the use of such units in the market. In the New Zealand ETS, CDR suppliers are included in the scope of the ETS and are issued units that have equal compliance value, but that are distinguishable from other allowances in the market. In all other ETSs currently making use of CDR units, CDR projects lie outside the scope of the ETS and receive carbon credits. Such credits are often only usable in the ETS subject to limits and restrictions. This is the case in the California Cap-and-Trade Program, for example.

(b) **Route to market: whether regulated entities purchase removal units from the government or directly from CDR suppliers.** This also influences the regulator's ability to establish limits on the use of removal units in the system, as well as how demand for them meets supply in the ETS, with potential impacts on price discovery. Currently, all systems incorporating removal units have direct transactions between regulated entities and CDR suppliers.

Table 2 below provides a summary of key considerations.

Also, it is important to note that choices on sectoral coverage and unit choice can impact the ability of regulators to address reversals. Enforcing liability on international carbon credit sellers through the ETS, for example, is likely to be much harder than doing the same for domestic, within-ETS entities.

Table 2: Design considerations on legal tender and routes to market (*)

	ETS emitters purchase units directly from CDR suppliers	**ETS emitters purchase units from the government**
CDR suppliers are allocated fully fungible allowances	*Market dynamics and pricing*: • Single market with direct price discovery • Low price transparency in case of over-the-counter (OTC) trades, high transparency in case of exchange-based trading • CDR prices fluctuate based on supply-demand dynamics • Dynamic pricing could encourage innovation and efficiency among CDR providers but expose them to price risk	*Market dynamics and pricing*: • Allowances allocated to CDR suppliers are sold through the government through e.g., consignment auctions • Price is transparent • Could present reduced price volatility, which could provide a stable environment for CDR technological development • Could be less responsive to market changes

	• CDR suppliers could potentially exercise market power if concentrated *Regulatory control and flexibility:* • Regulator cannot control the balance between abatement and removal • Under a net-positive ETS, this option could lead to a glut of compliance units in the market *Transaction costs:* • High in case of OTC trades; low in case of exchange-based trading.	• Regulator can address heterogeneous cost structures on the CDR supply side - Regulator can bridge cost gaps between abatement and removal *Regulatory control and flexibility:* • Regulator can control the volume of removal units that enters the system, as well as who has access to those units • Limits on the maximum number of removal-backed allowances that can be issued could affect the ability of CDR suppliers to be rewarded for the CDR carried out beyond that limit *Transaction costs:* • Could be equivalent to exchange-based trading, albeit with more administrative costs for the government
CDR suppliers are allocated units other than fully fungible allowances (e.g., 'credits')	*Market dynamics and pricing:* • Two markets: one for allowances, one for removal credits • Lower liquidity compared to single market • Low price transparency in case of over-the-counter (OTC) trades, high transparency in case of exchange-based trading • CDR prices fluctuate based on supply-demand dynamics • Dynamic pricing could encourage innovation and efficiency among CDR providers but expose them to price risk • CDR suppliers could potentially exercise market power if concentrated *Regulatory control and flexibility:* • Regulator can set limits on the use of removal units (e.g., a percentage of entities' compliance obligations) and control the balance between abatement and removal *Transaction costs:* • High in case of OTC trades; low in case of exchange-based trading	*Market dynamics and pricing:* • Credits allocated to CDR suppliers are sold through the government through e.g. consignment auctions • Price is transparent • Could present reduced price volatility, which could provide a stable environment for CDR technological development • Could be less responsive to market changes • Regulator can address heterogeneous cost structures on the CDR supply side - Regulator can bridge cost gaps between abatement and removal *Regulatory control and flexibility:* • Regulator can control the volume of removal units that enters the system, as well as who has access to those units. • Limits to the use of removal units inside the ETS do not hamper the ability of CDR suppliers to sell units into other markets. *Transaction costs:*

	• Aggregate higher transaction costs compared to single market	• Could be equivalent to exchange-based trading, albeit with more administrative costs for the government

(*) Note: Except where otherwise indicated, all possibilities depicted in the table are compatible with the net-positive, net-zero and net-negative ETS options. None are compatible with the absolute zero or no ETS options, as no trades take place.

5 DISCUSSION AND CONCLUSIONS

The future trajectory of ETSs is an open question with multiple possibilities. While current policy debates often imply that the only reasonable option for ETSs is to deliver net-zero emissions, this paper shows that other options are possible: ETSs could deliver net-positive, net-zero, net-negative, or even absolute zero emissions. While each of these four options could be a step in the evolution of an ETS over time, they are also steady states in and of themselves. The ETS could, moreover, also be phased out in favor of other policies. For each of these, ETSs can take slightly different functions compared to current designs, prioritizing different aspects of GHG mitigation pathways. Interviews for this paper indicated wide divergence among experts on which ETS design is more likely or beneficial. While most seemed to agree that an absolute zero ETS is not feasible, opinions differed widely otherwise. Some saw great benefit in a net positive ETS that keeps abatement and removal incentives separated, others advocated for net-zero ETSs for cost efficiency reasons. Some experts saw a net-negative ETSs as the main tool to achieve net-negative emissions jurisdictional targets, while others had strong feelings that the net negative component lies squarely under the responsibility of the State.

Expanding ETS coverage to encompass more or even all economic sectors could fundamentally alter the feasibility and desirability of different end states. A jurisdiction with an economy-wide ETS, for example, might need to incorporate removal units to accommodate sectors with limited abatement potential and achieve jurisdictional net zero targets, whereas a jurisdiction with a narrower ETS might more easily maintain a focus on emissions reductions without removals. Expanding the ETS scope can help mitigate some of the small-market challenges because more and diverse entities are likely to be active. This can generate efficiencies and ensure better market functioning.

Differentiating between gross and net emissions in ETS design is helpful but, so far, is not often done. This distinction is likely to become more important as jurisdictions fine-tune their emissions and removals goals in their pathway towards net-zero and net-negative economies. Clarity on gross and net emissions limits in ETS-regulated sectors will influence how ETSs will evolve, what role removal units will play in compliance, and how emissions and CDR will be managed across the economy. Higher gross emissions inside the ETS, for example, can make it harder to achieve jurisdictional net-negative targets if CDR is scarce. The potential use of removal units from other jurisdictions in lieu of domestic removals presents additional considerations, among others reducing costs and increasing flexibility, but introducing risks related to environmental integrity, permanence and governance, including potential dependency on external carbon removal markets.

While ETSs could drive demand for removal units and provide support to the development and deployment of CDR, they are unlikely to be sufficient. In systems with limits on the use of removal units, support will be constrained by these limits. In systems without such limits, support will be determined by where gross emissions settle based on the relative marginal costs of abatement versus removal. The net-negative ETS option provides the most substantial support for CDR deployment by requiring emitters to overcompensate for their emissions. However, even in that case, ETSs alone are unlikely to suffice in driving adequate CDR deployment. A back-of-the-envelope calculation suggests that requiring ETS residual emitters to remove 2 tCO_2 for every tCO_2e emitted in the second half of the century could contribute significantly to addressing the historical overshoot (see Box 3 on page 34). However, in practice, such an obligation would likely face strong resistance as it would place a heavy burden on already-strained ETS residual emitters. This highlights the importance of focusing on emissions abatement to reduce the reliance on removals to stabilize global temperatures to safe levels, as well as the need for a comprehensive policy mix for CDR.

Some ETS designs may be vulnerable to the risk that certain removal technologies are not viable at scale. While most mitigation pathways assume that several gigatons of CDR capacity will be added before mid-century, policymakers must plan for the risk that certain CDR technologies are not viable at scale (Larkin et al. 2018). Jurisdictions must therefore understand the consequences of CDR supply uncertainty, and design ETSs so that they can operate effectively in multiple supply scenarios. This is an area for further research.

Understanding the policy mix for net-negative emissions can be crucial for defining the role of ETSs in long-term climate strategies. Policymakers have the challenging task of designing policy mixes that drive ambition and also achieve net-negative emissions. While jurisdictions' current focus is to achieve global net-zero emissions by mid-century, post-net-zero strategies can have implications for current policies. For example, a jurisdiction that puts in place a comprehensive and dedicated basket of policy measures for CDR may prefer to keep removals outside its ETS, using the system to drive abatement only. To the extent that policymakers recognize the need for dedicated policies to cost-effectively drive CDR and net-negative emissions, early consideration of these issues can help clarify the potential role of instruments such as ETSs.

Speaking about the future of ETSs requires clarifying what we mean by "an ETS". Among others, ETSs could evolve into fundamentally different mechanisms such as 'removal trading systems' or carbon taxes. Moreover, terminology differences can complicate policy debates, particularly when discussing the emissions outcomes of evolving systems. For example, the options assessed in this paper focus specifically on the net emissions resulting from the actions and purchases of *ETS-regulated entities themselves*. Notably, this leaves out the emissions impact that the regulator could have by purchasing removal units with ETS auction revenues. While accounting for such purchases could theoretically transform a net-positive ETS into a net-zero or even net-negative system, this paper has kept public purchases separate from the definition of 'the ETS' for two key reasons. First, there are practical accounting challenges: public purchasing programs typically draw from multiple funding sources, ETS auction revenues may decrease as emissions decline, and it may be difficult to attribute precise CDR values to monetary units from ETS auction revenues. Second, and more fundamentally, removal unit purchases by regulated entities versus by regulators represent different distributions of environmental and financial risk across stakeholders, making them conceptually distinct approaches to emissions management. Semantics aside, as policy instruments change and adapt to evolving circumstances, titles will be less important than understanding the mechanics of the instrument and the role they are expected to play in the climate policy mix.

Several areas remain for further research. A deeper understanding of market dynamics in both transition and steady states is needed, particularly addressing the challenges of small, potentially illiquid markets as emissions decline. More research would be valuable in developing and assessing policy options (such as quantitative limits on CDR use) for addressing abatement deterrence while maintaining cost efficiency. More research is needed on policy packages for achieving net-negative emissions and the role of ETSs therein. Finally, considerations for intensity-based systems merit further investigation, understanding how the considerations explored here apply to systems without an absolute cap.

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International Carbon Action Partnership

ICAP
Köthener Straße 2
10963 Berlin
Germany

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