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Perspective

Procure, Bank, Release: Carbon Removal Certificate Reserves to Manage Carbon Prices on the Path to Net-Zero

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ABSTRACT

The European Union cap-and-trade emissions trading system (EU ETS) faces two challenges in the context of the European Green Deal. First, to meet the Paris temperature target, emissions in the energy and industrial sectors must fall to net-zero and then even become net-negative. Second, there is a concern that excessive CO_2 price spikes and volatility on this path will jeopardize the political acceptance and support for emissions trading as a climate policy instrument. Conditional supply of carbon removal credits (CRCs) to support dynamic carbon price caps would make it possible to stabilize the market in the transition from positive to net-negative emissions trading while keeping the net-emissions path unchanged. CRCs would be assigned for carbon removal achieved for example with methods like Direct Air Carbon Capture and Storage or Bioenergy with Carbon Capture and Storage and would be used by companies under the EU ETS to compensate for their emissions. However, we suggest that there would be no direct exchange between emitting companies under the EU ETS and carbon removal companies, i.e., the demand and supply side of CRCs, during an initial phase. Instead, we suggest assigning an institutional mandate to for example a carbon central bank (CCB) to organize the supply of CRCs. Under this mandate, carbon removal would be procured, would be translated into a corresponding number of CRCs, and a fraction of it could be auctioned to the market at a later point in time, provided that market prices exceed a certain (dynamic) price cap.

1. Introduction

While the current emissions reduction path of the European Union Emissions Trading System (EU ETS) foresees that allowance supply ends in the year 2057, the implementation of the European Green Deal brings forward the end of allowance supply to the year 2040. Afterwards, the EU ETS is supposed to become net-negative, which will require the inclusion of carbon dioxide removal (CDR) [1,2]. Accordingly, the EU needs to address how to organize the transition from a positive to a net-negative emissions trading system [3] and how to deal with expected allowance price increases and fluctuations due to now faster declining allowance supply [4]. The success in managing these challenges will be crucial for the political support for the EU's most important climate policy instrument. Perino et al. [5] point out that the existing, primarily quantity-based flexibility mechanisms of the EU ETS to adjust allowance supply are in its current design inappropriate to stabilize the market with respect to future allowance shortages—in turn they suggest to strengthen the price-based feedback on allowance supply. Here, we support this proposal, arguing that carbon price management becomes in particular important on the path to a net-negative emissions trading system and that a (dynamic) price cap should be supported by the conditional supply of carbon removal certificates (CRC). In contrast to using existing allowances from the allowance pool, the usage of CRCs would imply that the net emissions paths remain unchanged. However, a credible support of a price cap requires a sufficient number of CRCs in stock and in turn an upfront procurement program to build up the required CRC stock. Furthermore, we argue that these inventions should be implemented under an active, institutional mandate, responsible for ensuring a price corridor in the EU ETS and managing the CRC reserve. Such an institutional mandate, assigned for example to a carbon central

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bank (CCB), could also act as clearing house by addressing leakage and non-permanence issues in the conversion of physical carbon removal into CRC for specific CDR methods. Contrary to subsidized unconditional supply of CRCs, a procurement program with conditional supply of CRCs managed by a central agency would stipulate learning-by-doing for carbon removal methods without undermining learning-by-doing in the emissions abatement sector.

The article is structured as follows. In Section 2 we explain how implementation of the Fit for 55 package will reduce allowance supply, in Section 3 we review and discuss how the current flexibility mechanism are not appropriate in stabilizing the market, and in Section 4 we explain how CRC could be conditionally used to support a dynamic price cap. Section 5 concludes and classifies our proposal regarding the inclusion of CRC in the EU ETS in terms of the more fundamental role of CDR in climate policies.

2. Reduction in allowance supply in the EU ETS under the Fit for 55 package

Cap-and-trade emissions trading systems allow the straightforward implementation of greenhouse gas emissions budgets derived from temperature targets in climate policies. The remaining emissions budget determine the total number of allowances, i.e., the allowance cap. Allowances must be surrendered for each ton of CO_{2equiv} emissions, ensuring compliance with the overall budget. The EU has relied on such instruments since 2005 to reduce its emissions in the energy and industrial sector (since 2012, also including emissions in the aviation sector), covering about 40% of EU greenhouse gas emissions. After some initial difficulties and regulatory adjustments, particularly in response to the decrease in emissions in the aftermath of the 2009 financial crisis, the EU ETS has established itself as a successful climate policy instrument. The EU ETS achieved emissions reductions of 48% by 2021 relative to 2005 (if the initial values are corrected such that the sectoral and geographical coverage match the current configuration) [6]. The EU puts the total number of allowances on the market in tranches, whereby the annual amount of allowances entering the market via auctioning and free allocation decreases linearly. Companies can accelerate their emission reductions and save the corresponding allowances for later periods (banking), but they cannot postpone their emission reductions by borrowing allowances from future periods. Hence, while banking allows for some intertemporal adjustment, the linearly decreasing amount of allowances to some extent prescribes the emissions reduction path under the overall emissions cap.

The annual issuance of allowances in the EU ETS makes it possible to revise the overall cap and achieve a more ambitious reduction target than initially envisaged. Such a revision of the cap is currently underway in the EU ETS. While the current regulation foresees the annual amount of allowances entering the ETS decreasing by a linear reduction factor (LRF) of 2.2% [7] from 2021 onwards, the more ambitious targets to reduce emissions by at least 55% by 2030 and achieve net-zero emissions by 2050, as part of the Green Deal [8], has prompted the European Commission to propose the Fit for 55 package which foresee the LRF increasing to 4.2% [9].[1] The increase in the LRF implies that the total (gross) cap would be reduced from 29.5 $GtCO_{2equiv}$ to 15.8 $GtCO_{2equiv}$ and the date from which allowances are no longer issued would be brought forward from 2057 to 2040. Fig. 1 illustrates the implication of an increased LRF. The calculation of the required increase in the LRF uses as starting year 2021, accordingly, the actual implementation of the increased LRF at later point in time will require some additional (one-off) reductions in allowance supply to correct for allowance supply under the old LRF until the amendment of the directive enters into force.[2] Furthermore, note also that the actual cumulative numbers will still change, since i) the EU ETS is also intended to increase its scope by including further sectors like the maritime sector[3] and ii) the actual number of allowances entering the market is influenced by the Market Stability Reserve (MSR).

The MSR was introduced in 2019 to adjust the surplus of allowances from earlier trading phases. Depending on the total number of allowances in circulation, allowances are withheld from auctions and instead transferred to the MSR, where they are stored and either released back to the market or canceled.

In more detail, if the total number of allowances in circulation (TNAC) exceeds allowances equivalent to 833 $MtCO_2$, 24% of TNAC are transferred from the allowance auction volume to the MSR (from 2023 onward the share decreases to 12%). If the TNAC is below 400 million allowances, 100 million allowances will be released from the MSR and added to the auction volume (in case the amount of allowances in the MSR is below 100 million, all allowances will be released). The influence of the MSR on the total cap arises from the cancelation, since from the year 2023 onwards, allowances in the MSR in excess of the auction volume in the previous year will be invalidated. The effect of the MSR depends on firm's price expectation and associated banking decision, the latter influencing the TNAC. The revision of the EU ETS as part of the Green Deal also foresee adjustments of the various quantity triggers for intake, release, cancelation. In the proposal of the Commission, the intake of 24% is prolonged until 2030 (afterwards dropping to 12%) if TNAC is above 1096 $MtCO_{2equiv}$, for a TNAC between 1096 and 833 $MtCO_{2equiv}$, the intake is simply the difference between TNAC and 833 $MtCO_{2equiv}$. Furthermore, allowances in the MSR in excess of 400 $MtCO_{2equiv}$ will be invalidated, ensuring that the MSR holds a maximum of 400 million allowances no matter how many allowances have been auctioned in the previous year. The effect of the MSR on the cap is difficult to predict. Matthes and Cook [10] estimate that the cap reduction due to cancelation of allowances in the MSR until 2030 range between 2.8 and 3.9 $GtCO_2$ whereas the upper value implies a rather hypothetical, extreme banking scenario. However, irrespective of the MSR's effect on the total number of allowances still entering the market, Fig. 1 shows that the increase in the LRF makes it necessary for the EU to address the transition from a positive to a net-negative emissions trading system much earlier than under the current LRF.

3. Prize stabilization in the EU ETS: Market Stability Reserve and Article 29a

The EU ETS has been consistently criticized for having too low carbon price in its early periods—until the third quartal of 2020 when the prices started increasing and more than doubled within a year (see Fig. 2). In addition to fundamental factors (in particular recently with soaring gas prices during 2022), the price increase is explained with the launch of the MSR in 2019 and the already anticipated tightening of the EU emissions target under the EU Green Deal [4]. Both regulatory changes reduce (current and future) allowance supply and hence the

[1] A LRF of 4.2% was the proposal put forward by COM and agreed on in the General Approach, which is supported by the European Parliament (EP), although the EP wants a gradual increase of up to 4.6% by 2029 (see adopted amendment 677).

[2] The Commission is proposing a one-off reduction of 117 Mt in 2024, given that the adjusted directive enters into force in 2023 or a one-off reduction of 155 Mt in 2025. The European Parliament proposed to split the correction into two steps, an additional reduction of 70 Mt in the year following entry into force (i.e., either 2024 or 2025) and then a further reduction in 2026 by 50 Mt.

[3] The positions of the Commission, the Parliament, and the Council still differ about the timing of phase in and achievement of full compliance (full compliance either by 2024, 2026, or 2027 according to the European Parliament, the Commission, and the Council, respectively). While there is consensus that intra-EU travel is fully covered, there are different positions regarding extra-EU travel and how smaller ships (i.e. below 5000 gross tonnage) are supposed to be included.

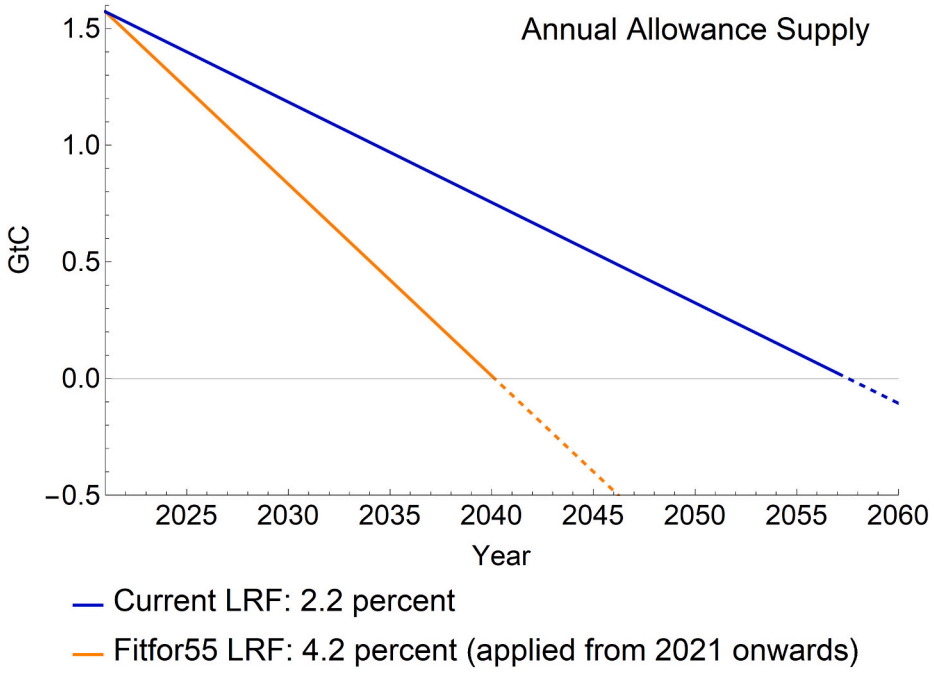

Fig. 1. Stylized implications of an increased linear reduction factor (LRF). The increase in the LRF is supposed to become applicable from 2021 onward, implying that the actual implementation requires additional (one-off) reductions the year following the entry into force of the revised Directive.

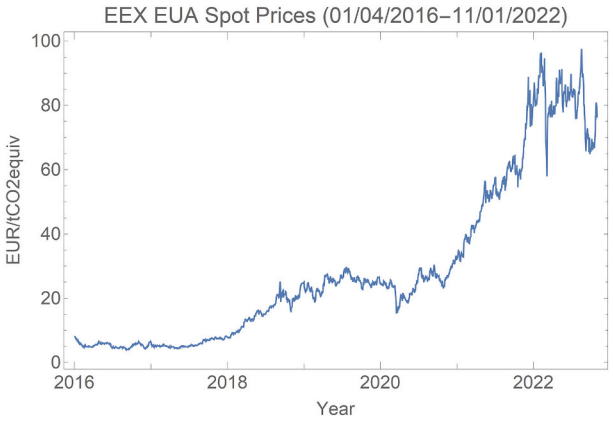

Fig. 2. EEX EUA spot price series (Phase 3 and Phase 4), obtained from Thompson Reuter, Refinitiv Carbon Research.

price increase rightly expresses the increasing scarcity. However, it appears unlikely that the price increase since 2018 already fully reflects expectations about allowance supply ending in the year 2040. Quemin and Trotignon [11] show that observed price development and banking behavior is consistent with rolling plaining horizons of firms and they find the best fit for a planning horizon of about 13 years (with discount rates obtained from futures' yield curves). This kind of shortsightedness can also be explained by that several smaller firms under the EU ETS do not necessarily have in-house trading desks and allowance future markets (so far) cover only a period up to ten years with thin trading volume in long-term contracts [11]. Accordingly, it seems likely that when the end of allowances supply appears on the firms' planning horizon, the price level will increase even further (beyond the interest-rate based increase following from dynamic efficiency). With the earlier end of allowance supply under the Fit for 55 package, the corresponding price increase should also move forward. Furthermore, the uncertainty regarding the cost of nearly complete abatement of emissions is still quite high, since structural changes or even disruptive changes and the development of new technologies are required to achieve zero emissions in the trading sectors – two aspects that are difficult to model [12].

In a cap-and-trade system, the fixed quantity of allowances provides, in principle, a perfectly inelastic supply curve and in turn any change in baseline emissions and technological innovation affect the carbon price level but not the emission outcome and might therefore not properly reflect how society assesses trade-offs between climate benefits and cost [5,13,14]. Innovations in abatement technologies and corresponding lower marginal abatement cost might imply that society prefers a higher level of climate ambition (and the other way around). Accordingly, passing the uncertainty regarding abatement costs fully on to consumers and companies results in socially inefficient outcomes—flexibility mechanism which allow addressing both, the price and the quantity, are considered to more appropriate in achieving efficient climate policies [14–16].

As explained in the previous section, the MSR was introduced in 2019 as a measure to adjust allowance supply. However, its effect on allowance supply predominantly relies on quantity triggers and not on price triggers. This can result in odd effects since if firms increase their price expectation (e.g., because of an anticipated or announced increase in the LRF), intertemporal cost minimization requires to increase the stock of banked allowances. However, a larger amount of banked allowances increases the TNAC and in turn the intake of allowance by the MSR is prolonged, resulting in a further shortage of allowance. Obviously, this effect works also in the opposite direction; lower price expectation followed by less banking result in less intake and cancelation of allowances in the MSR. The effect of overlapping climate policies with effect on allowance supply, for example a unilateral coal-phase out, is reduced by this MSR feedback. The effect is described as green paradox of emissions trading system with endogenous, quantity-trigger-based allowance adjustments [17]. Economists argue that the MSR's mechanism should be adjusted so that it operates with a price trigger, not a quantity trigger (e.g., [5]).

In fact, the EU ETS already contains a prize stabilization mechanism as detailed in Article 29a (Directive 2009/29/EC of the European Parliament and the Council). According to Article 29a, if, over six consecutive months, allowances prices are observed to be three times higher than the average for the previous two years, the Commission can

convene a meeting of the Climate Change Committee, which then discusses possible market interventions, potentially releasing 100 million allowances from the MSR to the annual auction volume. Up until now, Article 29a has never been invoked, despite considerable recent price jumps, indicating that it might not necessarily be best suited for controlling price volatility [18].

The revision of the EU ETS as part of the Fit for 55 package also foresees revising Article 29a; the European Parliament has already decided to lower the price trigger from three times higher to two times higher (relative to the reference price level) [19]. Since the adjustments to the EU ETS involve significant reductions in cumulative emissions, which will be further reduced by the MSR feedback, concerns about prices being too high could gain importance [4] and become a more prominent element in the EU trilogue negotiations on the EU ETS reforms. The Council of the EU has already declared that it will support the more automatic and responsive release of allowances from the MSR in case of excessive prices [20]. Initially, the REPowerEU program to reduce the dependence on Russian fossil fuels proposed by the Commission also foresaw a more active role of allowances held in the MSR [21]. However, due to concerns in particular in the European Parliament that releasing allowances from the MSR increases emissions (since otherwise allowances supposed to be canceled become active again), the proposal was changed into bringing forward allowances from the overall allowance pool to the auction volume ("frontloading") until an extra revenue of 20 billion EUR has been raised [22]. Obviously, bringing forward allowances in time implies less allowances in the future—showing the limitations of managing carbon prices consistently through time under finite allowance supply.

4. Supporting a price cap without increasing net emissions: Conditional supply of carbon removal credits

Irrespective of the specific adjustments of Article 29a, any additional release of allowances to support a maximum price implies bringing forward emissions, postponing the allowance scarcity and associated price peaks into the future. Using allowances from the MSR to stabilize prices involves fewer extra emissions reductions. Furthermore, the EU ETS reform plans foresee restricting the maximum number of allowances in the MSR to 400 million (see [9], which all legislative institutions have agreed upon), which limits the credibility of such a mechanism effectively stabilizing prices when faced with a speculative market.

Hence, CRCs could be auctioned off to stabilize a price cap.[4] Unlike the stabilization with additional allowances, the net emissions would remain unchanged (see Fig. 3). CRCs can be used by companies for compliance, i.e. they substitute allowances and compensate for emissions. Given the price-trigger becomes active (i.e. the price cap is hit) and additional CRCs are sold, the gross emissions are determined by surrendered allowances plus CRC in a given year, the net emissions are still determined by the number of allowances. Such an invention would require a sufficient supply of CRCs and hence an advance purchase program for CRCs, filling either the MSR with CRCs or creating a specific CRC reserve. Because the introduction of a more active price control would mean a departure from the current quantitative-based market control by the MRS, the MRS regulations would have to be adjusted accordingly.

In principle, both the EU Modernization Fund and the Innovation Fund could be used for advanced purchases of CRCs. Using allowance sales to finance procurement measures is, in principle, already part of EU climate policy (see previous section on current plans under the REPowerEU initiative). At present, the cost of for example Bioenergy with Carbon Capture and Storage (BECCS) and in particular Direct Air Carbon Capture and Storage (DACCS) are still above the market prices in the EU ETS. Advance purchase programs of carbon removal would thus mean supporting providers of these carbon removal methods that are not yet ready for the market. Such a procurement of carbon removal could be organized via technology-specific tenders (e.g. in reverse auction system, see [23] on the prospects of such a system in Sweden) and could also be partially settled as a forward transaction. The procurement of carbon removal serves not only filling a CRC reserve (or stocking up CRCs in the MSR) but would stipulate learning-by-doing for carbon removal methods [24]. Depending on the size and speed of the upfront procurement program, also the 400 million allowances left in the MSR after cancelation could be invalidated if an even more ambitious emissions reduction target is supposed to be achieved beyond 2030.

Note that upfront carbon removal procurement with only conditionally supply at a later stage is a very different approach than integrating them into the ETS unconditionally via subsidies. The latter might result into a (too) early subsidized integration of CRCs, undermining the incentives for learning-by-doing in the abatement sector. The conditional integration separates the timing of carbon removal measures and the corresponding issuance of CRCs from the release of CRCs in the EU ETS, making use of the fact that atmospheric carbon is a stock variable and in turn CRCs can be stored (i.e. banked). This is different to for example schemes incentivizing the integration of renewable energies into the power mix since here it is crucial when supply does happen. Conditional integration of carbon removal on the other hand requires sufficient CRCs in stock which motivates an early start of banking these CRCs. By deciding about the level of the price cap (or the price level of intervention), the budget risk from advanced CRCs purchases could be effectively managed.

Note that without direct exchange between emitting companies covered by the EU ETS and carbon removal companies (i.e., the demand and supply side), it is also possible to address accounting issues. The current CCS directive is suited to dealing with storage and possible leakage issues related to DACCS and BECCS, making these two carbon removal methods obvious candidates for integration into the EU ETS. Other carbon removal methods are not (yet) covered by regulation to deal with leakage or impermance. Procurement of physical carbon removal would happen under an active, institutional mandate, involving in a subsequent step translating the physical carbon removal into CRCs. Accordingly, this translation step could include correcting for the risk of leakage or withholding CRCs to account for non-permanence and hence, the CCB would not only act as market intermediary but also as a kind of clearing house.

The current design of the EU ETS and MSR suggests that the conditional supply of CRCs would be organized in a rule-based manner. However, a more discretionary approach would favor mandating a central institution like a CCB to organize price stability under shrinking allowance supply and during the transition from a positive to a net-negative emissions trading system [25]. Such a fundamental change would of course require defining an appropriate policy goal and the corresponding mandate for the CCB, including its resources. The policy goal could, for example, include a price and emissions reduction path in which the CCB itself decides when to intervene and thus also react to macroeconomic shocks. Obviously, there is a reciprocal relationship between a possible carbon price corridor and the size the CRC reserve and defining the former determines in turn the size of procurement programs and the other way around. However, there are alternatives to a CCB to provide active management of CRCs like an agency within the EU Commission.

5. Conclusion

The EU Emissions Trading System (EU ETS) is considered to be the EU's most important climate policy instrument and is one of the largest emission trading systems worldwide. Hence, any regulatory adjustments

[4] Note that we can distinguish between "hard" and "soft" support of the maximum price, the former requiring that sufficient CRCs are in stock while "soft" support would imply that the effective cap is (gradually) increased, becoming vertical again at the point where the CRC supply is exhausted.

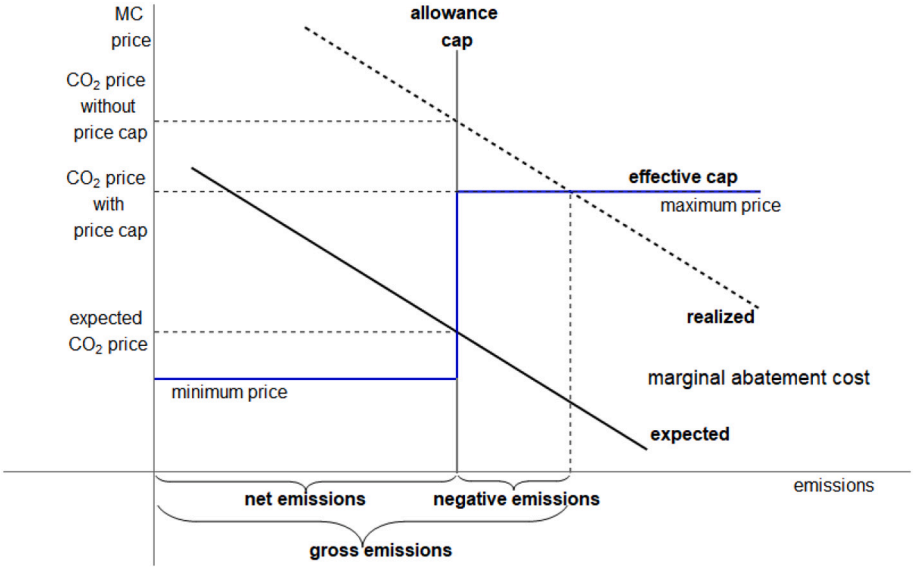

Fig. 3. Conditional integration of negative emissions via carbon removal methods. The figure shows a price corridor, i.e. a minimum and maximum price. The former would involve that less allowances are auctioned (or bought back) while the latter involves the supply of CRC such that the net emissions remain unchanged.

of the EU ETS and subsequently obtained experiences will affect the design of existing or new emission trading systems worldwide and in turn influence the role of emissions trading systems in future net-zero (or even net negative) emission climate policies.

In principle, cap-and-trade emissions trading systems like the EU ETS are by design well suited to achieving a defined reduction target. However, particularly given the considerable uncertainty regarding emissions abatement costs, hybrid policy instruments which combine quantity- and price-based control are considered to be superior. Uncertainty regarding abatement costs is expected to worsen, given that process innovations alone are insufficient and new technologies will need to be introduced to achieve net-zero and later net-negative emissions targets. One type of required technologies are carbon removal methods which remove atmospheric CO_2 with subsequent storage. These technologies will doubtlessly be needed in order to achieve the net-negative emissions target as envisaged by the EU. However, they will also be needed to compensate for emissions which are (too) costly to be abated. Hence, the two challenges should be combined to allow a smooth transition from positive to net-negative emissions trading by including carbon removal credits (CRCs) for price-based market interventions before entering the net-negative phase. Initially these two markets should be separated with upfront carbon removal procurement and conditional supply of corresponding CRCs under active institutional mandate. Contrary to subsidized unconditional supply of CRCs, a procurement program with conditional supply of CRCs managed by a central agency would stipulate learning-by-doing for carbon removal methods without undermining learning-by-doing in the emissions abatement sector.

While the Plenary of the European Parliament has already voted to explore a gradual integration of carbon removal in the EU ETS by inviting the Commission to provide a report on legal design options for including carbon removal, broad political support for including carbon removal in the EU ETS is lacking. Although a specific governance framework has not yet been defined [26,27], the political pressure is expected to increase once the announced Regulation on the certification of carbon removal has been adopted. The finalization of the Fit for 55 package and preparations for a certification scheme now require scientific input on plausible and practical adjustments to existing climate policy instruments like emissions trading to include carbon removal and make sure that ambitions in emissions reductions are not being undermined.

Our proposal for a conditional integration of carbon removal under an active institutional mandate clearly requires further investigation on the organization and volume of such procurement programs, possible costs and in turn future price-caps which minimize the budget risks and which carbon removal methods could be considered. The proposed non-direct exchange between demand and supply side provides the opportunity to act as a clearing house, widening the scope of possible CDR methods to be included. While the current design of the EU ETS and MSR suggests that the conditional supply of CRCs would also be organized in a rule-based manner, the uncertainty about future abatement and carbon removal cost and the development of underlying fundamental factors put into question whether all possibilities can adequately be addressed in advance. In turn, the active institutional mandate might be assigned to a carbon central bank, requiring in turn to define its institutional mandate and its resources.

In principle, more flexibility in managing the purchase and the inventory of purchased CRCs would provide further options for climate policy. This applies for example to carbon removal credits in the reserve which are not used because the price cap (or strike price) has not been achieved. Invalidating a certain percentage of CRCs in the corresponding reserve would make the removal "permanent," since the CRCs could no longer be used to compensate for emissions. While CRCs in stock imply net-zero carbon emissions, since they can be supplied at some point in time to compensate for emissions, invalidating CRCs results in net-negative emissions, i.e., de facto removal. This could provide an important bargaining chip for the EU in future climate negotiations, i.e., on invalidating a certain percentage of its CRC stock in exchange for other countries implementing or strengthening carbon-pricing instruments. Not to mention that CRCs in stock can be used for later net-negative targets if not used for price stabilization. Furthermore, while planned regulations with respect to a carbon border adjustments mechanism (CBAM) foresee different options to level out carbon-related costs for import and export goods with respect to non-EU countries without a comparable carbon price, the physical implications are not yet addressed. Accordingly, export- and import-related emissions under CBAM regulation might be covered by CRCs in order to keep the net-emissions unchanged. These considerations show the integration of carbon removal into climate policies should not entirely focus on techno-economic aspects, but also address their potential for dealing with issues like international carbon leakage in the context of globally non-cooperative climate policies. Having CRC in stocks provides various

options for a more active climate policy. Simply put, while most emissions scenarios consider that carbon removal becomes applied in the second half of the century (which implicitly means that society is borrowing carbon removal), we argue that society in general and the EU ETS in particular should start banking carbon removal now.

Declaration of competing interest

There are no competing interests.

Data availability

No data was used for the research described in the article.

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