Öko-Institut Consult GmbH

The EU ETS and the 2040 Climate Target

Berlin, 16.06.2025

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LIFE Effect

CARBON MARKET WATCH

The study was commissioned by Carbon Market Watch as part of the LIFE Effect project (LIFE23-GIC-BE-LIFE EFFECT, www.life-effect.org) and was funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

The authors would like to thank Vanessa Cook for proofreading this study.

Co-funded by
the European Union

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List of Abbreviations

BECCS	Bioenergy with Carbon Capture and Storage
CBAM	Carbon Border Adjustment Mechanism
CDM	Clean Development Mechanism
CDR	Carbon Dioxide Removal
CTP	Climate Target Plan
DACCS	Direct Air Carbon Capture and Storage
ECL	European Climate Law
ESR	Effort Sharing Regulation
ETS 1	EU Emissions Trading System covering power plants and industrial installations
ETS 2	EU Emissions Trading System covering buildings and road transport fuels
EUA	EU Allowance, emission unit in the EU ETS
GHG	Greenhouse Gases
ITMO	Internationally Transferred Mitigation Outcome
JI	Joint Implementation
LRF	Linear Reduction Factor
LULUCF	Land Use, Land-Use Change and Forestry
M EUA	Million EU Allowances
MSR	Market Stability Reserve
NDC	Nationally Determined Contribution
PAC	Paris Agreement Compatible
TNAC	Total Number of Allowances in Circulation

Summary

The European Union's Emissions Trading System (EU ETS) remains a cornerstone of European climate policy. Since its launch in 2005, it has undergone significant reforms to increase its effectiveness and align with increasingly ambitious climate targets. The ETS 1, covering emissions from electricity generation and industry, features an annually declining emissions cap that is set to reach near zero emissions by 2040. The ETS 2, which is set to begin in 2027, will cover emissions from buildings, road transport, and small industries with the goal of zero emissions by 2045. However, emission scenarios achieving climate neutrality by 2050 at the latest show that such a fast decarbonisation is not required. Consequently, after 2035 demand for emission rights will exceed supply, which will lead to a shortage of liquidity in the market. Without policy reforms or an increased ambition to reduce emissions, this imbalance could result in price hikes of allowances with potentially negative effects on industry and consumer prices.

This study analyses how to realign the ETS 1 and ETS 2 to meet the EU's 2040 target. For this purpose, we analyse the systems' current configurations and test three emission scenarios to evaluate the effectiveness of different reform options to recalibrate the ETS 1 and ETS 2 to ensure the continuous functioning of both systems in reaching the 2040 and 2050 climate targets. These include both demand and supply side measures, such as lowering demand through steeper emission reductions, adjusting the linear reduction factor (LRF) or including carbon dioxide removals (CDRs) in the ETS.

Key findings:

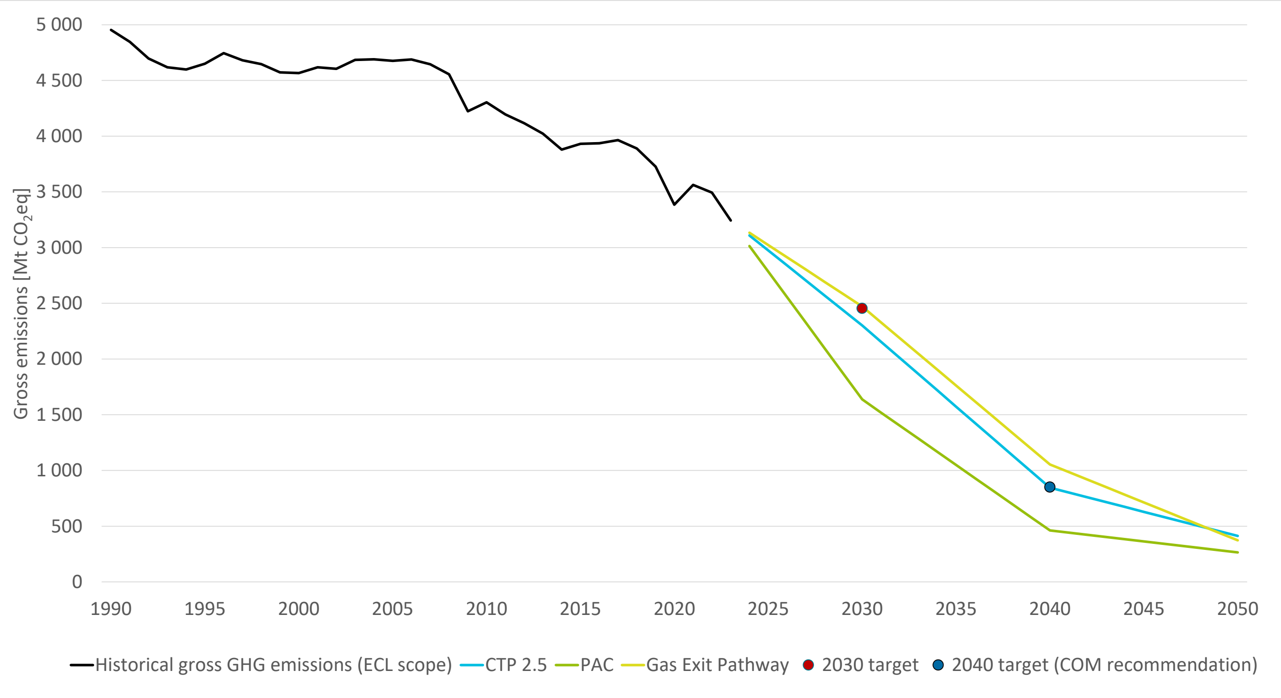
- Emissions from covered entities in the ETS 1 and ETS 2 do not need to reach zero emissions by 2050 even in the most ambitious scenario aligned with the Paris Agreement. This suggests that the current cap trajectory is much more ambitious than required. An ETS reform along with respective emission targets for the non-ETS sectors does not lead to a weakening of ambition.
- Market liquidity only becomes a concern after 2035 when EUA demand exceeds the supply. Instruments that can increase the liquidity in the ETS include revising the market stability reserve (MSR) or adjusting the LRF.
- The inclusion of carbon credits in the ETS poses a serious risk. We find that including Article 6 or low-quality carbon removals like biochar could undermine the environmental integrity and effectiveness of the ETS. These instruments should not be considered as an option to ease tension in the EUA market. While technological CDRs like bioenergy with carbon capture storage (BECCS) or direct air carbon capture storage (DACCS) may offer some potential to balance out supply and demand in the systems, uncertainties around their availability and affordability make them unreliable tools to address shortages of EU allowances (EUAs) leading up to 2040 on their own. Thus, technological CDRs would have to be complemented by other measures.
- Mitigation of emissions must remain the core focus of the ETS. All measures that are considered to increase liquidity in the carbon market need to align with the overarching principle of the ETS that is driving real emission reductions. Any ETS reform should reinforce confidence in the system and the EU's climate targets to avoid jeopardising the 2040 target and the 2050 climate neutrality target.

1 2040: The last stepping stone towards climate neutrality

The EU intends to become climate-neutral by 2050 at the latest and aims to achieve negative emissions afterwards. This target is laid down in the European Climate Law (ECL) and covers all greenhouse gas emissions and removals regulated under Union law. The ECL also sets the 2030 target as a domestic reduction of net greenhouse gas emissions by at least 55 % compared to 1990. The 2040 target sets the necessary speed of reduction after 2030. It strengthens the 2030 target and indicates the need for further emission reductions in all sectors; there will be very little room for laggards in future years. The necessary technological and infrastructural development for becoming climate neutral has to take place by 2040. As investments usually have lifetimes of decades, the setting of early and clear incentives is essential. The year 2040 is also key for the overall amount of GHGs emitted in the period up to 2050 and for the EU's contribution to climate change.

Figure 1-1 shows the development of gross emissions from three different carbon neutrality scenarios.[1] Remaining emissions in a range of 265 to 412 Mt CO_2eq have to be balanced with natural or technical removals. These three scenarios are used throughout the report (see chapter 2.3).

Figure 1-1: Different pathways for residual emissions in carbon neutrality scenarios



Note: 2030 and 2040 gross emission targets are shown: For 2030, the LULUCF contribution of 225 Mt CO_2e is added to the -55 % reduction target, while for 2040, 850 Mt CO_2e as mentioned in EC (2024a) is used. For all scenarios, the international transport emissions are taken from the 2.5 scenario based on the 2040 Impact Assessment (see Gores and Graichen (2024)).
Source: Oeko-Institut based on EC (2024b), Tsekeris and Karjalainen (2024) and Graf et al. (2023)

[1] Gross emissions are those greenhouse gas emissions that enter the atmosphere. This means that carbon capture and storage (CCS) is not shown in the graph. Net emissions are the remaining emissions after natural and technical carbon dioxide removals (CDRs), e.g. through forests and BECCS.

1.1 The 2040 climate governance and the role of the EU ETS

While target setting is important, and the first step in giving the direction of travel, the second step is to define supporting targets, instruments and mechanisms for their achievement. The EU ETS has proven to be a very important instrument over the last two decades: it gave confidence in the relevance and importance of mitigation of CO_2 emissions, both in the short term and for future years. The EU ETS has been accompanied by the Effort Sharing Regulation (ESR) and the LULUCF (Land Use, Land-Use Change and Forestry) Regulation, which define national targets up to 2030 for emissions not covered under the ETS 1. In addition, several instruments are in place to support the achievement of the 2030 target, especially the Renewable Energy Directive, the Energy Efficiency Directive as well as other regulations and standards. The ETS is not limited to the period up to 2030: The cap setting mechanism via the LRF and the functioning of the MSR give a clear end of the supply of EUAs as around 2040 for the ETS 1 and somewhat later for the ETS 2 if the system is not revised.

In the past, emissions have decreased most under the ETS 1. While EU-wide total emissions decreased by 31 % between 2005 and 2023, ETS 1 emissions decreased by 45 %. The extension of carbon pricing to other sectors such as buildings, road transport and small industry with the ETS 2 is the logical consequence. The share of EU emissions covered by the ETS 1, which currently amounts to 35 %, has been constantly decreasing due to higher emission reductions under the EU ETS. The ETS 2 covers almost 40 % of total EU emissions. These are also part of the scope of the ESR. Emissions under the ESR decreased only 17 % between 2005 and 2023.

There are various reasons for these different paces of emission reductions under the ETS 1 and the ESR: Clearly, setting a price on CO_2 is a very relevant means, but it is by no means the only reason for emission reductions. The main emission reduction took place in the sector of energy industries (see Nissen et al. (2024)). Many policies and instruments added to this success story of this part of the stationary ETS: European and national policies and measures and regulatory law contributed by supporting the shift to renewable energy or less carbon-intensive energy sources, enhancing energy efficiency, and supporting infrastructure development. Other emissions covered under the ETS 1, like industrial or aviation emissions, did not decrease in a similar way and are not projected to do so. ETS 2 or shipping emissions are not projected to decrease significantly due to their inclusion under the ETS, as long as CO_2 prices are kept within a socially acceptable range. Other policies like the fuel blending mandates will be more effective in decarbonising both sectors. Marginal abatement costs vary broadly between sectors, but many non-economic barriers also hamper the price signal, especially for investment decisions of private consumers. The long-term energy costs including carbon pricing is only one factor and is often outweighed by other drivers. Thus, as long as prices are kept within a socially acceptable range, additional instruments are necessary (see Hünecke et al. (2025)). In addition, complementary measures have the added benefit of keeping ETS prices lower.

To achieve the 2040 target, it is important to implement a broad range of different EU policies and instruments. While the price for CO_2 under the EU ETS will remain a relevant element after 2030, additional EU-wide policies like renewable energy and energy consumption targets and regulatory instruments like CO_2 emission standards for vehicles and buildings will be required. In addition, Member States must set in place additional instruments which are designed in a way to match their specific situations. For the indication of the necessary ambition of each Member State and shared responsibility, the setting of national targets is important. They are needed to incentivise complementary climate policies at national and local levels (Meyer-Ohlendorf et al. (2025)).

1.2 The role of carbon dioxide removals

All climate neutrality scenarios show residual GHG emissions up to 2050 and beyond, even under the EU ETS (see, for example, scenarios in Figure 1-1). These remaining emissions are due to technical or economic reasons or a lack of public consent for mitigation in specific areas. To achieve greenhouse gas neutrality in the target year, negative emissions are therefore needed to balance these emissions. The European Climate Law states that this is to be accomplished within the Union, which means that it is a domestic target. Negative emissions can result either from land-based sinks or from technical applications. Natural removals are limited because of conflicting land-use needs and can vary considerably due to natural disturbances. These removals are not permanent, but in addition to removing CO_2 from the atmosphere they can contribute to other targets like biodiversity and adaptation. Technical removals, like DACCS, Bioenergy with Carbon Capture and Storage (BECCS), biochar or enhanced weathering and the related infrastructure are still in their infancy. Storage in geological formation can be understood as storage for at least several hundreds of years. But even if capture, storage and infrastructure are technically developed and risks of leakage are contained, technical removals will always be marked by high consumption rates of energy and area, and, in the case of BECCS and biochar, conflicting interests on biomass use (see Schneider et al. (2024a)).

Only the phase-out of fossil fuels allows for the most reliable approach to carbon storage to be used: keeping fossil fuels underground. All other ways of storing CO_2 are not nearly as safe to keep the emissions out of the atmosphere. Balancing a ton of emitted GHG with a ton of negative emissions is always based on a compromise which should take utmost account of criteria such as permanence, additionality, double claiming, risk and equity. While clearly needed to offset residual emissions, the effect of natural and technical sinks will continue to be questionable and related efforts and risks will remain relevant in the years ahead.

As a lead principle, targets and instruments to incentivise negative emissions need to be designed in a way that emission reductions are not substituted and that their integrity is secured. If negative emissions should be integrated in instruments focused on emission reduction like the ETS, strong criteria are required to account for the fact that there is no equivalence between emitted greenhouse gases and negative emissions. One reason for such an integration would be to follow the polluter pays principle when offsetting emissions based on high-quality negative emissions, taking into account the varying quality of negative emissions.

Combining GHG emissions and technical sinks in a single instrument is challenging for setting the target of the instrument and its compliance, especially because the uncertainties about quantities and prices of technical CDR remain high. In general, the price of CDR is related to the quality of certificates. At least in the medium term, the cost of technical removals will far exceed the CO_2 price. If not well regulated, cheap and uncertain natural removals could flood the market and distort the functioning of instruments. The Carbon Removal Certification Framework (CRCF) and its proposed methodologies could pave the way for certificates for natural removals. With the current developments of this framework, there is a high risk that certificates with even lower quality standards than those laid down under Article 6 of the Paris Agreement could be generated (for more information see Schneider et al. (2024b)). The experience of including excessive and dubious CDM and JI credits in the EU ETS and the usage of fraudulent upstream emission reductions under the Fuel Quality Directive (UBA 2024) demonstrate potential risks and the potential to undermine the effectiveness of the ETS.

Separate emission and removal targets, on the level of overarching EU greenhouse gas targets and on the level of instruments, are most appropriate ways of ensuring the integrity of both. Objectives of single instruments need to relate to each other for the joint achievement of the overall targets. Regular revisions of elements related to technical removals will be needed to ensure that they are fit for purpose and do not lead to unintentional effects (for more information see CMW (2025)).

1.3 The role of international transport

While emissions from all sources have decreased on the EU level since 1990, those from international aviation and shipping have increased considerably and are expected to further increase in the future, mainly due to higher demand for long-distance transport. International transport is often overlooked and is not considered in national target setting. The EU ETS includes a proportion of aviation emissions since 2012 and of shipping emissions since 2024.

For the reporting and target setting on EU level, there are different scopes which are used. In this report, we focus on the scope defined in the ECL and quantified by the European Commission in its 2040 Impact Assessment (JRC 2024). This includes aviation and navigation in the EU and European Economic Area (EEA) and 50 % of shipping voyages that depart or arrive outside the EU, as reported under the EU ETS. With this scope, the EU ETS does not cover the full share of European international transport emissions in the aviation sector, and it also does not include non-CO_2 effects from aviation.

In 2024, the scope of the EU ETS was expanded to cover flights to and from outermost EU regions to other ETS countries. Another extension to all flights departing from the EEA might happen from 2027, if CORSIA is found to be failing. In addition, aviation's non-CO_2 emissions may become part of the ETS from 2028, which would include the full climate impacts of aviation in the ETS. If these emissions are included under the EU ETS, they would be regulated by EU law and would also need to be covered by the 2040 target.

Even within the current scope, the relevance of emissions from aviation and shipping will increase considerably in future, while emissions from most other sources will converge towards zero. The share of international transport in gross European emissions amounted to 2 % in 1990, 4 % in 2023 and is projected to amount to 5 % in 2040 in the CTP2.5 scenario. This underlines the growing relevance of these emissions and the need to design additional targets to tackle them to avoid that the EU fails to meet its 2040 target and to assume responsibility for its climate impact.

In our analysis, we apply the current rules for coverage under the EU ETS.

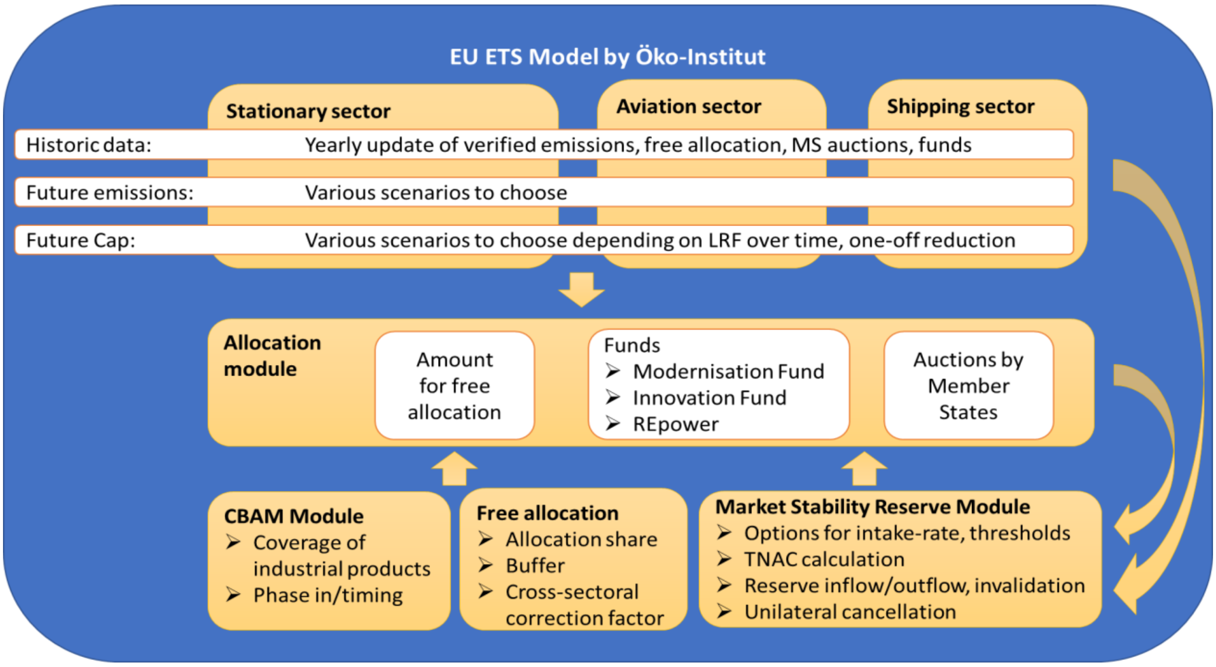
2 Methods and data

The following section provides an overview of the quantitative and qualitative assessment as well as the different scenarios we analyse and that serve as the basis for the assessment in section 4.

2.1 Quantitative assessment

We use our ETS 1 and MSR tool and the ETS 2 and MSR tool to model the scenarios and quantify the impact of different liquidity measures[2]. Both models are implemented as spreadsheet models with macros used for running a large number of scenarios and visualising results. The ETS 1 model can show the impact of policy decisions such as those relating to changes in auctioning and free allocation shares, Carbon Border Adjustment Mechanism (CBAM), the MSR, aviation, maritime, the link to the Swiss ETS and the ESR flexibilities on the overall supply of allowances. By running through the three emission scenarios and flexible assumptions on the magnitude of hedging needs, the tool can determine what policy changes or external shocks mean for the balance of demand and supply, for the required emission reductions and the achievement of emission reduction targets. Figure 2-1 provides an overview of the elements of the ETS 1 and MSR tool. The different modules of the tool can be switched on and off and allow the separate issues to be analysed in greater detail.

Figure 2-1 Elements of the EU ETS 1 and MSR model by Oeko-Institut



Source: Oeko-Institut

The EU ETS 1 model covers stationary installations in all 30 countries participating in the EU ETS as well as aviation and shipping. The link to the Swiss ETS is implemented as is the impact of the ESR flexibility on the total number of allowances in circulation (TNAC). The ETS 2 model is not as complex. It is calibrated to the current ETS 2 configuration. It allows us to assess supply and demand, taking into account the MSR and the price trigger mechanism.

An important limitation to both ETS and MSR tools is that they are static, emissions are provided endogenously. There is no direct interaction with the MSR and cap, i.e. in high emission scenarios, TNAC might become negative. This would imply non-compliance by the covered entities. It is up to

2 Liquidity measures in this report refers to measures that increase the supply of EUAs in the ETS in the run up to 2040. In theory, there could also be a lack of liquidity despite a large oversupply if there are not enough sellers.

the user to select emission scenarios, LRF and MSR parameters appropriately. The tool is also not able to calculate CO_2 prices or the impact of certain parameters on the price development.

2.2 Qualitative assessment

While the quantitative assessment will form the core of this study, many questions can only be assessed qualitatively, e.g. whether there is a need for national targets or not. Similarly, the interpretation and conclusions based on the results of the quantitative assessment will require judgements. We suggest building upon the assessment criteria used in a study that we conducted on the reform of the EU ETS for the Finnish Parliament (Graichen et al. 2019):

- **Abatement potential:** This refers to the ability of the policy measures to reduce GHG emissions effectively. Options such as strengthening the cap or enhancing the MSR demonstrate high abatement potential, while measures like extending the scope of the ETS have lower potential. The abatement potential is measured by the total supply of allowances (the emission budget).
- **Timing of impact:** The evaluation also considers how quickly a policy can deliver the anticipated effect of increasing liquidity in the ETS. Enhancing resilience through mechanisms like the MSR offers short-term impacts, while structural changes like adjusting the LRF require more time to take effect. Similarly, an option to allow industrial CDRs – e.g. DACCS – in 2030 already would have minimal impact due to the lack of projects.
- **Interaction of different measures:** This criterion looks at the interdependencies of different policy options under the different emission scenarios. For example, the impact of another LRF on the overall emission budget strongly depends on the rules for the MSR. More resilient combinations lead to similar values for key parameters, e.g. TNAC in 2040. The higher the dependency of key parameters on the emission scenario, the higher the volatility of the ETS.

We will not assess the political feasibility of the proposed measures because the topic is highly sensitive and widely debated. Political dynamics surrounding the issue of the *ETS endgame* or homestretch[3] remain deeply uncertain, and any attempt to evaluate feasibility would rely on speculation rather than concrete evidence.

2.3 Scenario data

To determine likely GHG emission paths in the ETS 1 and ETS 2, we select scenarios modelling GHG emission pathways in the EU27 for different sectors. The selected scenarios differ in their speed of decarbonisation and achieve climate neutrality between 2040 and 2050. Specifically, we select the following three scenarios:

- The **Climate Target Plan (CTP)** Impact Assessment Scenario **2.5** of the European Commission, achieving climate neutrality by **2050** (EC 2024b);
- The **EU Gas Exit Pathway,** achieving climate neutrality by **2050** (Graf et al. 2023); and
- The **Paris Agreement Compatible Scenario (PAC) 2.0**, achieving climate neutrality by **2040** (Tsekeris and Karjalainen 2024).

[3] We use the phrases “ETS endgame” and “ETS homestretch” to refer to the period in the ETS when the cap approaches zero.

Table 1 provides an overview of key figures for 2040 from the different scenarios.

Table 1 Keys figures in 2040 by scenario

	COM CTP2.5	Gas Exit Pathway	PAC 2.0
GHG target [a]	90 %	89 % [b]	102 %
H_2 demand	33 Mtoe [c]	50 Mtoe [d]	49 Mtoe [d,f]
H_2 production	88 Mtoe	45 Mtoe [d]	n/a
e-fuels demand	11 Mtoe [c]	18 Mtoe	44 Mtoe [d,f]
Technological carbon capture	283 Mt CO_2 [g]	77 Mt CO_2 [e]	29 Mt CO_2 [h]
LULUCF removals	317 Mt CO_2	361 Mt CO_2	519 Mt CO_2

Notes: a – GHG reduction targets refer to net emissions relative to GHG levels in 1990
b – Excludes GHG emissions from international aviation and shipping
c – Refers to final energy consumption
d – Includes exclusively renewable/green hydrogen
e – Includes carbon capture and storage, including BECCS (accounting for 23 Mt CO_2)
f – Refers to final energy demand in EU28
g – This includes all carbon capture, i.e. for storage of fossil emissions (CCS), for negative emissions (BECCS, DACCS) and for use (CCU)
h – This scenario includes only CCU, not CCS

Sources: Oeko-Institut based on EC (2024b), Tsekeris and Karjalainen (2024) and Climact (2025)

2.3.1 COM Climate Target Plan (CTP) 2.5

The Commission published three scenarios that differ in their speed of decarbonisation along with the recommendation for a 90 % emission reduction target by 2040. CTP1 achieves 78 % GHG emission reductions by 2040, whereas CTP2 and CTP3 achieve 88 % and 92 % GHG emission reductions by 2040, respectively. **CTP2.5** is calculated as the average of CTP2 and CTP3 and hence corresponds to the Commission's proposed target of achieving a net 90 % GHG emission reductions by 2040. Therefore, we focus on CTP2.5.

This pathway is characterised by a high adoption of carbon technologies primarily in the industry and power sector along with a high uptake of hydrogen and resulting e-fuel production. By 2050, 453 Mt CO_2 will be captured by carbon capture technologies while hydrogen and e-fuel production amount to 185 Mtoe and 60 Mtoe, respectively.

Emission reductions in the buildings sector are achieved through electrification (i.e. installation of heat pumps) and enhanced renovation rates. Mitigation in the transport sector is driven by CO_2 standards for cars and vans along with a shift from cars to active modes and public transport. In addition, CO_2 standards for HDVs and efficiency improvements in freight and delivery operations contribute to emission reductions.

To determine the GHG emission path in the ETS 1 and ETS 2, we determine what share of GHG emissions in the modelled sectors can be attributed to the respective schemes. GHG emissions in the power and district heating sector, energy-related industry emissions and other energy sectors are assigned to ETS 1 and ETS 2 with different shares. Non-energy related industry emissions and emissions from international transport are fully assigned to ETS 1, whereas emissions from domestic transport and residential and services are fully assigned to ETS 2. In 2050, the remaining emissions in the ETS 1 and ETS 2 amount to 58 Mt CO_2 and 52 Mt CO_2, respectively.

2.3.2 EU Gas Exit Pathway

The EU Gas Exit Pathway, developed by Agora Energiewende in collaboration with Artelys, TEP Energy and the Wuppertal Institute, projects an **89 % reduction in domestic GHG by 2040**. This is very close to the target of achieving a 90 % GHG reduction by 2040 proposed by the Commission.

The EU Gas Exit Pathway focuses on phasing out gas imports from Russia by 2027 and fully phasing out fossil gas consumption by 2050. It is a cost-optimised pathway prioritising hydrogen and bioenergy resources only for use cases without more efficient alternatives, i.e. industry and international shipping and aviation. Instead, the main drivers of GHG reductions are the deployment of renewable energy (96 % of electricity generation in 2050) and the high rate of direct electrification, particularly in the heat sector. This means a faster decline in gas consumption than in the Fit for 55 proposal. Technological carbon capture is projected to amount to 106 Mt CO_2 in 2050.

The buildings sector is the first one to fully decarbonise by means of efficiency improvements, electrification (e.g. heat pumps) and decarbonised district heating, resulting in a nearly fossil-gas free buildings sector by 2040. Domestic transport has not been modelled. Rather, the study relies on existing analyses by Transport & Environment.

To determine GHG emissions in the ETS 1 and ETS 2, we assign modelled sectors to the ETS 1 and ETS 2 scope and apply the modelled GHG emission reduction paths in these sectors to actual emissions in the ETS 1 and ETS 2 reported in 2020. In 2050, remaining emissions in the ETS 1 (excluding aviation and shipping) and ETS 2 amount to 40 Mt CO_2 and 7 Mt CO_2, respectively.

2.3.3 Paris Agreement Compatible (PAC) scenario 2.0

The PAC2.0 scenario, which has been developed by CAN Europe in collaboration with EEB, RGI and REN21, provides a scenario aligned with the Paris Agreement that achieves carbon neutrality on the EU27 level before 2040. Hence, the scenario is more ambitious than the 90 % GHG reduction target proposed by the Commission for 2040.

The PAC2.0 scenario focuses on achieving emission reductions by means of 100 % renewable energy production combined with scaled-up energy storage. This includes a substantial expansion of the H_2 infrastructure. It relies heavily on electrification across sectors as well as removal enhancements in the LULUCF sector. The energy demand in the EU27 is projected to decline through lifestyle changes, energy efficiency, technological innovation and circularity. In addition, the scenario projects both substantial renovations of buildings and electrification in the heating of buildings and the transport sector.

The projected demand for hydrogen amounts to 50 Mtoe in 2050. Carbon capture does not play a significant role as CCU technologies will only be deployed for selected industries with very high process emissions (e.g. the cement industry), capturing only 34 Mt CO_2 in 2050.

The modelled GHG emissions are assigned to the ETS 1 scope and its split into stationary emissions and emissions from aviation based on the ETS split in the CLIMACT 2050 Pathways Explorer (Climact 2025). The CLIMACT 2050 Pathways Explorer also provides data on sectoral emissions outside the ETS 1 scope. From this category, we apply the modelled GHG emission reduction paths in the buildings, transport, industry, and energy supply sectors to actual ETS 2 emissions reported in 2021. In 2050, the remaining emissions in the ETS 1 (excluding shipping) and ETS 2 amount to 99 Mt CO_2 and 41 Mt CO_2, respectively.

2.3.4 Comparing the different emission scenarios

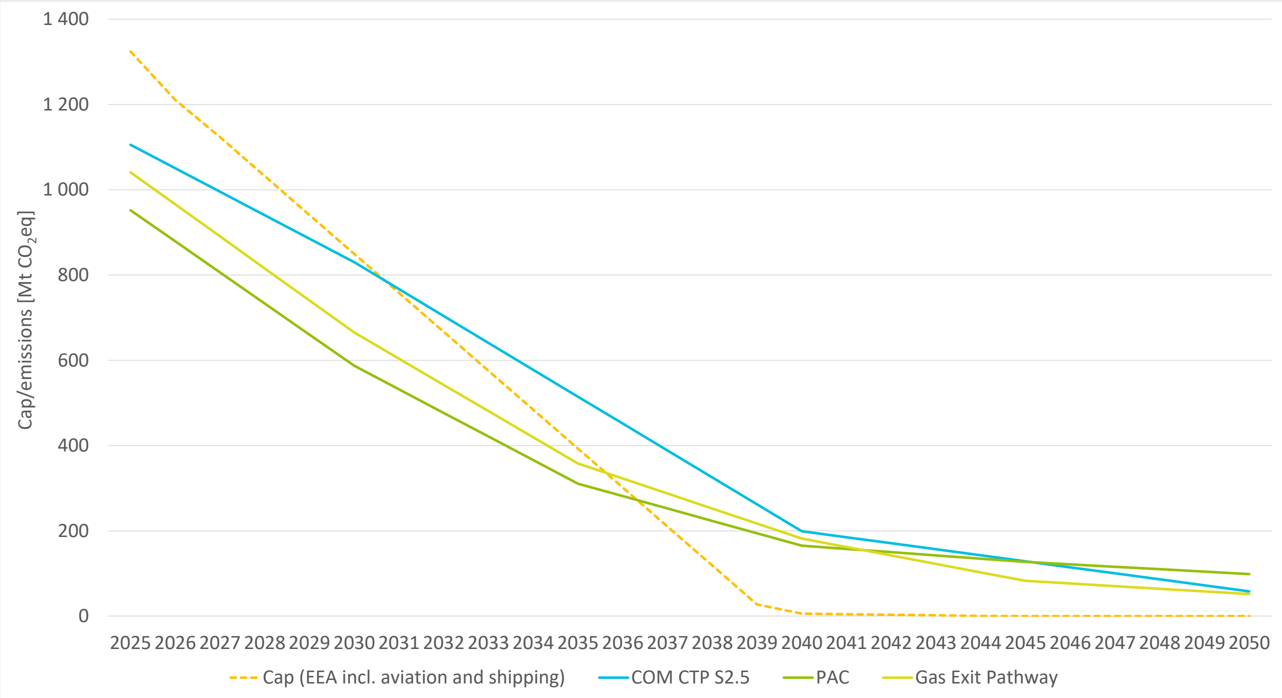
Figure 2-2 and Figure 2-3 show the cap development of the EU ETS 1 and EU ETS 2 along with the emission projections of the three analysed scenarios, the CTP2.5, Gas Exit Pathway, and PAC scenario until 2050. We use the CTP2.5 projections for aviation and shipping for gap-filling the Gas Exit Pathway scenario which only models the stationary sector. For the PAC scenario, the CTP2.5 shipping projection is used for gap-filling. While the cap of the ETS 1, indicated by the dashed orange line, reaches almost zero in 2039,[4] none of the scenarios achieves zero emissions by then. This means that there will be a deficit of EUAs at some point in all scenarios. The PAC (green line) and the Gas Exit Pathway (dark blue line) scenario follow similar emission projections up to 2040. However, the PAC scenario projects a steeper emission reduction in the early years than the Gas Exit Pathway scenario. Both scenarios estimate that emissions will exceed the cap in 2036, which results in a deficit of allowances from 2036 onwards. After 2040, emissions in the Gas Exit Pathway scenario decrease further from 185 Mt CO_2 to 40 Mt CO_2 in 2050. Emissions in the PAC scenario almost plateau after 2040 and reach 53 Mt CO_2 by 2050. The CTP2.5 scenario (light blue line) paints a slightly different picture. Up to 2040, emission reductions decline at a much slower rate than in the other two scenarios, which means that emissions already exceed the cap in 2032. After 2040, emissions decline linearly until 2050 to reach similar levels as the Gas Exit Pathway scenario.

The cap of the EU ETS 2 reaches zero five years later in 2044. Similar to the ETS 1, no scenario projects the emissions to also reach zero by 2044. The PAC scenario estimates the deepest emission reduction, emissions only rise above the cap after they have already declined substantially to 62 Mt CO_2 in 2043. Emissions in the Gas Exit Pathway remain under the ETS 2 cap up to 2038 and decline linearly to zero by 2050, leading to a large deficit of allowances in the 2040s. The CTP2.5 scenario already breaches the cap in 2027 and leads the ETS 2 into an allowance deficit up to mid-century. The deficit from 2027 to 2040 is only minimal as the projected emissions follow the cap closely. However, after 2040 emissions in the CTP2.5 scenario are substantially higher than the cap and reach around 50 Mt CO_2 by 2050.

Other key differences between the scenarios lie in their assumptions about the role of the LULUCF sector and the role of technical CDRs in reaching net zero emissions by 2040. The PAC scenario, which has the most ambitious GHG emission reduction target, relies heavily on carbon sinks in the LULUCF sector to meet this target. They project that 519 Mt CO_2 will be stored in the LULUCF sector in 2040, which is 136 Mt more than predicted in the Gas Exit Pathway and even 202 Mt more than in the CTP2.5 scenario. In contrast to the reliance on LULUCF sinks, the CTP2.5 scenario, with 283 Mt CO_2, depends most on emission reductions via technical CDRs to achieve the 2040 target. The Gas Exit Pathway and PAC scenario only assume a fraction of this, with shares amounting to 27 % and 10 %, respectively. Whether such large-scale biological and technical removals will be available to permanently offset emissions from installations and entities regulated under ETS 1 and 2 is a contentious question.

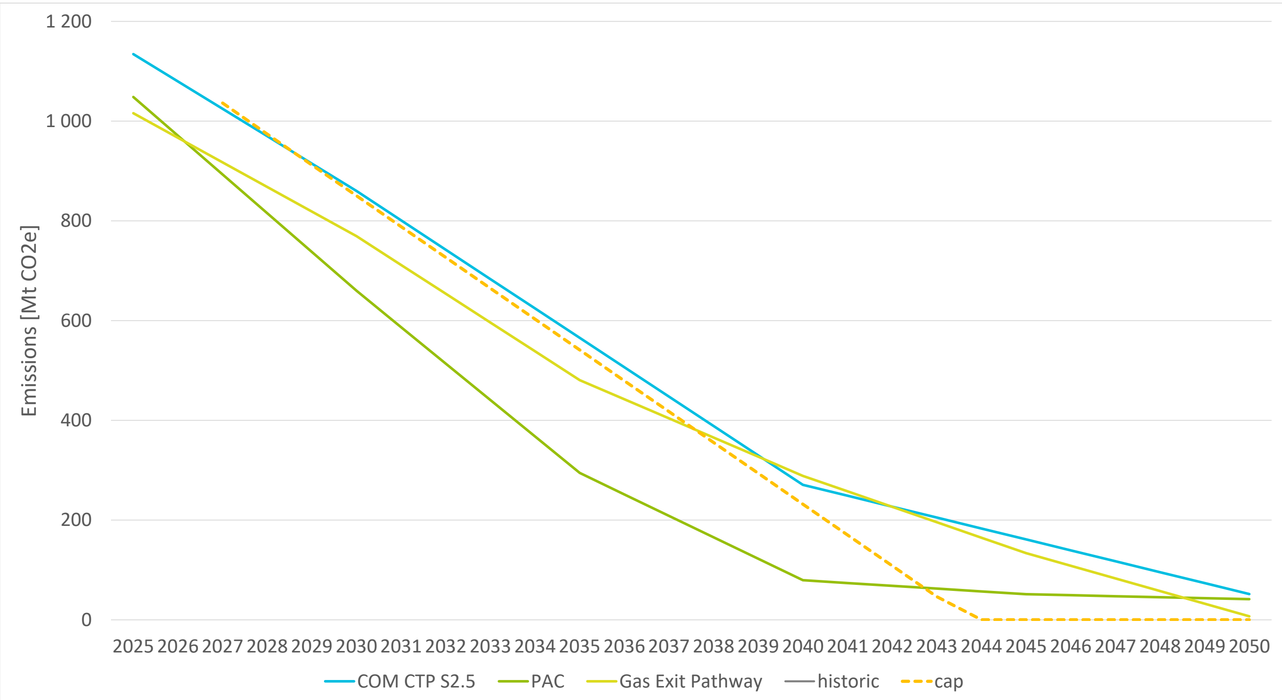
[4] The cap remains above zero until 2043 due the aviation cap; however, the quantities after 2040 are negligible.

Figure 2-2: Cap and emissions development for the ETS 1 (EEA scope incl. aviation and shipping)



Source: Oeko-Institut based on EC (2024b), Tsekeris and Karjalainen (2024) and Graf et al. (2023)

Figure 2-3: Cap and emissions development for the ETS 2



Source: Oeko-Institut based on EC (2024b), Tsekeris and Karjalainen (2024) and Graf et al. (2023)

3 Current configuration of the ETS 1 and ETS 2

This chapter will form the base case against which the policy options in chapter 4 will be assessed. Based on the current configuration of the ETS 1 and ETS 2 and the emission pathways described above we analyse the performance of the ETS up to 2050. Assuming that the ETS Directive will not be changed, we assess the following for each emission pathway:

- when the MSR will withhold/release allowance; and
- when the availability of allowances both under the cap(s) and the remaining allowances in the MSR/holding accounts reaches zero.

It is important to remember that our ETS MSR tool is not dynamic, i.e. it does not include any feedback of demand due to the scarcity of supply and the resulting price increase for ETS allowances. The results presented in this study are subject to assumptions about the scope of both ETSs. These assumptions are necessary to ensure consistency across scenarios.

For the base case, we assume that the current scopes of the EU ETS 1 and the EU ETS 2, as defined in the EU ETS Directive, remain unchained (2003/87/EC). In the aviation sector we only include CO_2 emissions. We assume no changes to the workings of the MSR 1 and MSR 2. This includes maintaining the current thresholds for the intake and release of allowances in the MSRs. For the ETS 2, we assume that the CO_2 price limit will remain above 45 EUR per EUA up to 2030 (in EUR2020, approx. 60 EUR in 2030 prices). This means that the MSR will release 20 million additional allowances into the market each year. We further assume that the REPowerEU Regulation is fully implemented and finalised by 2030 and that no additional measures are taken after 2030. We base the residual emissions on estimates from each scenario. We also assume that free allocation is completely phased out by 2034 for sectors currently covered under the CBAM. For other sectors, we assume that free allocation continues under current rules. We do not analyse different CBAM configurations, e.g. the extension of CBAM to other sectors, because the extension of CBAM does not directly impact the overall supply or demand of allowances in the EU ETS endgame. While the phase-out of free allocation and the expansion of CBAM could lead to a reduction in emissions and, along with it, a reduction in EUA demand, if EUA costs exceed the mitigation costs, we do not consider this a liquidity-enhancing measure below. We anticipate that the emission reduction that an extension of CBAM could bring about is already reflected in the emission projections of the modelled scenarios.

We model the TNAC development for all three scenarios for the EU ETS 1 and 2. Annex I contains the graphs for each scenario showing the projected emissions, the development of the TNAC and the MSR without any additional liquidity enhancing measures. Figure 3-1 shows the TNAC trajectory for the COM CTP2.5 scenario under the EU ETS 1. The shaded blue area refers to the TNAC and the blue line to the TNAC visible to the market (see Box 1), the dashed back line shows the projected emissions. The allowance supply is shown by the bars and consists of free allocation (dark red), sold or auctioned EUAs (pink), and MRS outflow (green).

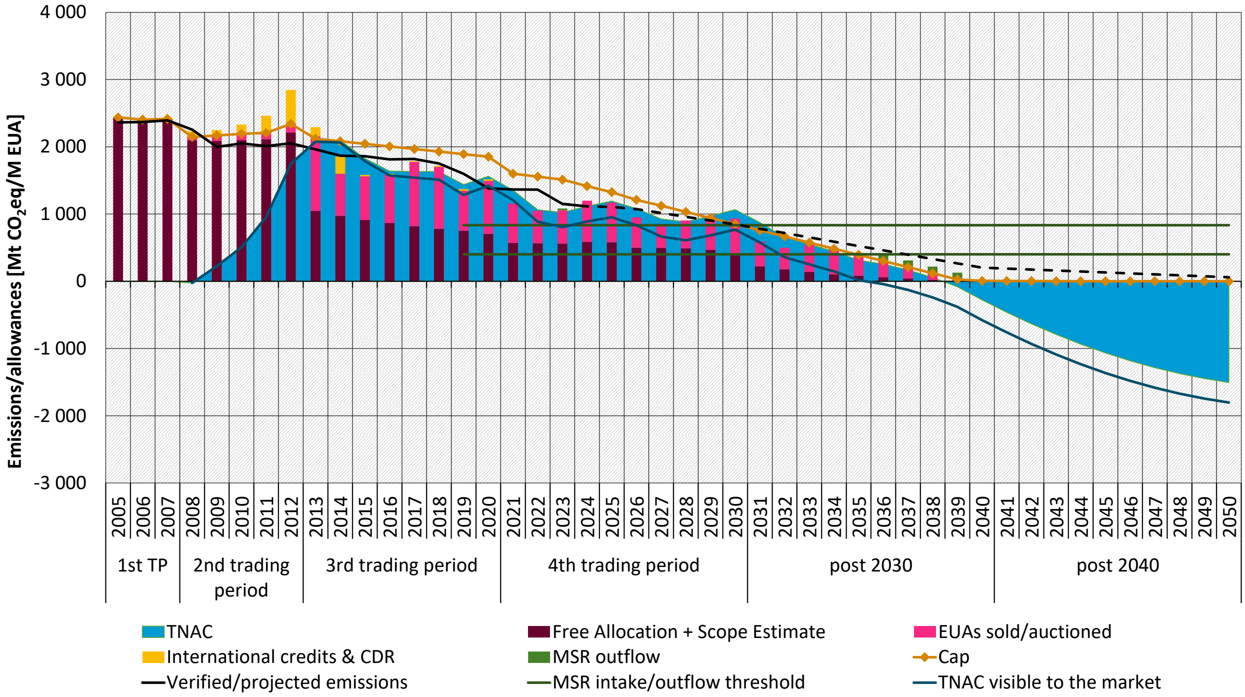
Box 1 Total number of allowances in circulation

The Total Number of Allowances in Circulation (TNAC) is the key parameter used in the operation of the MSR. It captures the difference between all emissions rights (including from project mechanisms) which have entered the ETS since 2008 and the demand for compliance, i.e. the quantity of units surrendered by operators. Therefore, TNAC captures the liquidity of the EUA market. In our calculations and this paper, we use the terms *TNAC* and *TNAC visible to the market*. We use TNAC for the definition as set out in the MSR Directive. This value is also used when checking whether the TNAC is above/below the MSR thresholds. TNAC visible to the market ($TNAC_{VtM}$) includes other demand not included in the official TNAC calculation. Most importantly, it reflects the net demand from aviation between 2013 and 2023 (189 M EUAs) and the usage of ETS units for compliance under the ESR (up to 108 M EUAs). The net demand from linking with the Swiss ETS is also not included in the TNAC definition. In this paper, we assume a balanced linking (no net flow). For the ETS 2, TNAC already captures all demand and there is no need for using $TNAC_{VtM}$.

We use TNAC as the main indicator for assessing the balance between supply and demand. A negative value means that operators would not be able to comply with their obligations under the ETS Directive whereas a very high value would indicate a structural oversupply. Reform options that keep the TNAC value within the thresholds of the MSR (400 to 833 M EUAs in the ETS 1) are evaluated positively whereas a negative value shows that the ETS rules would be more restrictive than required by the different scenarios.

While the EU ETS cap, indicated by the yellow line, reaches zero by 2040, emissions do not. The MSR that took allowances up to 2031 gets triggered in 2036 when the TNAC first falls below the outflow threshold and begins to release its remaining 400 million EUAs until they are exhausted in 2040. From 2036 onwards, EUA demand exceeds supply leading to a deficit in TNAC visible to the market. This deficit grows over time and reaches more than 1 803 million EUAs in 2050. This situation presents a twofold problem. First, without any price controls or regulatory changes, this anticipated EUA shortage will drive up prices as supply falls drastically and demand remains stable or even increases as installations try to secure enough EUAs to comply with the EU ETS. While moderate price increases can initially incentivise further emission reductions if EUA prices excess mitigation costs. Some sectors might even not be able to fully cut emissions of their operations by 2040 even under pressure of high EUA costs. For those sectors, further price spikes will not reduce emissions further but instead increase operational costs. While there is no empirical evidence for carbon leakage stemming from the EU ETS thus far, extremely high EUA prices could increase the risk of carbon leakage. This could further enhance existing EU manufacturing issues caused by high electricity prices and global production overcapacity, which could lead businesses to relocate their operations to regions with less stringent climate policies or they might shut down entirely. Such outcomes would not only severely harm the European economy but also fail to reduce global GHG emissions if emissions simply shift to less regulated areas. Secondly, once the TNAC enters into a deficit, some installations will no longer be able to comply with the EU ETS. Without ambitious decarbonisation strategies or policy interventions these installations would face substantial non-compliance penalties. In turn, this could force businesses that cannot fully decarbonise to relocate their operations or completely shut down – two undesirable outcomes that undermine the economic resilience and climate goals of the EU.

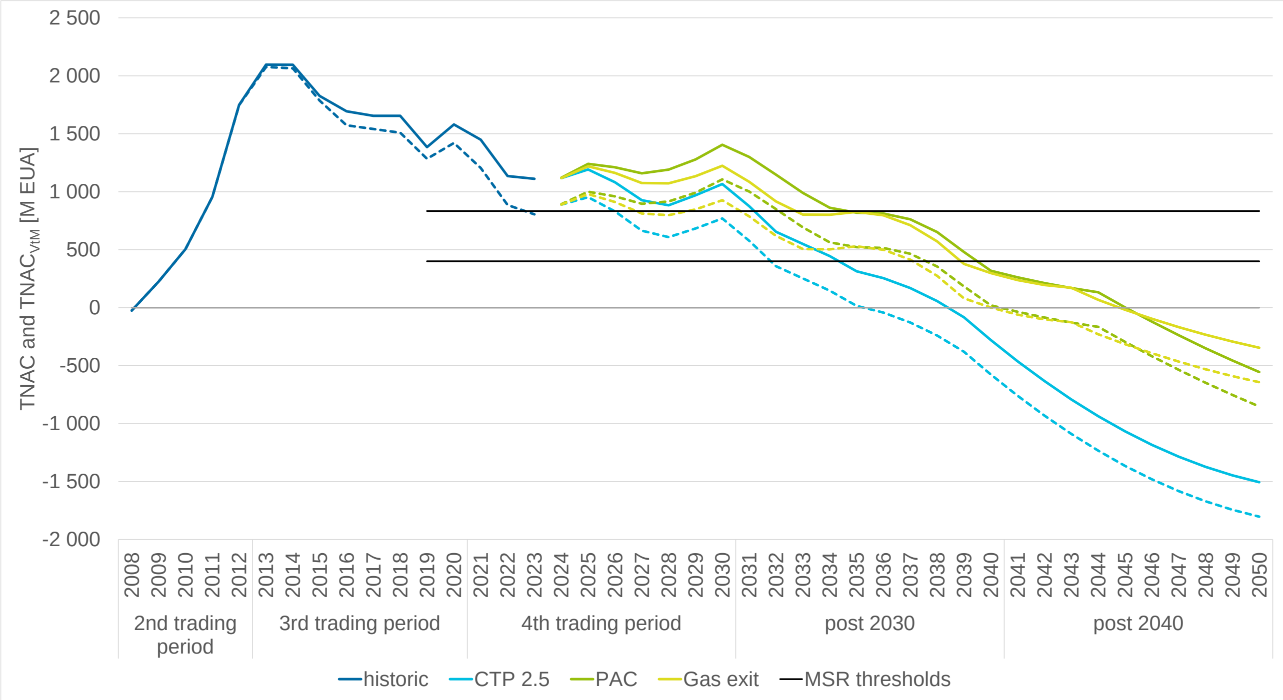
Figure 3-1: Development of the ETS 1 under the COM CTP2.5 scenario



Source: Oeko-Institut

Even though CTP2.5 is the least ambitious of the three scenarios in this study, the overall pattern remains the same across all scenarios. Figure 3-2, Figure 3-4 and Table 2 show the development of the TNACs for all three scenarios in the ETS 1 and the ETS 2. In every scenario of the ETS 1 EUA demand exceeds supply at some point before 2050. In the CTP2.5 scenarios, the TNAC visible to the market deficit is first reached in 2036. The Gas Exit Pathway and PAC scenario reach a deficit five years later in 2041. While the TNAC deficit in CTP2.5 is substantially larger than in the other two scenarios, the key message remains the same: even in the most ambitious scenario, the EUA demand does not decline in line with the fast-shrinking supply. This imbalance only becomes a visible constraint after 2035, leading to a shortage of EUAs, which intensifies in the years before 2050 and which would drive up EUA prices to very high levels.

Figure 3-2: ETS 1: TNAC and $TNAC_{VtM}$ development in the ETS 1 up to 2050



Note: The dashed lines show the TNAC visible to the market, approx. 300 M EUAs lower than the TNAC value after 2030.
Source: Oeko-Institut

Table 2 TNAC visible to the market in the ETS 1 and ETS 2 base case

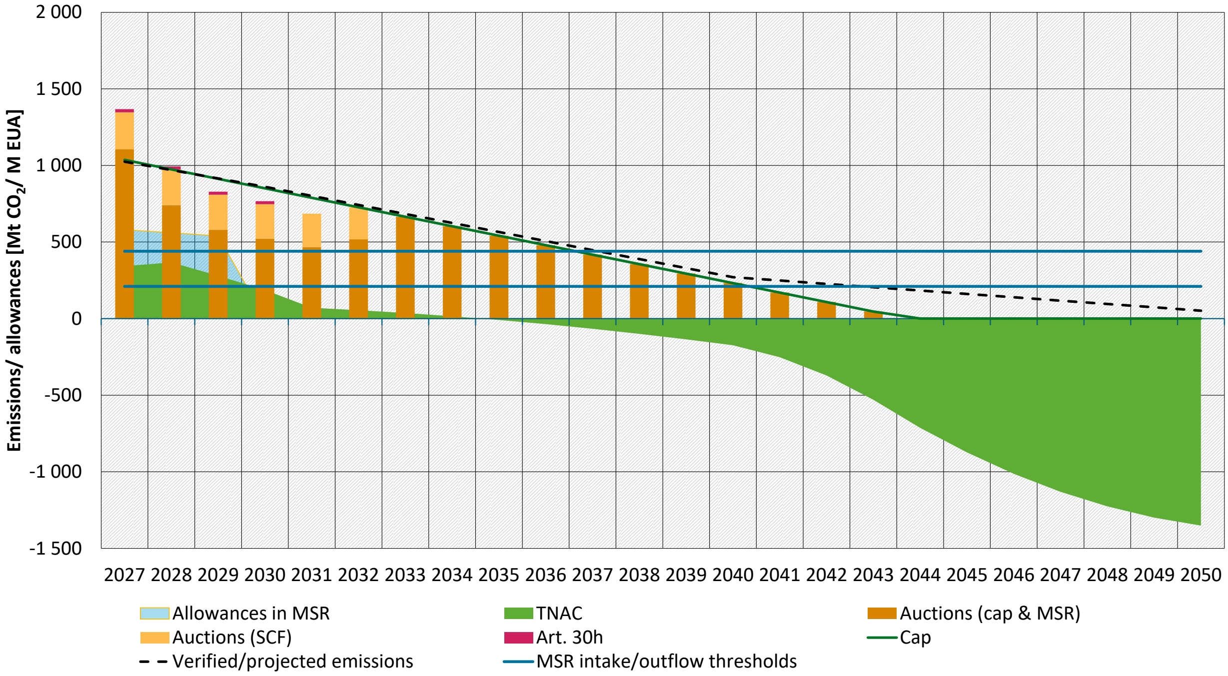
		First year with TNAC deficit	$TNAC_{VtM}$ by 2040 [M EUA]	$TNAC_{VtM}$ by 2050 [M EUA]
COM CTP2.5	**ETS 1**	2036	- 577	- 1 803
	ETS 2	2031	- 254	- 1 431
Gas Exit Pathway	**ETS 1**	2041	1	- 643
	ETS 2	2045	194	- 248
PAC 2.0	**ETS 1**	2041	21	- 852
	ETS 2	[N/A]	1 505	323

Notes: The term *TNAC visible to the market ($TNAC_{VtM}$)* includes demand for ETS allowances which are not covered by the official TNAC definition of the ETS 1 (see Box 1).

Source: Oeko-Institut

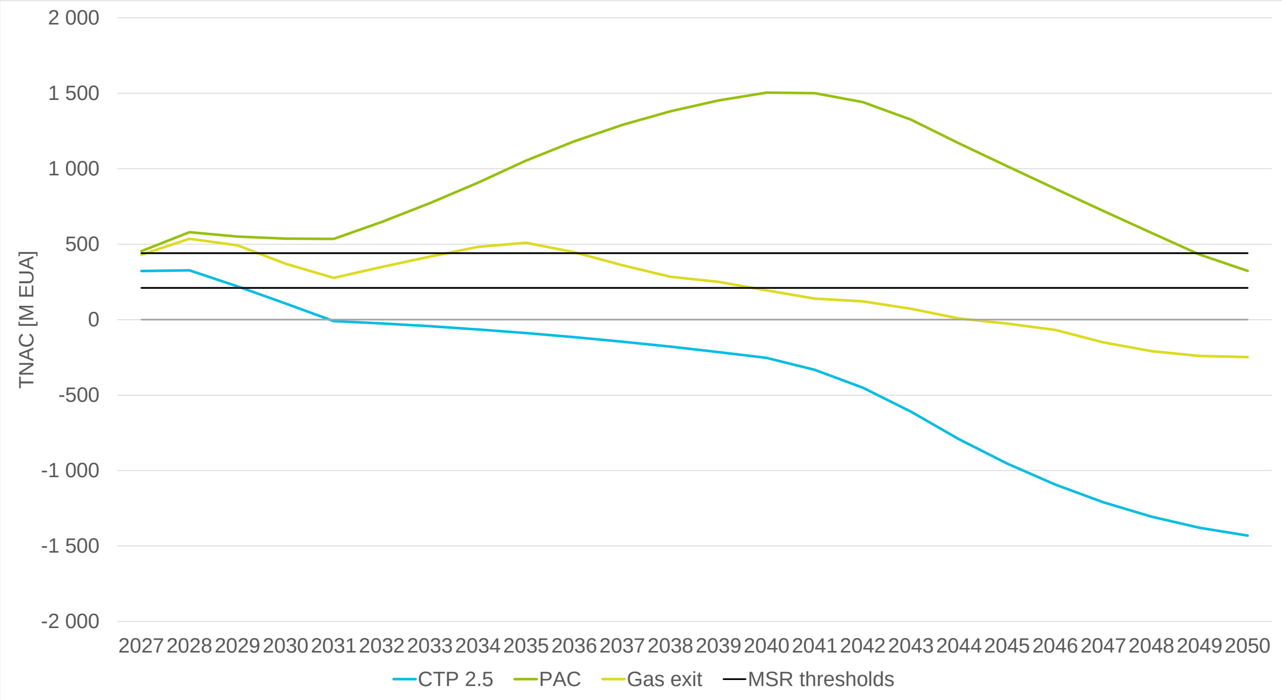
A similar market dynamic appears in the ETS 2 until 2050. In the CTP2.5 and the Gas Exit Pathway scenario, the TNAC also enters a deficit as occurred for the ETS 1. In the CTP2.5 scenario, the projected emissions exceed the cap as early as 2031 (see Figure 3-3). Even though the cap does not reach zero until 2044, demand quickly surpasses supply, which results in a deficit of allowances. The TNAC, which is shown as the green shaded area, becomes negative already by 2031. The MSR, shown in light blue, only provides additional liquidity up to 2030 and becomes non-functional afterwards. As a result, the TNAC deficit grows significantly, reaching more than 1 400 million EUAs by 2050. Entities regulated under the ETS 2 will face similar liquidity shortages as those regulated under the ETS 1. In the absence of price controls or regulatory changes, EUA prices will surge, resulting in very high costs for consumers. The PAC scenario is the only one that does not project a deficit of allowances before 2050. In this case, emission projections in the ETS 2 start significantly lower than the cap, which allows for a large build-up of TNAC in the market. The MSR is not strong enough to avoid this build-up but does accumulate a significant number of allowances over time. Once emissions exceed the cap in 2043, the previously accumulated TNAC is sufficient to meet market demand. Despite projected residual emissions of around 40 Mt CO_2, the MSR does not need to release additional allowances into the market to increase liquidity up to 2050 (see Figure 6-6 in Annex I). The surplus of EUAs can only materialise if the steep projected emission reductions in the early years help build up the TNAC surplus.

Figure 3-3: TNAC development for the ETS 2 – CTP2.5 scenario



Source: Oeko-Institut

Figure 3-4: TNAC development in the ETS 2 up to 2050



Source: Oeko-Institut

It is clear that, across both ETSs, demand for allowances exceeds supply leading up to mid-century. This imbalance leads to surging EUA prices that are unsustainable for both industry and consumers. Such extremely high prices risk triggering an outflux of businesses from Europe, also known as carbon leakage, or even a permanent closure of businesses. It is clear that policymakers must act to address this issue of dried-up markets in the ETS 1 and ETS 2 before prices spiral out of control. This can be accomplished without undermining the environmental integrity and the climate targets of the EU: all scenarios compatible with climate neutrality by 2050 show remaining ETS emissions up to 2050, the current cap development is more ambitious than required. The following section explores a range of different instruments that could ease tension in the market and increase liquidity as the cap approaches zero.

4 Reforming the EU ETS in light of the 2040 target and beyond

As shown in chapter 2.3.4, all EU greenhouse gas neutrality scenarios used in this study show remaining emissions for both ETSs up to 2050. Table 3 provides an overview of these emissions and a set of projections by Strategic Perspectives achieving 85 % to 95 % net reduction by 2040. For the ETS 1 (including aviation and shipping in the current scope), the remaining emissions in 2040 range between 150 Mt CO_2 and 385 Mt CO_2; for the ETS 2, the range is between 80 and 400 Mt CO_2. For the year 2050, excluding the Strategic Perspectives Scenarios which do not achieve climate neutrality, there will still be 50 to 100 Mt CO_2 emissions in the ETS 1 and 7 to 55 Mt CO_2 in the ETS 2. In contrast, the cap in the current configuration reaches (nearly) zero by 2039 in the ETS 1 and 2044 in the ETS 2.

Table 3 Remaining ETS emissions [in Mt CO_2] in 2040 and 2050 in different scenarios

	ETS 1		ETS 2	
	2040	2050	2040	2050
COM CTP S1	385	60	401	55
COM CTP S2	246	59	296	52
COM CTP S2.5	199	58	271	52
COM CTP S3	153	57	245	51
PAC	165	99	79	41
Gas Exit Pathway	182	52	289	7
Strategic Perspectives, 85 % by 2040	330	168	391	189
Strategic Perspectives, 90 % by 2040	272	143	295	135
Strategic Perspectives, 95 % by 2040	243	124	214	89

Note: The scenarios by Strategic Perspectives do not achieve full climate neutrality by 2050, partly due to a lower assumption on removals from the LULUCF sector. Only the CTP scenarios include emissions from shipping in the ETS scope, the Gas Exit Pathways does not include emissions from aviation in the ETS scope. The CTP2.5 scenarios has been used to gap-fill.
Sources: Oeko-Institut with data from EC (2024b), Kalcher and Makaroff 2023, Graf et al. 2023 and Tsekeris and Karjalainen 2024.

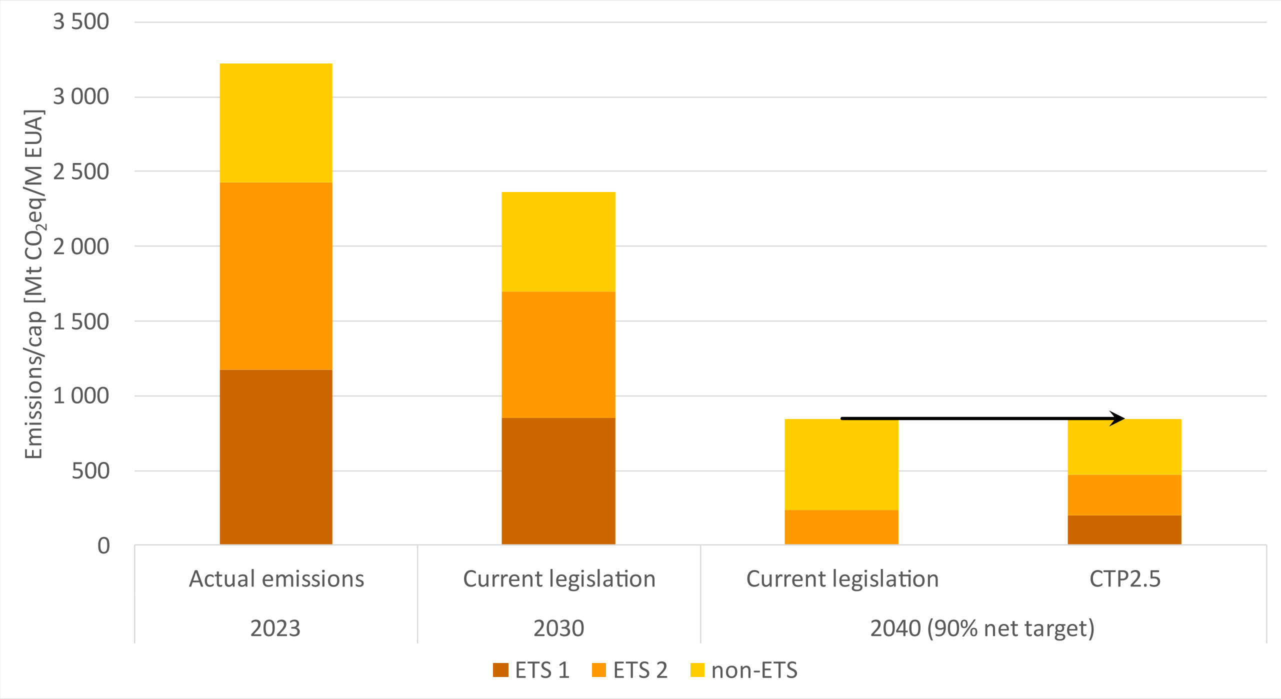
This chapter therefore discusses different options to ensure a functioning of the ETS up to 2040 and beyond. Increasing supply for both ETS does not mean that climate ambition should be reduced – the issue is the correct distribution of the remaining emissions between the different climate regimes ETS 1, ETS 2 and non-ETS (Figure 4-1). Today, the share of ETS 1 emissions is 36 %; this share will remain constant until 2030 based on the current legislative framework. Afterwards, with the cap reaching almost zero in 2039, the ETS 1 share would decline to 1 % of gross emissions in 2040. For the ETS 2, the current share of 39 % declines to 27 % by 2040. The non-ETS share goes the opposite direction: it starts at 25 % today but would reach 72 % by 2040. Out of the non-ETS emissions, agriculture is the largest contribution but still less than half of these emissions (Graichen et al. 2024):

- A quarter of non-ETS emissions are linked to energy consumption, e.g. from heavy machinery but also non-CO_2 emissions from fuel combustion and fugitive emissions from pipelines.
- Waste and industrial processes outside of the ETS both contribute approx. 15 % each.

Energy-related emissions outside the ETS will decline steeply together with the emissions in the ETS 1 and 2: lower gas demand will translate to less leakage, N_2O and CH_4 emissions from fossil combustion will phase out as well. Waste emissions have been declining constantly and are expected to continue to do so in the future as well. As a result, in 2040 non-ETS emissions will be mainly coming from agriculture with small contributions from the other sources. If the ETS legislation is left unchanged, agriculture would be able to increase its emissions whereas sectors covered by the ETS 1 would not be able to have net emissions anymore. Such a distribution is problematic not only due to the challenge for industry in the ETS 1 but also because agricultural emissions need to decline to achieve climate neutrality in 2050. The current LRFs for both ETS were set with the aim of achieving the 2030 target, the intention was not to preclude the distribution of remaining emissions in 2040.

The right two bars in Figure 4-1 illustrate our approach in the case of the CTP2.5 scenario: Gross emissions, i.e. GHG entering the atmosphere without deducting CDR, remain constant. What changes is the allocation of the remaining emissions to the different climate regimes. In the following, we discuss how this can be achieved without lowering the overall ambition of a net 90 % target and without the use of international credits under Article 6 of the Paris Agreement.

Figure 4-1: Gross emissions by climate regime until 2040 under current legislation and the CTP2.5 scenario



Source: Oeko-Institut

4.1 Aligning supply and demand

4.1.1 Lowering demand

Lowering demand, i.e. decreasing emissions beyond the different scenarios, would be the optimal development for the climate and postpone or even avoid the need to increase supply in both ETSs. The experience in the ETS 1 has been that emissions have declined consistently much faster than the cap – both through policy intervention and unforeseen shocks such as the Euro crisis. Especially the much faster than anticipated increase of electricity generation from renewable sources has driven the CO_2 emission reduction in the energy sector. Similar success stories could result in emission developments below the current climate neutrality scenarios. At the same time, especially in the ETS 1, a large share of the low hanging fruits – electricity generation from fossil fuels and especially coal – are being used up. Decreasing emissions in the industry sector and especially from some production processes is more challenging but also possible. In the ETS 2, scenarios largely depend on the assumptions on the penetration rate of electric vehicles and the uptake of heat pumps. If the actual uptake is higher, e.g. because battery prices and connected prices for new electric vehicles keep falling or consumers react more strongly to the carbon prices, it will be possible to achieve lower emission pathways. The EU, and national governments in particular, need to actively support this by providing information, implementing regulations, and establishing support schemes. Undermining confidence in the ETS and climate targets, e.g. by casting doubt on the ETS 2 or the CO_2 emission standards for vehicles, will result in higher emissions, higher CO_2 prices and jeopardise climate neutrality by 2050.

4.1.2 Increasing the scope of the ETS/merging the ETS 1 and ETS 2

Merging the ETS 1 and 2 might increase supply in one or the other ETS at least for a while. Especially in the CTP2.5 scenario, there is a time gap of five years between the moment when the TNAC in the ETS 2 and the ETS 1 become negative. In addition, the cap in the ETS 2 reaches zero five years later than the cap for the stationary sector, i.e. there would be some more supply available for operators in the ETS 1 they would also compete with more actors for the remaining scarce allowances. The overall balance of supply and demand across the two ETS combined would not be changed by a merger.

In theory, a merger should improve market efficiency, as it allows the cheapest mitigation option to be realised first. Different prices in both ETSs are an indication of market inefficiencies – cheaper abatement potential remains in one system whereas more costly measures need to be taken in the other. However, in practice such a merger can be difficult and risky to implement. Merging the two systems would require a fundamental change in how these systems operate or will operate. Policymakers should fully understand the consequences of combining these two before merging them. Experiences with the ETS 1 have shown that it takes time to establish a functioning system. Since the ETS 2 will only start operating in 2027, a merger should not be considered before the system is established and better understood.[5] A softer link between the two systems could also be used initially, e.g. by limiting the amount of EUAs which can be transferred or setting conditions such as a minimum price difference.

Fundamental ETS design questions that would need to be resolved include combining the upstream approach in the ETS 2 with the downstream approach in the ETS 1, developing rules and parameters for both the MSR as well as the price containment mechanisms and setting the joint LRF. Another key challenge is the heterogeneity of entities regulated under each system. While the ETS 1 covers larger power plants and industrial installation, the ETS 2 covers smaller installations and emissions from buildings and road transport. These sectors may have a different willingness to pay for EUAs. Research indicates that the transport and buildings sectors can typically bear higher prices than industry (Graichen et al. 2024). This imbalance may raise EUA prices beyond what many entities in the ETS 1 can afford. This could potentially delay urgently needed climate action if sectors with a higher willingness to pay for their emissions, pay to pollute instead of reducing their emissions. If sectors with a higher decarbonisation potential and a higher willingness to pay for their emissions (e.g. the transport sector) purchase allowances instead of mitigating their emissions, this could shift the responsibility to actually mitigate emissions disproportionally to those sectors that cannot afford high EUA prices increasing the risk of carbon leakage. The risk of carbon leakage is minimal in the ETS 2 due to the nature of regulated entities (e.g. building emissions and road transport demand cannot be outsourced to outside the EEA). This risk is higher in the ETS 1: European produced products can often easily be substituted by imports from third countries with weaker climate policies or cleaner industrial production facilities. If EUA prices rise as a result of the merger the risk of carbon leakage could increase. The ETS 2 includes price containment mechanism to prevent price spikes driven by entities with a higher willingness to pay for their emissions, which means they rather pay for an additional EUA instead of reducing emissions. However, it is unclear how this price containment mechanism would function in a merged system.

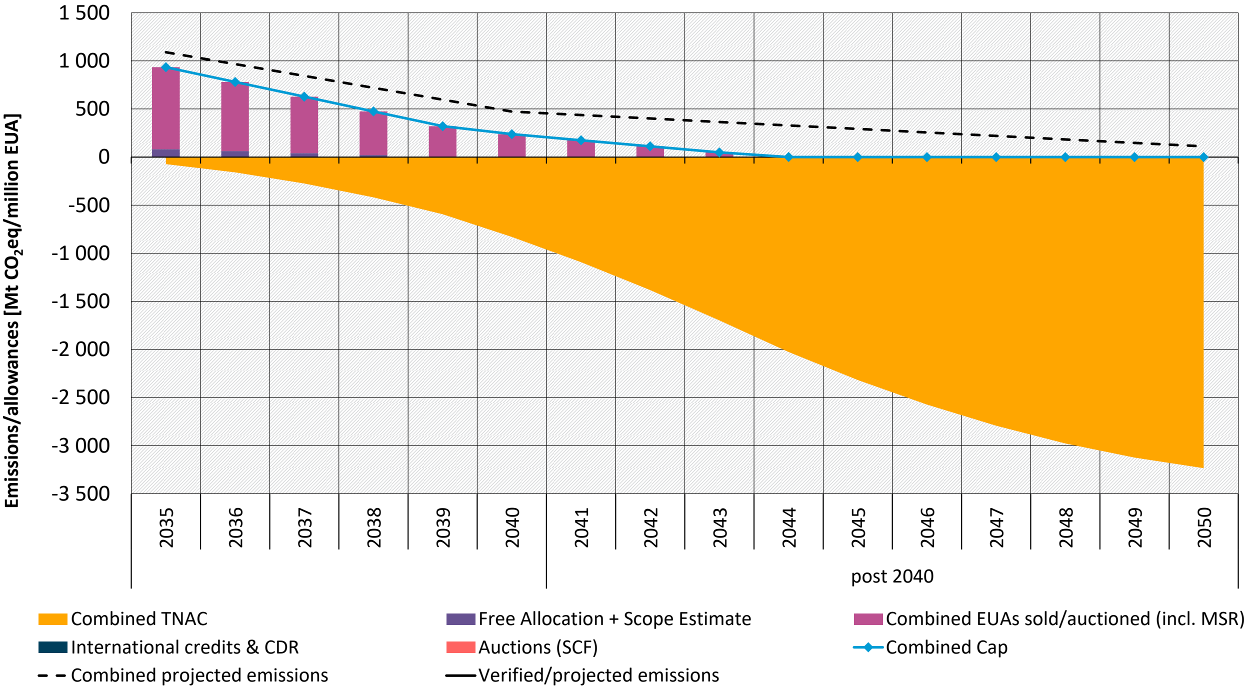
Despite the short-term economic efficiency gains, a merged ETS might jeopardise achieving the climate neutrality target: some sectors might not start their transition soon enough if there is an abundance of cheaper units available initially. Once this supply is used up, these sectors might not

[5] Merging the ETS 2 sectors into the ETS 1 is subject to a review clause due in 2031.

be able to decarbonise quickly enough. Separate ETSs limit this danger somewhat. In a joint system, governments might need to adopt complementary policies and measures to protect against such a development.

We analysed whether and in what ways merging the ETS 1 and ETS 2 could increase liquidity in the market. For this purpose, we combine projected emissions, EUAs auctioned/sold, the cap, and TNAC values for both systems. Figure 4-2 shows the development of the TNAC for a combined ETS under the CTP2.5 scenario (corresponding graphs for the other two scenarios can be found in Annex II). The graph presents estimates from 2035 onwards. Since the ETS 2 only starts operation in 2027, a merger should only take place after the ETS 2 has had sufficient time to stabilise.

Figure 4-2: Combined EU ETS 1 and 2 under the COM CTP2.5 scenario



Source: Oeko-Institut

In this scenario, merging the two systems does not increase liquidity in the ETS 1 to a substantial extent. Due to high projected emissions in the ETS 2 under the CTP2.5 scenario, the TNAC in the combined system enters a deficit only one year later than in the standalone ETS 1. Table 4 compares the TNAC development for a merged ETS across all three scenarios with the TNAC development of the ETS 1 alone. It is important to note that these calculations are based on a static model. They do not account for potential changes in the EUA price or demand that could result from merging the two systems. Therefore, the results present simplified estimates of how a merger could impact supply in the EU ETS endgame, if we assume that both systems are combined without adjusting the cap. Practical implementation challenges also remain unresolves, e.g. how to combine the two MSRs, align upstream and downstream regulation, or distribute auction quantities across Member States.

As Table 4 shows, the extent to which merging both ETS is an appropriate measure to increase liquidity in the markets depends heavily on the underlying emission projections. In the CTP2.5 scenario, merging does not really alleviate pressure on ETS 1 entities, due to high estimated emissions in the ETS 2. However, in scenarios with more ambitious emission reductions, merging can relieve pressure for large installations. In the PAC scenario, which is the most ambitious one, merging delays the onset of a TNAC deficit for the ETS 1 entities by seven years. This is because

ETS 2 emissions remain well below the cap, with the result that a surplus of allowances can build up over time and later increase the liquidity in the system after the merger. In contrast, in the Gas Exit Pathway scenario, the TNAC enters a deficit two years after it would have in the standalone ETS 1, suggesting that a merger would only offer limited benefits in the EU ETS endgame. This makes it difficult to conclude if a merger sufficiently eased tension in the ETS 1 as the cap approaches zero.

Table 4 TNAC* development for a merged system of ETS 1 and 2

	First year with TNAC deficit	TNAC by 2040 [M EUA]	TNAC by 2050 [M EUA]
COM CTP2.5	2035	-816	-3 220
Gas Exit Pathway	2043	94	-876
PAC 2.0	2047	1 489	-857

Note: The TNAC value is the sum of $TNAC_{VtM}$ for the ETS 1 and TNAC for the ETS 2.
Source: Oeko-Institut

The extent to which merging both systems can lead to additional GHG emission reductions is contentious. By merging the two systems, the scope of the EU ETS increases, which in itself does not lead to any emission reductions. Any abatement benefits would depend on whether the increased scope leads to more cost-effective mitigation by prioritising the cheapest mitigation options. However, as described above, the entities regulated under the ETS 1 and 2 differ significantly in their ability and willingness to pay for emissions. This heterogeneity could result in sectors with high decarbonisation potential, like the transport sector, to opt to pay instead of reducing their emissions, because they can afford to do so. If that were the case, merging these two systems could even have adverse impacts and delay urgently needed climate action.

Further, as depicted in Figure 4-2 merging the systems in 2035 does not substantially reduce pressure on entities regulated under the ETS 1. The CTP2.5 scenario projects that emissions in the ETS 2 already exceed the cap within four years of operation. By the time of the merger, the deficit in the ETS 2 is almost large enough to absorb any remaining allowances from EU ETS 1. As a result, entities regulated under the ETS 1 will experience a TNAC deficit one year later than they would have without the merger. Therefore, the merger might not ease the market tension sufficiently. Even in a more ambitious scenario, a merger only delays the TNAC deficit, offering benefits in the short term (e.g. see the PAC scenario).

Given the uncertainties around the effectiveness of the merger and the fact that it would not solve the liquidity shortages, this measure should be combined with other instruments. However, once both systems are fully merged, all future adjustments to the system such as changing the LRF or adjusting the MSR would affect both groups of regulated entities (formerly ETS 1 and ETS 2). This creates a risk that sectors with a high willingness to pay, but also significant decarbonisation potential, could continue to emit and purchase allowances rather than to reduce their emissions. This would weaken incentives for decarbonisation in those sectors and could delay overall climate action. To preserve the environmental integrity of the ETS and maintain flexibility in policy design, it may be more effective to link both systems instead of fully merging them. This could involve setting a cap on the net transfer of allowances between the two systems or allowing cross-system use of allowances if prices surpass a defined threshold. A link between the two systems would also enhance their compatibility with different measures as additional measures could then be targeted more efficiently to the problems of each ETS.

4.1.3 Increasing supply by changing the linear reduction factor

Since 2013, the cap of the ETS 1 is set by a linear reduction factor (LRF) which reduces the supply by a fixed percentage of the average emissions in the second trading period (2008 to 2012). The initial LRF was 1.74 %; for 2020 onwards, it was increased to 2.2 %. In the latest reform of the ETS, the LRF has been increased to 4.3 % from 2024 onwards and to 4.4 % starting in 2028. If unchanged, the 4.4 % level would continue after 2030, leading to a cap of zero in 2039[6]. At the same time, the current LRF was set with a view to 2030: it was part of the Fit for 55 package, which aims to achieve a GHG reduction of 55 % compared to 1990. Based on the modelling, the ETS 1 contribution to this target was set at 61 % below 2005 emission levels, which then translated to the LRF updates. While the underlying modelling did continue to 2050, the impact assessment focused on the period up to 2030 and does not mean that the LRF should continue unchanged after 2030. The same applies to the cap development of the ETS 2.

4.1.3.1 ETS 1

In the following, we assess the impact of two different variants of the LRF post-2035. We propose that the current LRF is kept unchanged until then at the earliest. The last coal-powered electricity plants will likely close down sometime after 2030 and the use of gas will decline rapidly as well. Consequently, all emission projections used in this study are below the cap in 2030, i.e. changing the LRF too soon might lead to a new surplus in the market.

Variant 1: 2.2% from 2035 onwards

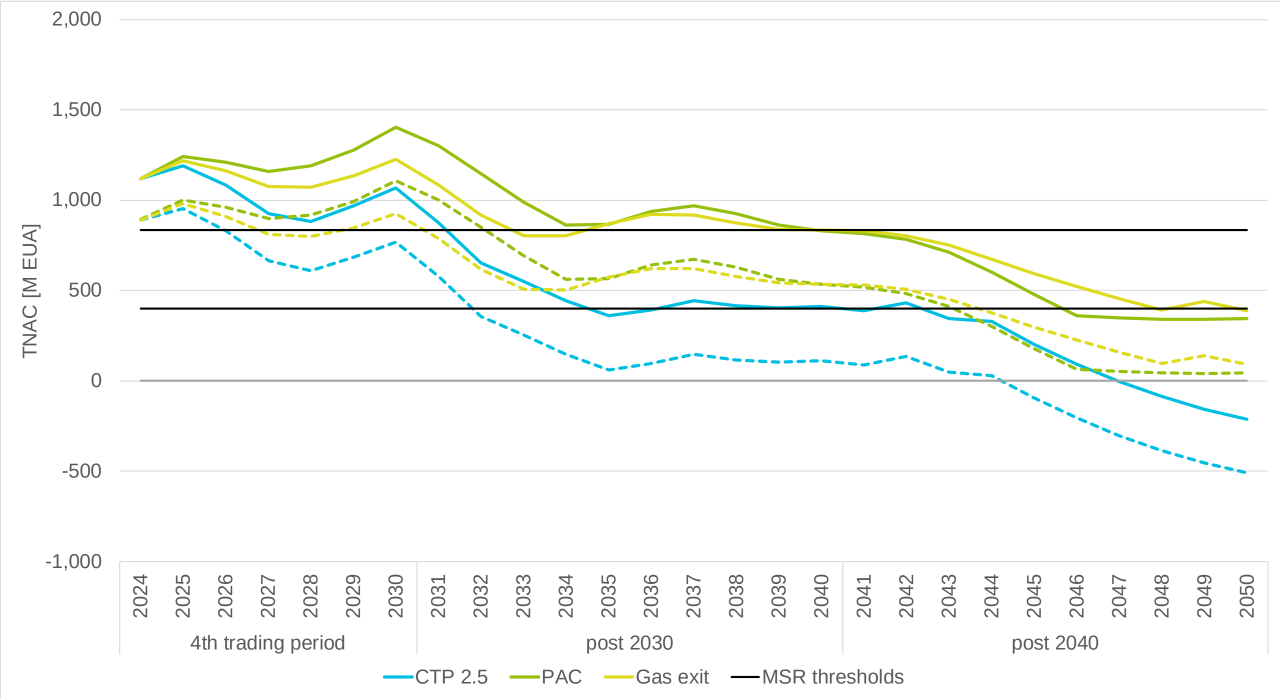
In this variant, we divide the LRF for the stationary, shipping and aviation ETS by two in the year 2035 and keep it unchanged afterwards. This would bring the LRF back to the 2.2 % level which was used in the years 2021 to 2023. The cap would only reach zero by 2044 – five years later than under current legislation (Figure 4-3).

In this variant, the $TNAC_{VtM}$ remains positive up to 2044 in the CTP2.5 scenario, the projection with the highest ETS emissions. TNAC would remain around the lower threshold between 2035 and 2042, the MSR would start issuing its allowances in 2035 for the first time. In the other two scenarios, $TNAC_{VtM}$ remains positive beyond 2050 and the TNAC stays just below the lower MSR threshold, Operators would be able to fulfil their obligations until mid-century. $TNAC_{VtM}$ remains within the MSR thresholds until 2044, i.e. liquidity would be in the optimal range that was set when the MSR was established.[7]

6 The cap of aviation ETS is calculated separately and will only reach zero in 2045. In the current scope, the aviation cap will amount to 6 M EUAs in 2040.

7 See chapter 4.1.5 for a discussion of the threshold values.

Figure 4-3: ETS 1: TNAC and TNAC$_{VtM}$ under an LRF of 2.2% from 2035 onwards



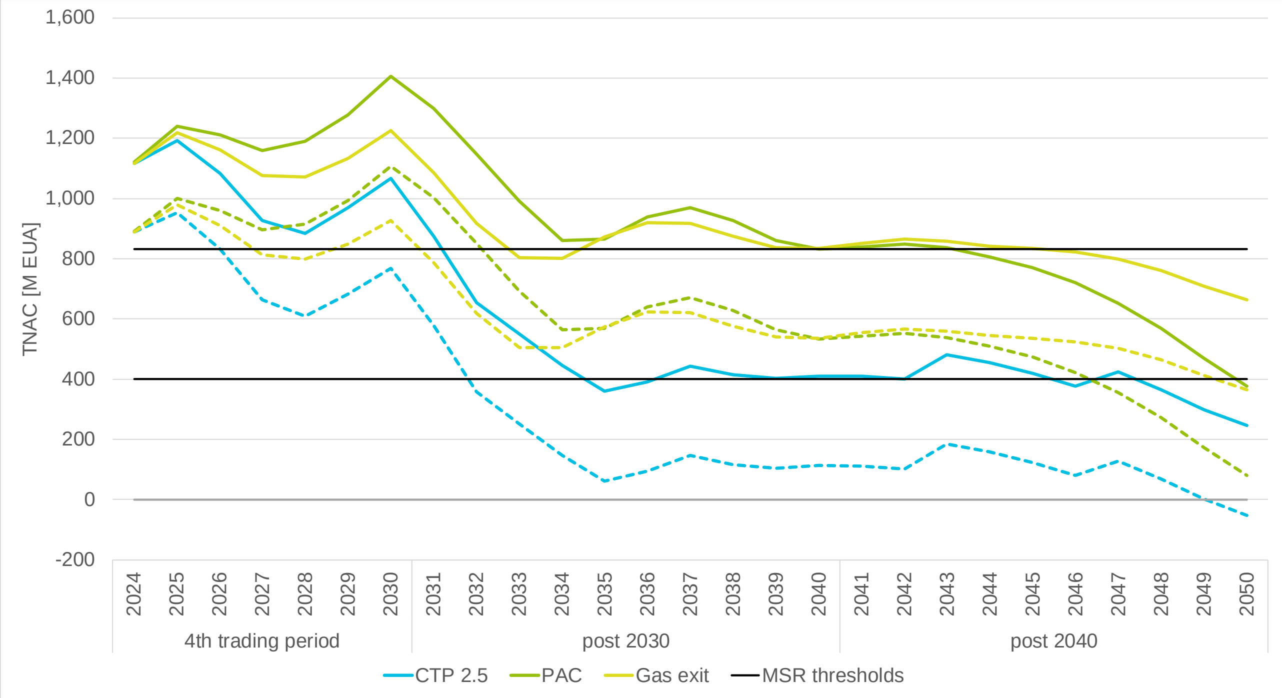
Notes: Dashed lines show TNAC$_{VtM}$, full lines the official TNAC value.
Source: Oeko-Institut

Variant 2: 2.2% from 2035 and 1.1% from 2040 onwards

In this variant, we divide the LRF for the stationary, shipping and aviation ETS by two in the year 2035 and again in 2040, i.e. reducing the LRF to 1.1% for the last ten years. The cap would only reach zero by 2048, nine years later than under current legislation.

In this variant, the TNAC$_{VtM}$ would remain positive until 2049 in the CTP2.5 scenario and beyond 2050 in the other two (Figure 4-4). TNAC and TNAC$_{VtM}$ would remain around the range defined by the two thresholds until mid-century in the PAC and Gas Exit Pathway scenarios, operators would be able to fulfil their obligations until mid-century.

Figure 4-4: ETS 1: TNAC and $TNAC_{VtM}$ under an LRF of 2.2% from 2035 and 1.1% from 2040 onwards



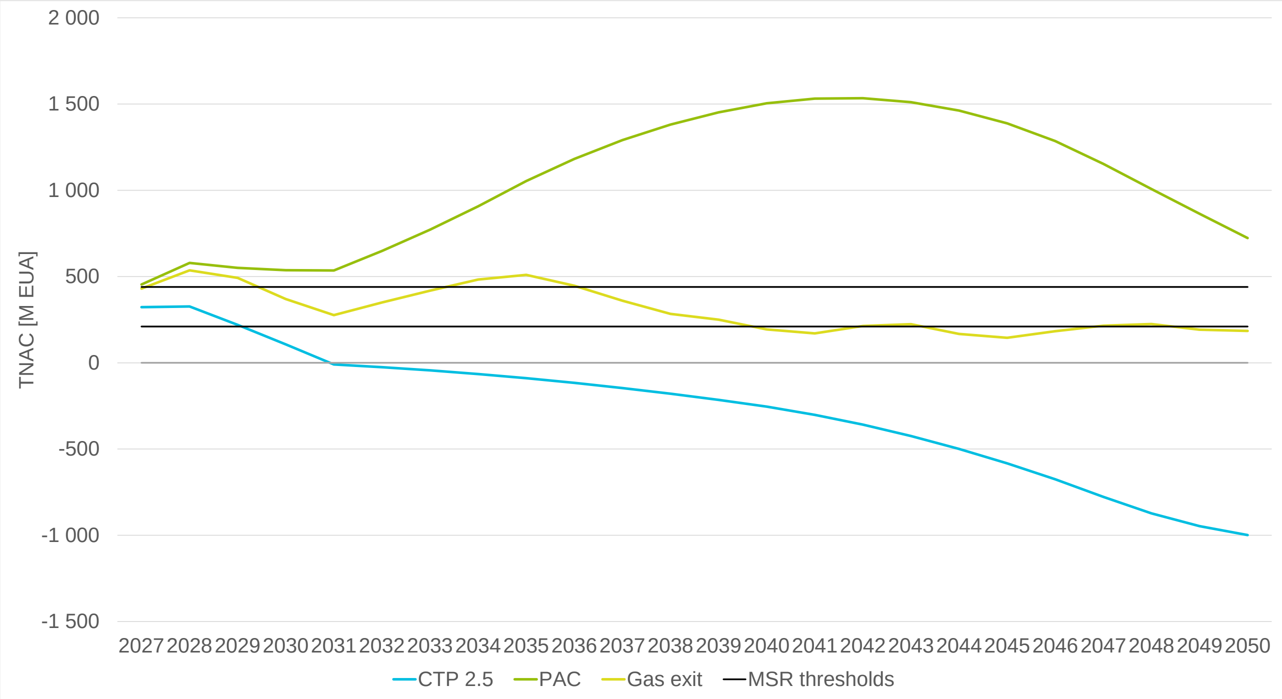
Notes: Dashed lines show $TNAC_{VtM}$, full lines the official TNAC value.
Source: Oeko-Institut

4.1.3.2 ETS 2

Following the approach for the ETS 1, we halve the LRF of the ETS 2 in this variant but only in 2040. The resulting TNAC development is shown in Figure 4-5. The large disparity in the emission development between the three scenarios is reflected in the result. In the Gas Exit Pathway scenario, the TNAC would remain within or around the thresholds until 2050; in the PAC scenario, the surplus peaks in 2042 instead of 2040; afterwards the MSR would withhold sufficient allowances to lower the TNAC gradually. In the CTP2.5 scenario, the negative TNAC would remain, but the deficit would be somewhat smaller (approx. 400 M fewer EUAs).

From these graphs and the large uncertainty about the emission development in the ETS 2 sectors, it becomes clear that a change of the LRF will not be sufficient or potentially even helpful to achieve a balanced ETS. While this variant would remedy the shortage in the Gas Exit Pathway scenario, it would exacerbate the surplus problem in the PAC scenario while not sufficiently addressing the large deficit in the CTP2.5 scenario.

Figure 4-5: ETS 2: TNAC under an LRF of 2.65% from 2040 onwards



Source: Oeko-Institut

4.1.4 Increasing the supply by means of CDRs

Carbon dioxide removals will play a crucial role in achieving greenhouse gas neutrality goals. However, the discussion about integrating CDRs in the ETS must be approached with caution to avoid CDRs undermining the effectiveness and core principle of the ETS, which is the reduction of emissions connected to a strong carbon price signal. In addition, as discussed in chapter 1.2, mixing GHG emissions and technical sinks in a single instrument is challenging as it is always based on the general compromise to assume an equivalence between emissions that enter the atmosphere and those that are stored. This section only addresses the ETS 1 due to the large uncertainties about demand in the ETS 2. Despite this, many considerations would apply similarly to an integration of CDR in the ETS 2.

To assess whether and how CDRs can also play a role in the EU ETS to provide additional liquidity in the ETS endgame, we need to address two questions. Firstly, what types of CDRs, if any, should be considered to ensure that the environmental integrity of the EU ETS remains intact? Secondly, how can these CDR credits enter the EU allowance market in a way that effectively eases pressure as the cap approaches zero without frustrating its focus on mitigation action?

We distinguish between two types of CDRs: natural and technological. Natural CDRs include removals from natural sinks such as forests or wetlands. Technological CDRs refer to the use of technologies such as DACCS and BECCS to remove and store carbon from the atmosphere. In order for CDRs to be considered as an instrument for increasing the liquidity in the EUA market, CDRs from the atmosphere need to be permanent. There are several issues, including concerns about additionality, double counting, and appropriate baselines, that raise severe doubts about the quality and environmental integrity of natural CDRs (see section 1.2). It is highly contentious whether natural sinks can provide the needed certainty that one tonne of CO_2 is permanently removed from the atmosphere. Given these uncertainties, we only consider technological CDRs as a credible instrument for increasing liquidity in the EU ETS endgame.

Box 2 Comparison of biochar and BECCS

Pyrolysis processes can be used to convert biomass into biochar. Pyrolysis of biomass takes place in the absence of oxygen and produces carbonisation gases, liquid fractions such as tar and carbon-rich solids such as biochar. Biochar can be very stable against decomposition (e.g. in soil) and is considered a permanent carbon sink by many (Abhishek et al. 2022), although there is no scientific consensus about this (Budai et al. 2023). However, only 50 % of the biomass-carbon is converted into biochar; the remaining 50 % is emitted as CO_2. Reducing these emissions would require an additional CCS process. About 30 % of the energy content of biomass can be used for electricity and heat if used for energy purposes. For biochar to be used as a carbon sink, its energetic potential must remain unused. Biochar can generate other benefits, e.g. as a soil enhancer, additive in building materials and feed additive. CDR costs from biochar range between 150 and 550 EUR/t CO_2 (Pinzuti 2023). However, additional costs for the remaining CO_2 emissions are not yet included.

BECCS refers to the energetic use of biomass with capture and permanent storage of CO_2 emissions from combustion. Only about 15 % of the CO_2 emissions from combustion are released into the atmosphere. The CCS process requires energy equivalent to about 25 % of the bioenergy produced. The net energy use from a BECCS pathway is therefore about 75 %. The CO_2 storage costs for BECCS currently range from 55 to 225 EUR/t CO_2 (Thrän et al. 2024).

BECCS shows a significantly higher efficiency for permanent carbon storage compared to biochar at lower prices. To improve the efficiency of biochar additional CCS processes would be needed. This would mean that biochar plants – just like BECCS plants – would have to be connected to a CCS infrastructure which would negate the advantage of decentralised biochar production. Solid biomass, which is preferably used in biochar pyrolysis, can be easily transported to BECCS plants. In addition, BECCS can achieve higher utilisation rate of biomass and thus also higher substitution effects, e.g. by avoiding fossil fuels. Finally, the permanence of biochar is still not proven and might be much lower than hoped for. Overall, biomass should therefore be used in BECCS pathways wherever possible, ideally as the final step in a cascade of biomass use. Thus, BECCS could potentially play a role in the ETS whereas biochar should not.

While technological CDRs like BECCS and DACCS can remove and store carbon for over a millennium, they are not the silver bullet. Both technologies are currently still under development and are not yet readily available at scale for reasonable costs. All technological CDRs require substantial inputs of electricity and resources for transport and storage to remove and store carbon which further increases their operational costs. In addition, biomass used as input for BECCS is a limited resource, which is demanded by many sectors and has to fulfil high sustainable standards. Cost estimates for DACCS in 2050 range from 100 to 300 USD per t CO_2 removed, cost estimates for BECCS fall into a similar range of 100 to 200 USD per t CO_2 removed (Edenhofer et al. 2023). Estimating the costs of technologies in 25 years is challenging and involves substantial uncertainties. Currently, the costs for DACCS still exceed 1 000 USD per tonne (Höglund 2024). In addition to these high costs, the climate protection potential of these technologies is limited. Table 5 shows a range of different estimates for the annual removal potential of BECCS and DACCS technologies in the EU27 by mid-century. The estimates vary widely for both technologies that are driven by high uncertainties, mostly connected to the underlying assumptions on price developments and whether the availability of sustainable biomass and other underlying assumptions as, for example, the availability of infrastructure and storage capacities has been rigorously assessed.

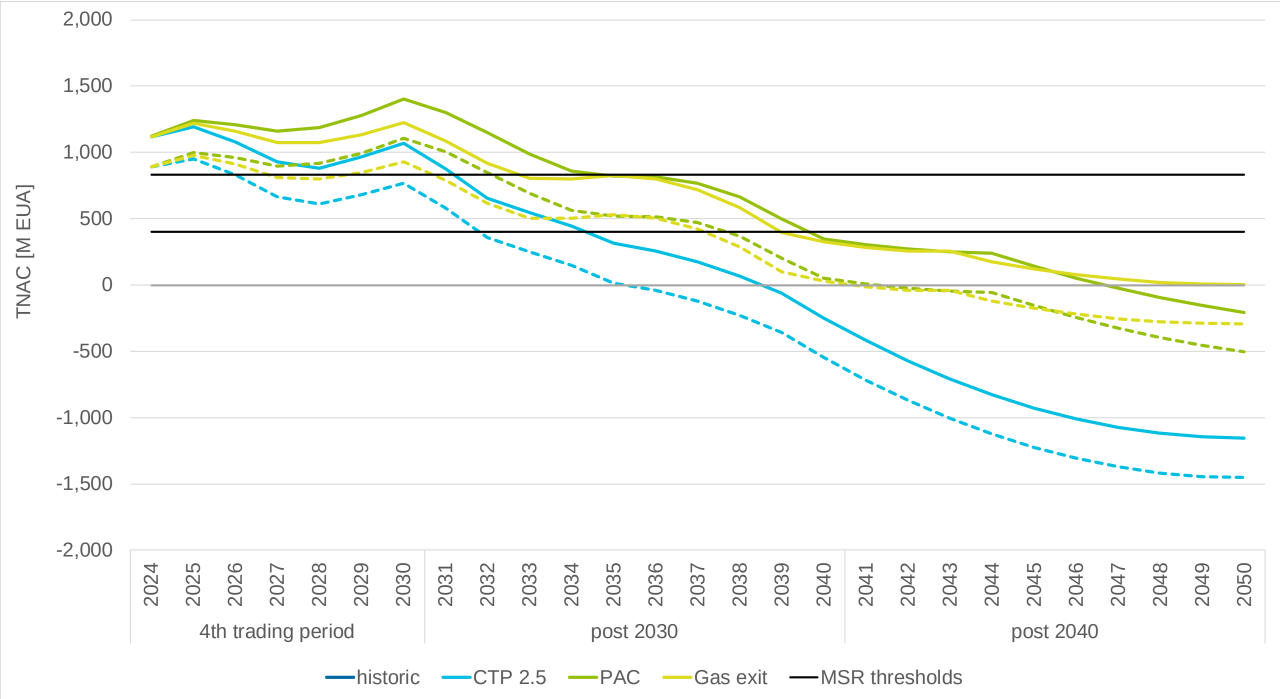
Table 5: Removal potential BECCS and DACCS for the EU27 by 2050

Study	BECCS [Mt CO_2 per year]	DACCS [Mt CO_2 per year]
European Scientific Advisory Board on Climate Change (2023)	147-248	0-22
EC (2024b)	39-61	0-59
Sultani et al. (2024)	40-70	0-50
Abegg et al. (2024)	N/A	9-353

Source: ESABCC (2025), EC (2024b), Sultani et al. (2024), Abegg et al. (2024)

As shown in Section 3, all emission scenarios already project a deficit of TNAC before 2050. It is questionable whether these technologies will be readily available at scale in time to address the liquidity shortage in the EUA market leading up to 2040, when it is most critical. If the impact of technological CDRs can only materialise significantly after 2040, policymakers will need to complement it with additional liquidity measures to avoid EUA prices spikes and non-compliance of regulated entities. To put the abatement potential of BECCS and DACCS into context, we compare the estimated annual removals to the average annual emissions projected in the three scenarios between 2040 and 2050. In the CTP2.5 scenario, average annual emissions for this ten year period reach 292 Mt CO_2, with 131 Mt CO_2 stemming from the ETS 1 and 161 Mt CO_2 from the ETS 2. The Gas Exit Pathway scenario projects 251 Mt CO_2, while the PAC scenario projects only 208 Mt CO_2 across both ETSs. To fully offset these emissions, BECCS and DACCS would need to deliver removals at the upper end of their estimated potential. While Table 5 suggests that this is theoretically possible, there is a substantial risk that these technologies will not reach full commercial maturity in time to meet this demand. Further, other emission sources might rely on technological CDRs to compensate for their emissions, which means that the available amount of technical CDR will not be exclusively free for use in the ETS. But, even if these technologies do not reach their full removal potential, technological CDRs can still play a role in alleviating tension in the EU ETS allowances market. Figure 4-6 shows how small the effect of CDRs in the ETS 1 are if the technical potential of the technologies is at the lower end of estimates and not used exclusively for abatement within the ETS. For this calculation, we assume that technical CDRs enter the market in 2036 with 2 Mt abatement potential, increasing by 2 Mt each year until 2040. From 2040 onwards, the abatement potential increases by 4 Mt annually. This is a conservative approach to the availability of technological CDR for use in the ETS. Given the novelty of technologies, it is unclear how much permanent removal capacity will be available until 2050 for commercial prices. For the Low CDR scenario*,* we assume a cumulative amount of 350 Mt technological CDR until 2050. This does not change the year when the $TNAC_{VtM}$ enters a deficit in the CTP2.5 and Gas Exit Pathway scenario. In the PAC scenario, it also has limited impact and only pushes the deficit back by one year. In the case of the Low CDR scenario, they do not provide sufficient liquidity to market. If the available CDR technologies are used in the ETS 1, they cannot simultaneously be used in the ETS 2. Thus, for CDRs to play a crucial role in increasing the liquidity in both systems, the technological potential must be at the higher end of the estimates.

Figure 4-6: ETS 1: TNAC under an increase through CDRs from 2036 onwards (350 Mt cumulative by 2050)

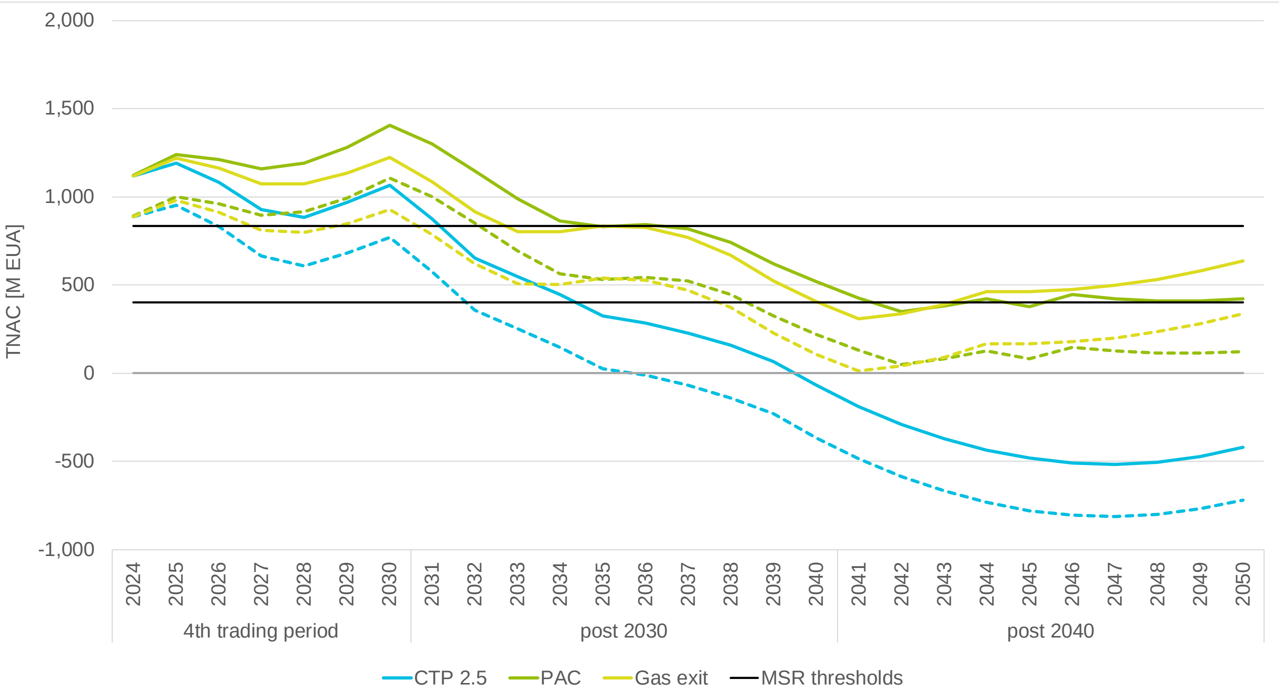


Notes: Dashed lines show $TNAC_{VtM}$, full lines the official TNAC value.
Source: Oeko-Institut

Figure 4-7 shows the TNAC development for all three scenarios in a high CDR scenario. For this scenario, we follow the assumptions on the availability of BECCS and DACCS from the CTP2.5 scenario, which amount to a cumulative 1 085 Mt between 2036 and 2050. If we assume that all this available technological CDR budget is free for use in the ETS 1, we find that there are no liquidity concerns in the PAC and Gas Exit Pathway scenario up to 2050. But even if the large amount of CDRs entered the ETS 1 under the CTP2.5 scenario, the $TNAC_{VtM}$ enters a deficit in 2036. It is contentious whether this amount of technological CDRs will be available by 2040 and 2050 to alleviate the liquidity concerns in the ETS. Further, it is likely that not all the available CDRs can be used to compensate for emissions in the ETS 1. Thus, it remains unclear whether a high CDR scenario is achievable.

There are two main ways in which CDRs could be used to increase liquidity in the EUA market. Firstly, CDR credits could be directly allowed in the EU ETS, effectively increasing its cap. Secondly, a standalone system could allow regulated entities to account for removals separately. We do not analyse how CDRs could enter the EU ETS market as this topic lies outside the scope of this report. However, it is an important consideration for safeguarding the integrity of the EU ETS. The first approach treats one tonne of removed CO_2 as a perfect substitute to one tonne of reduced CO_2. While technological CDRs can offer long storage durations, they cannot be considered fully equivalent to actual mitigation. If the EUA and CDR markets were fully integrated, it might shift incentives away from mitigation towards removing carbon, which is not in line with the core objective of the EU ETS and the urgency of which action is needed to limit global warming. The extent of this shift would depend on the relative prices of the EUAs and technological CDRs. Once the removal of one tonne of CO_2 becomes cheaper than the mitigation of one tonne of CO_2, entities will stop abating their emissions and instead rely solely on CDRs, fully exhausting the technical potential of BEECS and DACCS and potentially ignoring sustainability limits to deployment. But already the prospect of allowing CDRs in the ETS could create a moral hazard and encourage entities to scale back their mitigation efforts today in anticipation of relying on CDRs in the future, which could delay urgently needed climate action. Further, it could send a signal to the market that opens the door for increasing the supply in the ETS through carbon credits, which risks paving the way for including low-quality CDRs (e.g. LULUCF credits) in the future. To mitigate this risk, it would be more effective to establish two parallel systems and not allow a direct uncontrolled influx of CDRs into the ETS. This structure would allow the regulators to control the supply of CDRs that can be used to increase liquidity in the EUA market while preserving the system's environmental integrity. Further, two separate frameworks would also make it easier to combine CDRs with other liquidity enhancing instruments. In Chapter 4.4, we explore the combination of different liquidity measures that could ease the tension in the EUA market once the TNAC approaches a deficit.

Figure 4-7: ETS 1: TNAC under an increase through CDRs from 2036 onwards (1 085 Mt cumulative by 2050)



Notes: Dashed lines show $TNAC_{VtM}$, full lines the official TNAC value.
Source: Oeko-Institut

Increasing supply though CDRs effectively functions as an increase of the cap; thus, it does not encourage further emissions reductions. If CDRs become cheaper than the mitigation of emissions it could even disincentivise further emission reductions. However, technological CDRs like BECCS and DACCS have the potential to credibly remove and store carbon from the atmosphere for a long time and thus qualify as a potential instrument to increase liquidity in the EU ETS leading up to 2040. However, the realistic abatement potential remains unclear. Estimates in the literature vary widely and are highly sensitive to the cost assumptions of BECCS and DACCS in the future. Technological CDRs should therefore be seen as one part of a broader strategy to achieve the EU's climate targets rather than the single solution to liquidity shortages in the ETS.

The timing when the full abatement potential of BECCS and DACCS can be reached is uncertain. All three scenarios project a substantial TNAC deficit before 2050. It is contentious whether these technologies will be available at scale in order to meet this demand leading up to 2040. Thus, it remains impossible to project with certainty how much carbon can be permanently removed and stored in the near term. If the deployment of technological CDRs is slower than anticipated, it might not be able to stabilise the EUA markets during its most critical phase.

Given the uncertainties around both the abatement potential and the timing of impact, technological CDRs should not be regarded as a major solution in addressing liquidity shortages in the EU ETS. These uncertainties could transcend into the EUA market and lead to additional volatility in the system. If the anticipated removal potential fails to materialise in time, the stability of the EU ETS could be at risk. While CDRs can help reduce the stress in the EUA market in the lead-up to 2040 to some extent, they should be complemented by other instruments. If CDRs are traded in a standalone system, it could be easily combined with additional measures like MSR or LRF adjustments. A balanced and reliable policy mix is essential to ensure that liquidity is reinstated in the EU ETS endgame.

4.2 Reforming the MSR

4.2.1 ETS 1

The MSR 1 has been quite effective in removing the historic surplus in the ETS 1 and keeping the TNAC value stable despite consistently lower emissions than the cap until now. At the same time, based on the analysis above, it is not able to ensure sufficient supply towards 2040 and beyond when the cap reaches zero (Figure 3-2). In the following, we discuss the impact of alternative threshold values, applying $TNAC_{VtM}$, other rules for invalidation and replenishing the MSR on supply and demand. Other potential changes such as the intake rate or the quantity of allowances released are not further analysed.

4.2.1.1 Updating the thresholds

In the current configuration, the MSR withholds allowances if the TNAC is above 833 M EUAs and issues allowances if the TNAC is below 400 M EUAs. If above the threshold, the MSR withholds 24 % of the TNAC but no more than the difference between TNAC and 833 M EUAs. If the MSR issues allowances, 100 M EUAs are auctioned additionally from the holdings of the MSR. Any allowances above 400 M EUAs in the MSR are invalidated, i.e. the MSR is only able to issue four times if there is a structural undersupply (see below).

The threshold range was set based on the assumed hedging demand, especially in the power sector which does not receive free allocation. With the rapidly declining emissions from electricity generation, the debate has moved to the hedging need from industry. Yet, even with the CBAM mechanism that reduces free allocation to industry, the current thresholds are unlikely to reflect the hedging need in the future: already in 2030, the cap will be lower than the upper MSR. Five years later, even the lower threshold will be higher than the cap. When the MSR was first discussed, ETS 1 emissions still amounted to around 2 000 Mt CO_2eq – ten times higher than the scenarios for 2040.

Due to the difference between TNAC and $TNAC_{VtM}$, the market already sees thresholds with 300 M fewer EUAs (e.g. see Figure 3-2). This would have the same effect as lowering the thresholds by 300 million while keeping the current definition.

Updating the thresholds does not have a significant impact on the supply and demand for allowances in the ETS. It would shift the date in which the MSR becomes (in-)active by a few years but this would only impact the balance in the short term. For this reason, we do not explore options to update the thresholds in this study.

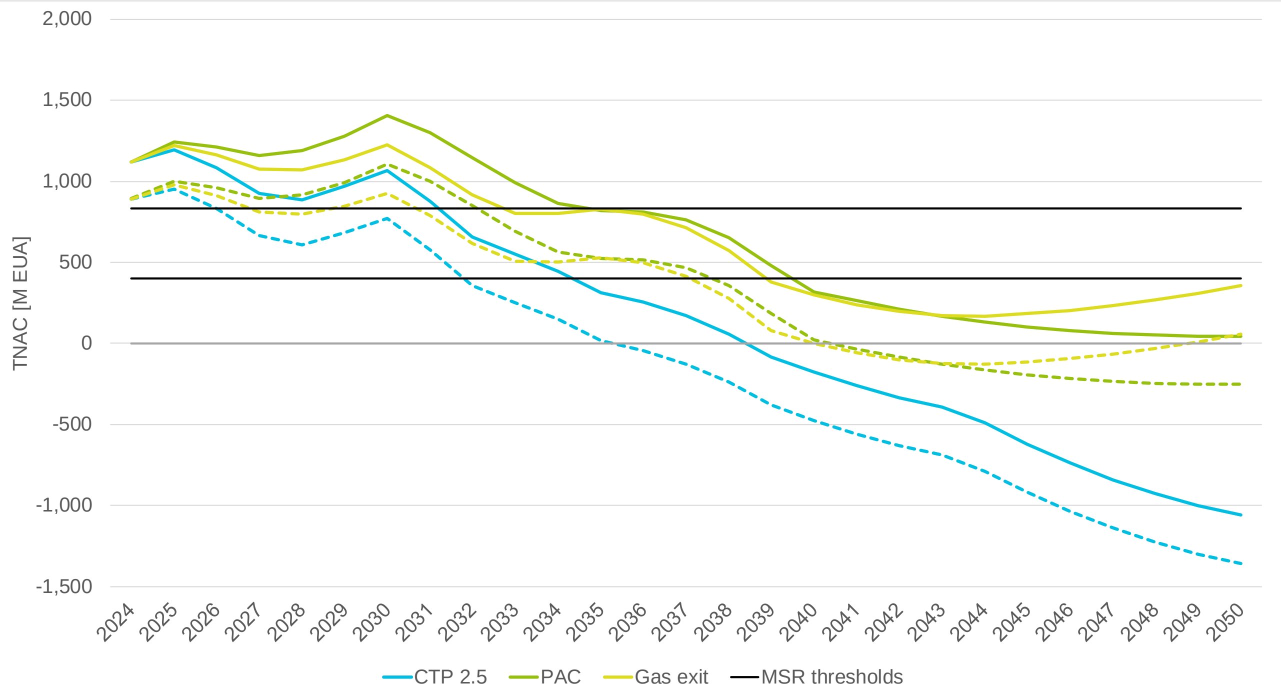
4.2.1.2 Updating the invalidation mechanism

In the current configuration, the MSR can only hold 400 M EUAs by the end of each year. Any excess allowances are invalidated and removed from the ETS. This was necessary to permanently remove the large historic surplus; without this provision, the MSR would only move the excess allowances to the future and would not ensure a tighter market. Because of this provision, the MSR will only be able to issue additional allowances four times once the TNAC falls below the lower threshold.

Looking at the ETS endgame, this provision could be changed to ensure a minimum but limited liquidity after 2040. In addition to the 400 M EUAs in the MSR at the end of 2030, any further allowances withheld after 2031 would remain valid and could therefore be issued later when the liquidity declines steeply (Figure 4-8). This temporal shift of allowances does increase the supply of allowances towards 2050 but remains too weak to ensure a functioning market by itself. In the CTP2.5 scenario, there is very little intake of allowances in the MSR 1, leading to an almost unchanged overall TNAC development compared to the base case.

The advantage of this approach is that there is no need to update the cap development and that it does not increase the planned budget for the ETS as defined by the cap. It would provide market actors with a certain but strictly limited supply of allowances.

Figure 4-8: ETS 1: TNAC development without invalidation after 2030



Notes: Dashed lines show $TNAC_{VtM}$, full lines the official TNAC value.
Source: Oeko-Institut

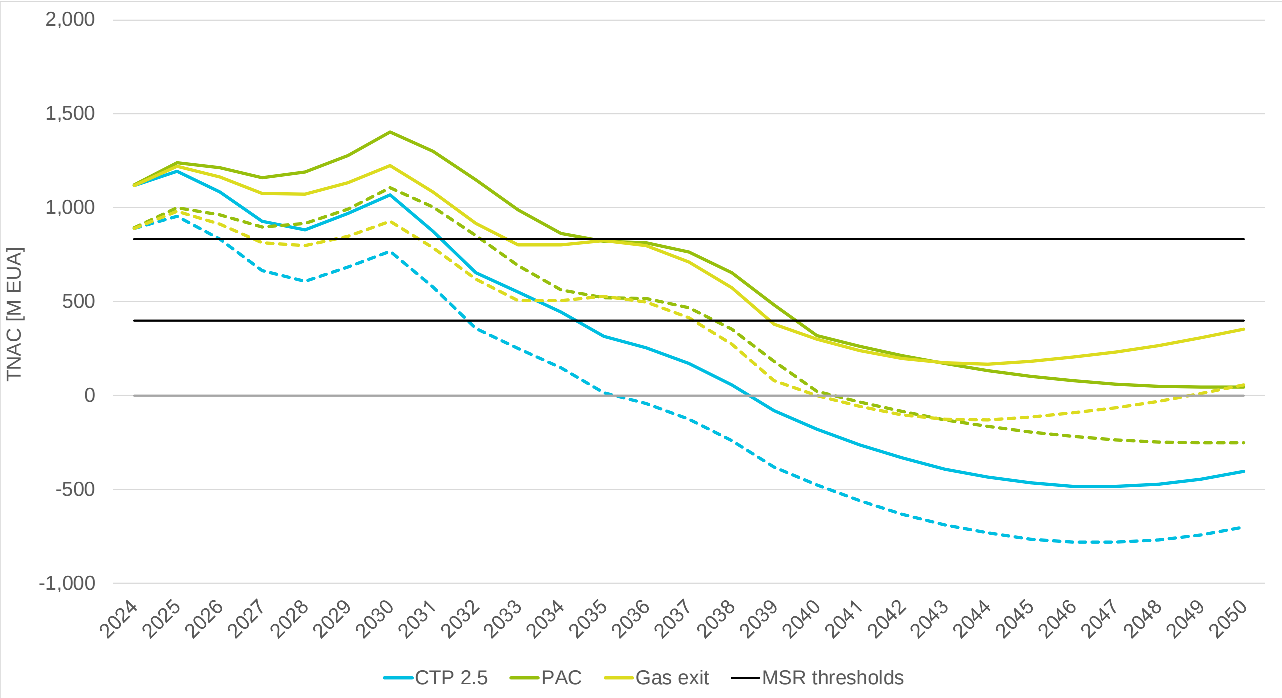
4.2.1.3 Replenishing the MSR

This option builds upon the no invalidation mechanism above but ensures that there is always supply in the MSR. If MSR holdings fall below 200 M EUAs, the MSR is refilled with 100 M EUAs. This provides even greater certainty to all market actors; the MSR is always able to issue allowances if the TNAC falls below the lower threshold. For the Gas Exit and PAC scenario, there is no difference compared to the no invalidation approach. In the CTP2.5 scenario, the MSR is able to issue allowances reducing the TNAC deficit by 655 M EUAs by 2050. Despite this, the TNAC would remain negative up to mid-century.

Similarly to changing the LRF, replenishing the MSR would increase the total emission budget for the ETS 1 sectors compared to current rules. This does not need to negatively impact climate neutrality or the EU's overall ambition: as discussed above, all scenarios show the remaining ETS 1 emissions, i.e. the remaining emission budget needs to be distributed across all sectors.

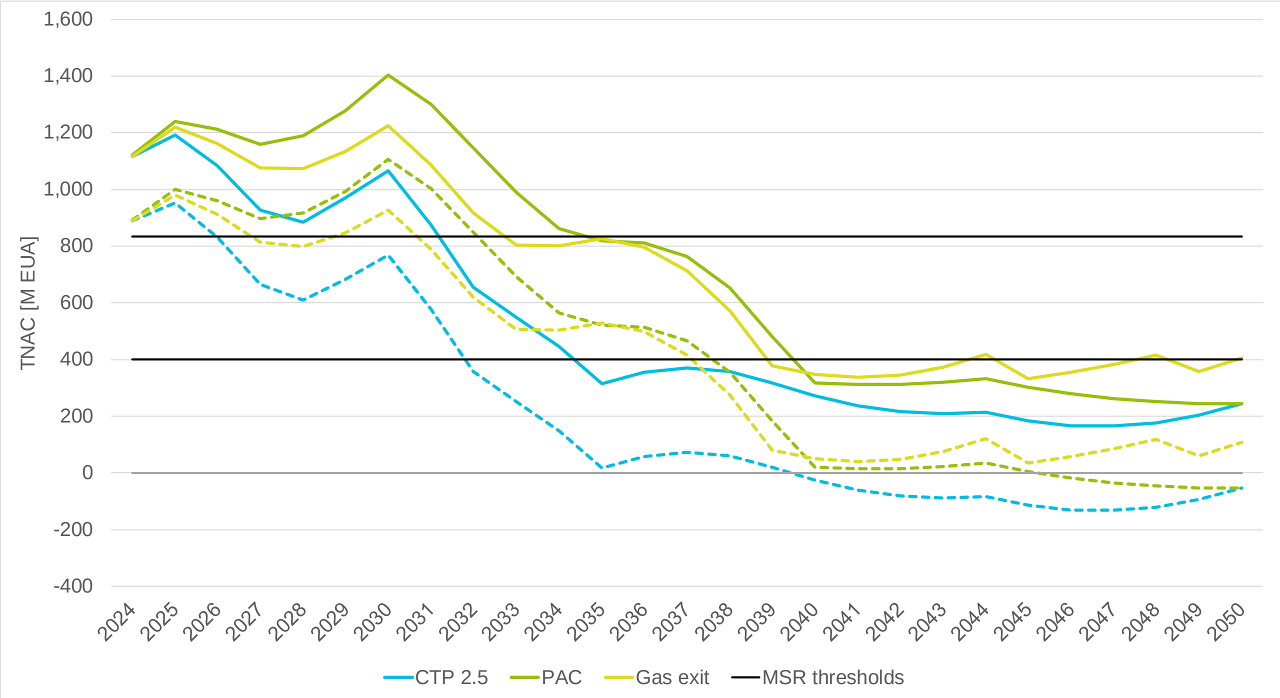
To strengthen this approach, it would be necessary to increase the outflow of the MSR initially. Figure 4-10 shows the situation if the outflow is increased to 200 M EUAs/yr in 2035, to 150 M EUAs in 2040 and back to 100 M EUAs in 2045 (Replenishment+). With these parameters, the TNAC remains within or close to the target value for all years and scenarios until 2040. Subsequently, the TNAC stabilises somewhat below the lower threshold up to 2050.

Figure 4-9: ETS 1: TNAC development with replenishment mechanism



Notes: Dashed lines show $TNAC_{VtM}$, full lines the official TNAC value.
Source: Oeko-Institut

Figure 4-10: ETS 1: TNAC development with replenishment mechanism and increased outflow



Notes: Dashed lines show $TNAC_{VIM}$, full lines the official TNAC value.
Source: Oeko-Institut

4.2.2 ETS 2

The assessment of the current configuration of the MSR 2 (Figure 3-4) has shown that the MSR 2 is not able to react appropriately to the very different emission scenarios. Depending on the emission scenario, the TNAC value can amount to anywhere between -1 400 M EUAs and +1 500 M EUAs. One of the reasons for this large range is the fact that the MSR intake does not depend on the size of a potential surplus but rather a fixed quantity of 100 M EUAs per year. Updating that quantity in a similar way to the MSR 1 – i.e. 24% of the TNAC value and no less than 100 M EUAs – greatly reduces the intake volume and therefore decreases the TNAC. While effective, there is a limit in very low emission scenarios towards 2040: the cap becomes so low by then, that the MSR cannot withhold the full 100 M EUAs anymore. Once this point is reached, there is no way to remove a historic surplus; it would decline slowly in line with the remaining emissions.

However, in higher emission scenarios, the MSR 2 is not able to release any allowances into the market. The initial quantity of 600 M EUAs becomes invalid by the end of 2030 and there would be no new supply to the MSR, the TNAC would never be above the upper threshold of 440 M EUAs. As a result, the MSR would not be able to supply additional allowances to the market. A possible solution to this would be an automatic resupply of the MSR whenever holdings fall below a certain threshold. This is similar to changing the LRF, i.e. it creates a higher supply through legislation. Both approaches – a lower LRF (i.e. a higher cap) or resupplying the MSR – create additional allowances for the ETS increasing the overall emission budget allocated to the covered sectors. Compared to changing the LRF, it has the advantage that this approach directly reacts to the market situation: only in cases of high demand would the MSR be refilled; if emissions decline faster than the cap no new allowances would be created. This approach would not jeopardise achievement of the 2040 and 2050 targets; it is not necessary to achieve zero emissions by 2044 (the year in which the cap reaches zero). The issue is the allocation of the remaining EU-wide gross emissions to different regimes – ETS 1, ETS 2 and non-ETS sectors. As long as the sum of these components is compatible with the 90 % and climate neutrality target, it does not negatively impact environmental integrity.

Figure 4-11 shows the TNAC development for all three scenarios under a reformed MSR. Specifically, we

- updated the intake rate to 24 % but not less than 100 M EUAs;
- resupply the MSR with 100 M EUAs whenever its holdings fall below 200 M EUAs; and
- invalidate any holdings above 400 M EUAs in the MSR 2.

The last point is necessary in the case of the PAC scenario; without this invalidation, the MSR would contain around 3 000 M EUAs by 2050 compared to remaining emissions of only 40 Mt CO_2. We did not modify the outflow quantity (100 M EUAs per year); looking ahead to 2050 and beyond, this value will need revising. The same applies to the mechanism refilling the MSR – the quantity of additional allowances needs to be in line with the remaining emission space for ETS 2 sectors.

With these modifications, the MSR is better able to contain the TNAC within the desired range; however, it remains too slow. The MSR 2 would still not be strong enough to prevent a large surplus in the PAC scenario but would be able to bring the TNAC to the range defined by the thresholds by 2045. In the two other scenarios, the effect of the MSR replenishment mechanism is apparent: Around the year 2040 the TNAC falls below the lower threshold and the MSR starts to issue 100 M EUA/yr. Initially, this is not enough to prevent a negative TNAC value for a few years but liquidity subsequently returns. It might be necessary to strengthen the MSR even more, i.e. by increasing the intake rate in cases of a very high surplus.

Figure 4-11: ETS 2: TNAC development under a reformed MSR

Source: Oeko-Institut

4.3 Inclusion of Art. 6 in the EU ETS

Article 6 of the Paris Agreement aims to foster international cooperation to reduce global GHG emissions through carbon markets. The central idea behind this mechanism is that a global market for mitigation can be the most cost-efficient way to reduce global GHG emissions by realising the cheapest mitigation options first. In theory, this would minimise the costs to achieve the global climate targets. However, Art. 6 in its current form will likely fail to deliver on this promise. Rather than fostering cost-effective mitigation, Art. 6 risks incentivising weak nationally determined contributions (NDCs), exploiting host countries, and undermining real decarbonisation efforts.

The following section specifically refers to Art. 6.2 and 6.4 of the Paris Agreement. Art. 6.2 establishes a framework for unilateral, bilateral, and multilateral trade of Internationally Transferred Mitigation Outcomes (ITMOs) in return for financial support. These trades require corresponding adjustments, which is the tool of Art. 6 that avoids the double counting of emissions or emission reductions. Once authorised carbon credits are transferred from the host country to the buying country or entity, the host country needs to deduct the corresponding amount of emission reductions from their own GHG inventory (Crook 2022). This ensures that only *one* partner claims the emission reductions towards their climate target. Art. 6.4 established a carbon market that is overseen by the UNFCCC that enables the trade of mitigation units between different parties (including companies, countries, individuals) (Crook 2022). This might also involve the trade of unauthorised credits which do not require corresponding adjustments.

Proponents of Art. 6 argue that it is the most cost-efficient way to reduce global GHG emissions while also providing a much-needed source of climate finance to low-income counties suffering from the impacts of the climate crisis. However, critics highlight two main risks that Art. 6 might undermine domestic and global climate action. Firstly, there are concerns about the quality of credits traded under Art. 6. As described in section 2.2, there are various concerns when it comes to the quality of carbon credits in general, the most prominent include concerns about additionality, permanence, double counting, and appropriate baselines. The experience with past and current offset schemes has shown that only a very low share of credits actually fulfils minimum standards, most credits are of dubious quality or have no climate benefit at all. Fraud and the abuse of such systems have been a recurring issue despite rules for verification and certification. This means that it is contentious whether a credit traded via Art. 6 can actually deliver the promised emission reduction. Secondly, while Art. 6 can channel climate finance to emerging economies that sell credits, it may make it significantly harder for those host countries to achieve their NDCs. If a host country sells substantial volumes of ITMOs with corresponding adjustments, it effectively increases the efforts needed to reach its own NDC. This creates a perverse incentive for host countries to set weak NDCs so that they can both achieve their NDC and increase climate finance flows by selling ITMOs. This will not deliver any *additional* global emission reductions. This fundamental flaw in the mechanism severely limits its additional abatement potential and can even delay urgently needed climate action. Past experiences with a similar mechanism, the Clean Development Mechanism (CDM) have shown similar problems. Research even found that some projects authorised under the CDM are linked to severe human rights violations (Schade and Obergassel 2014). For these reasons, Art. 6 credits should be treated with extreme caution. To mitigate the risks mentioned above, an alternative approach to Art. 6 could be to use it primarily as a climate finance tool without allowing parties to claim emission reduction towards their climate targets. This could increase international climate finance flows without undermining domestic climate action.

Allowing the use of Article 6 units in the ETS could be achieved by two different approaches. Similarly to the inclusion of CDM and Joint Implementation (JI) in the ETS until 2020, operators could be allowed to use a limited number of units for compliance. Setting such a limit would require care. The main reason for the huge surplus in the ETS 1 was allowing 1.6 billion credits into the system. Alternatively, governments could be responsible for buying and introducing Art. 6 units, e.g. by auctioning additional EUAs and acquiring corresponding amounts of ITMOs. The second approach has advantages and would be preferable if Art. 6 is included at all:

- Governments would have full control over the type of units and projects that would be allowed. They could react quickly if new information emerges about the quality of specific projects or partners. If operators would use credits directly, updating rules and requirements might necessitate legislative acts and operators might enjoy investment protection.
- Art. 6 allowances will be much cheaper than ETS allowances. This price difference should remain with governments; revenues should be used to finance mitigation action. Allowing operators to directly use the cheaper credits would undermine the price signal and contravene the polluter pays principle mandated by EU law (Article 191(2) TFEU C2008/115/01).
- The historic surplus in the ETS 1 is approx. as large as the quantity of project mechanisms that were allowed into the market. The combination of cheap CDM and JI units with the financial crisis in 2009 led to the huge surplus, low prices and limited effectiveness. If governments control the inflow of credits, they could quickly react to unforeseen circumstances such as a global crisis and limit the inflow.

Complete exclusion of Art. 6 from the ETS remains the best option due to the many inherent and practical shortcomings of international offsetting mechanisms. In addition, its inclusion would put the EU's decarbonisation pathway at risk due to delayed action and governments would lose auctioning revenues. As shown above, additional supply in the ETS can be achieved through other means without undermining the EU's climate ambition. In its latest report, the European Advisory Board on Climate Change strongly opposes the inclusion of Art. 6 in the EU's target for the same reasons (ESABCC 2025): '*Using international carbon credits to meet this target, even partially, could undermine domestic value creation by diverting resources from the necessary transformation of the EU's economy, including investments in infrastructure, skills and innovation. International credits might appear cost-effective from a global perspective, but they entail significant risks to carbon markets and environmental integrity, including concerns about additionality, emissions being displaced to other regions (leakage) as well as robust monitoring, reporting and verification.*'

The abatement potential of including Art. 6 credits in the EU ETS is low and might even lead to adverse impacts for two main reasons. Firstly, as stated above, the abatement potential of credits traded under Art. 6 is highly contentious. The Carbon Credit Quality Initiative (CCQI) reviewed 22 carbon credit methodologies that are widely used today and may be used under Art. 6 and found that only one met the minimum standards for credibly reducing one tonne of CO_2 (Schneider et al. 2023). It is extremely challenging to accurately estimate how much carbon a certain project reduces compared to a baseline. Thus, it is unclear how much real abatement potential Art. 6 has overall. While Art. 6 provides the opportunity to trade high-quality credits, it also opens the door to cheat the system and trade cheap low-quality carbon credits that do not reflect additional emission reductions. This can only be mitigated to a very limited extent with safeguards and restrictions in the rules governing the usage of such credits due to unavoidable uncertainties in establishing baselines, perverse incentives and fraud.

Secondly, experience gathered with the CDM has shown what happens to the ETS when flooded by a myriad of cheap carbon credits. After CDM credits were linked to the ETS 1 prices plummet due to a severe oversupply of allowances in the market. EUA prices dropped below 10 EUR per t CO_2 (Komanoff 2017). At these prices, entities regulated under the ETS 1 had minimal to no incentives to decarbonise their operations. Instead of reducing emissions, entities could just purchase cheap credits and continue to pollute. Many CDM credits also failed to deliver the mitigation they promised. One tonne of CO_2 'reduced' through a CDM project did not correspond to a tonne of domestically mitigated CO_2. In some cases, the mechanism even created perverse incentives to emit more. For example, companies deliberately increased the production of the GHG HCFC-22 to capture and destroy the GHG byproduct HFC-23 and sell CDM credits for it. As a result, the ETS 1 did not function as intended and had to undergo various reforms that included limiting the influx of low quality CDM credits into the system. If Art. 6 credits were allowed into the ETS without sufficient safeguards in place there is a high risk that the mistakes of the CDM will be repeated. Art. 6 credits could cause an extreme surplus of allowances, which would lead to low prices, reduce the incentives for domestic decarbonisation and undermine the environmental integrity of the EU ETS. In conclusion, Art. 6 credits should not be allowed into the EU ETS as oversupply poses a severe risk to the abatement potential of the system. If an increase of supply is required, it could be done directly through the MSR or the LRF (see sections 4.1.3 and 4.2).

The availability of Art. 6 credits up to 2040 cannot be defined with certainty, as it depends on the methodologies that will be approved for the mechanism and the global demand, among other factors. However, the International Emission Trading Association (2023) estimates that already by 2030, Art. 6 credits in the order of USD 100 billion per year could be sold on international carbon markets, suggesting an abundant supply of Art. 6 credits. Without or even with weakly restricting the types of credit that could be used in the EU ETS, this creates a severe threat to the functioning of the ETS – Art. 6 credits could rapidly flood the EUA market. This early influx of credits is likely to have a long-lasting negative effect on the functioning of the EU ETS and the residual emission levels of covered entities. With a substantial surplus of allowances, prices will plummet, similar to the price falls that were observed after CDM credits entered the EU ETS. It will take substantial time to re-establish a functioning ETS with EUA prices high enough to incentivise domestic climate action. Art. 6 has the potential to fundamentally destroy the effectiveness of the EU ETS, which is the core instrument in European climate policy.

Once the EUA market has been opened for Art. 6 credits, other measures might become redundant. There will be no need for additional measures to increase liquidity. However, there might be a need for additional measures to remove the surplus of allowances created by Art. 6 credits. If Art. 6 credits were directly linked to the EU ETS, they could completely negate the climate impact of the system. However, Art. 6 credits could still play a limited role in easing liquidity concerns in the EU ETS if they are not directly allowed in the EU ETS and thus cannot be traded as a substitute for EUAs. For this, strong quality criteria need to be instated that can help to ensure the environmental integrity of the credits. These credits could include technological CDRs that might play a role in the EU ETS endgame as described in section 4.1.4. In this case, the market for Art. 6 credits should exist outside the EU ETS as a standalone system.

Any use of Art. 6 might require changing the European Climate Law. The latter defines the 2030 and 2050 targets as domestic targets, i.e. without the use of international offsets. Domestic mitigation action should remain the priority. International offsets cannot serve as a substitute for domestically abated emissions. Using international credits to meet climate targets weakens national ambition and has the potential to delay urgently needed climate action. At the same time, Art. 6.1 of the Paris Agreement states that the mechanism can only be used to increase ambition. Allowing the use of Art. 6 would therefore require increasing the EU's climate ambition, e.g. by achieving climate neutrality earlier than 2050.

4.4 Combination of CDR inclusion with other reform options in the ETS 1

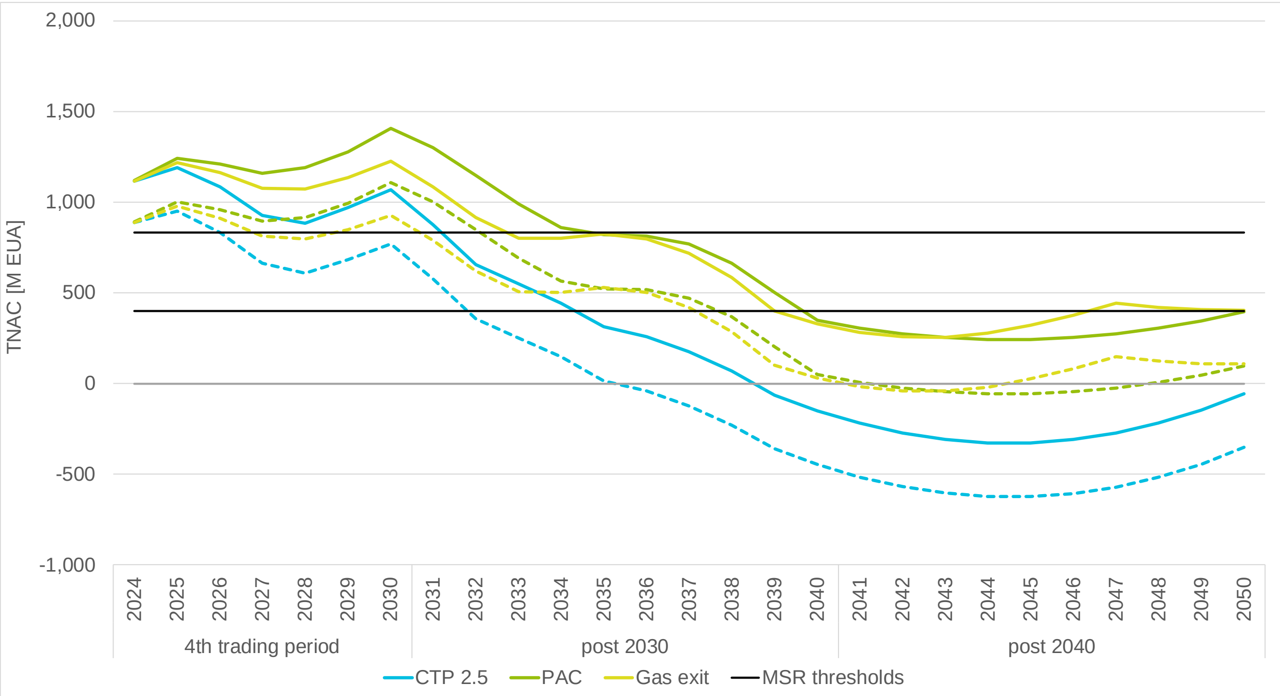
As discussed above, it is uncertain whether a sufficient quantity of high-quality CDRs will be available up to 2050 to align supply and demand ETS 1 by itself. Even if such a quantity would be available, there would still be competing demand from other sectors, e.g. the ETS 2. At the same time, we showed that the lower CDR estimate in this study is insufficient to ensure an adequate supply of allowances for the ETS up to 2050. In the following, we therefore show two possible combinations of reform options that include the Low CDR supply and would achieve a balanced ETS 1.

Due to the large uncertainties about demand, it is not useful to include combined options for the ETS 2 at the moment. In the PAC scenario, CDR would not be necessary at all. However, in the CTP 2.5 scenario, even the high CDR supply would not be sufficient for a balanced ETS.

4.4.1 Low CDRs with MSR replenishment

In this option, we combine the replenishment mechanism (without changing outflow quantities) with extra supply from the Low CDR scenario. As shown in Figure 4-12, the TNAC remains around the lower threshold in the 2040s for the PAC and Gas Exit Pathway scenarios. In the Commission projection, the TNAC becomes negative for almost ten years but recovers towards 2050. A CDR cumulative supply of about 500 M EUAs would be necessary to avoid a negative TNAC in the CTP 2.5 scenario.

Figure 4-12: ETS 1: Low CDRs with MSR replenishment

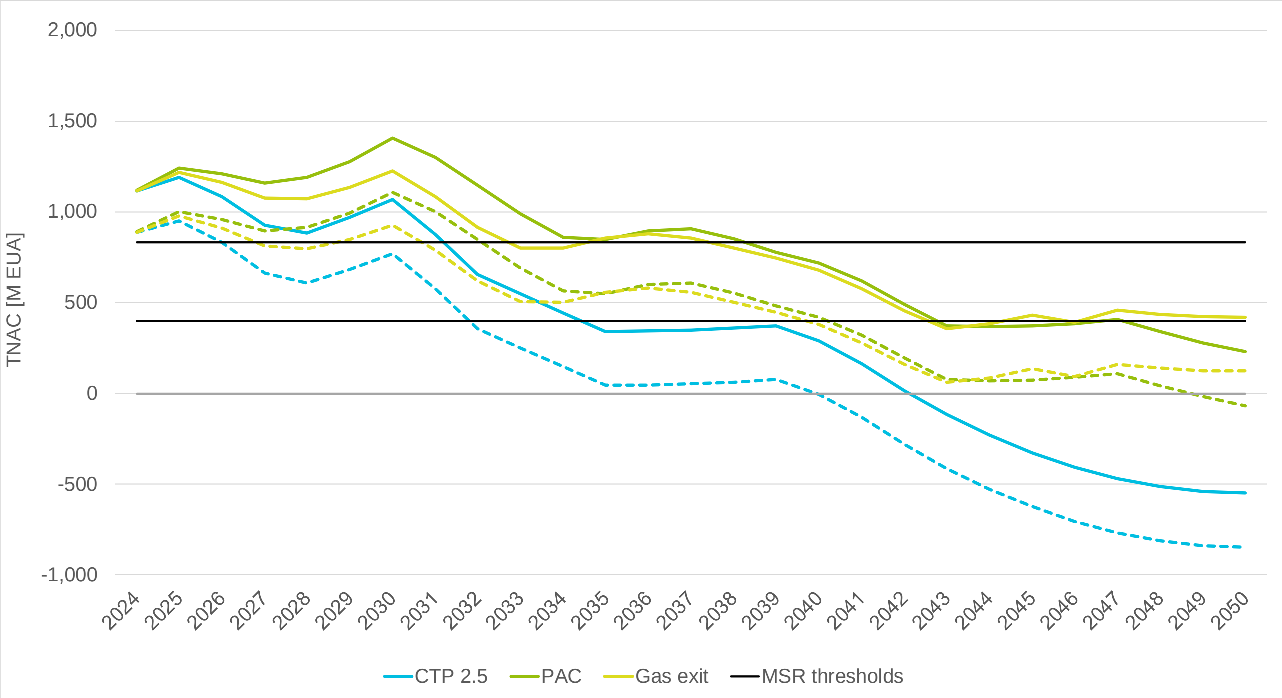


Source: Oeko-Institut

4.4.2 Low CDRs with an LRF of 3.0 % from 2035 onwards

Combining 350 Mt of CDRs with an LRF of 3.0 % from 2035 onwards leads to a very similar result as the combination with the MSR replenishment. In the PAC and Gas Exit Pathway scenarios, the $TNAC_{VtM}$ would remain positive in all years but the TNAC recovery in the CTP 2.5 scenario starts later, and the value remains negative until 2050. Again, a CDR supply of about 500 M EUAs would be required in this combination to avoid negative TNAC in all scenarios.

Figure 4-13: ETS 1: Low CDRs with LRF of 3.0 %



Source: Oeko-Institut

5 Comparison of options achieving a balanced supply and demand in the ETS 1 up to 2050

Of the assessed options and combinations in this study, five are able to balance supply and demand in most climate neutrality scenarios:

1. LRF of 2.2 % from 2035 onwards and 1.1 % from 2040 onwards.
2. MSR replenishment+: The MSR is refilled if it runs empty; outflow is set to 200 M EUAs/yr in 2035, 150 M EUAs in 2040 and back to 100 M EUAs in 2045.
3. CDR high: 1 085 Mt CO_2 removals which can be used in the ETS 1 until 2050.
4. Replenishment with low CDR: The MSR is refilled if it runs empty with unchanged outflow, 350 Mt CO_2 from CDR enter the ETS 1 until 2050.
5. LRF 3.0 % with low CDR: The LRF is reduced to 3.0 % from 2035 onwards, 350 Mt CO_2 from CDR enter the ETS 1 until 2050.

The TNAC in the CTP2.5 scenario drops below the MSR threshold around 2034 in all options but remains close to the lower threshold in options 1 and 2 until 2050 (Figure 5-1). In the CTP 2.5 scenario all combinations relying on CDR supply are not sufficient to prevent a negative TNAC value in the 2040s. In the PAC and Gas Exit Pathway scenario TNAC remains within or close to the MSR thresholds until 2050 in all five possible reform options listed above (Figure 5-2 and Figure 5-3). A TNAC somewhat below the lower threshold is not necessarily a problem: these thresholds were set at a time when total emissions in the ETS were ten times higher than the value projected in 2040 in the three scenarios.

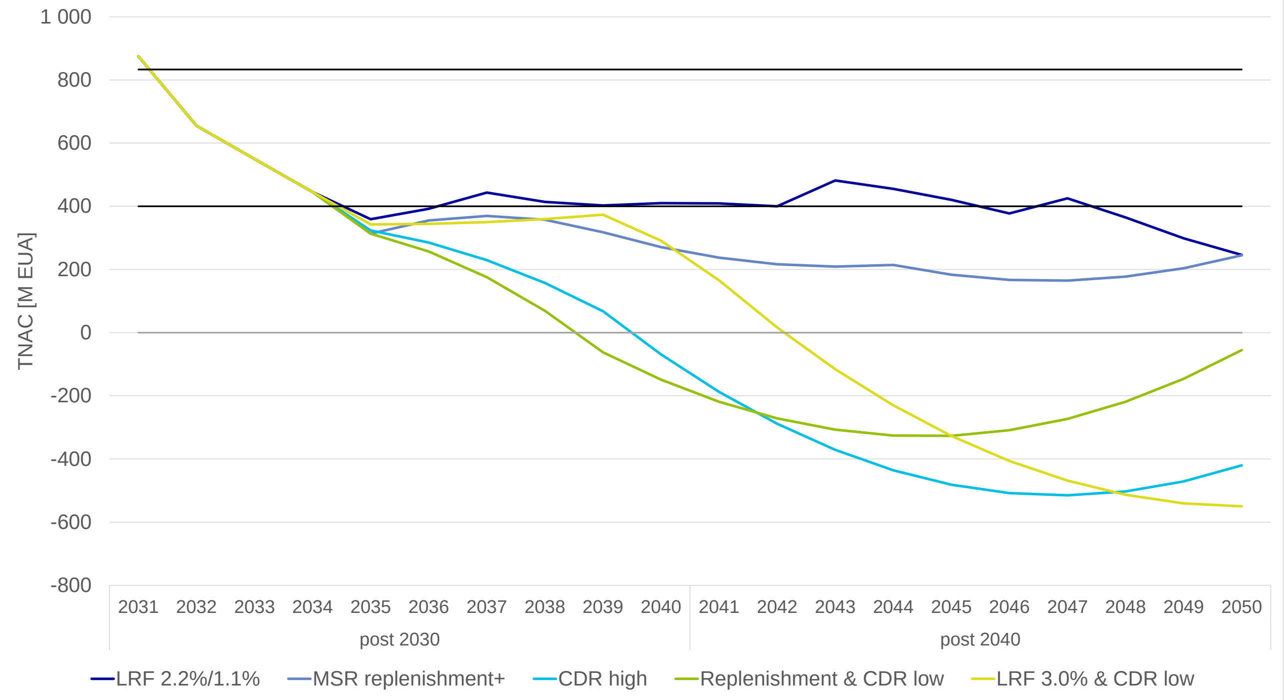
Table 6 shows the cumulative emissions cap and the total EUA supply in millions in the period of 2031 to 2050 for all five options and for each scenario. The depicted supply only refers to the supply entering the ETS from 2031 onwards. In addition, there are approximately 1 000 M EUAs already in the market, the TNAC at the end of the year 2030. The large differences in total supply are due to the activity of the MSR: in the PAC scenario and to a smaller extent the Gas Exit Pathway scenario, the MSR is withholding significant volumes of EUA which never enter the market. For comparison: The cumulative emissions over this period are 6 156 Mt in the CTP2.5 scenario, 5 496 Mt and 4 710 Mt in the PAC and Gas Exit Pathway scenario.

Table 6: Cumulated cap and supply in all three scenarios from 2031 to 2050

	Cap	CTP 2.5			PAC			Gas Exit		
		Supply			Supply			Supply		
		Total	*MSR*	*CDR*	Total	*MSR*	*CDR*	Total	*MSR*	*CDR*
Current configuration	3 550	3 219	*34*	*0*	1 322	*-914*	*0*	2 329	*-411*	*0*
LRF 2.2%/1.1%	5 302	4 970	*34*	*0*	1 834	*-1 734*	*0*	2 995	*-1 153*	*0*
MSR replenishment+	3 550	4 969	*1 784*	*0*	2 122	*-114*	*0*	3 079	*339*	*0*
CDR high	3 550	4 304	*34*	*1 085*	2 288	*-1 024*	*1 085*	3 308	*-514*	*1 085*
Replenishment & CDR low	3 550	4 669	*1 134*	*350*	2 272	*-314*	*350*	3 079	*-11*	*350*
LRF 3.0% & CDR low	4 156	4 174	*34*	*350*	1 936	*-1 085*	*350*	3 006	*-600*	*350*

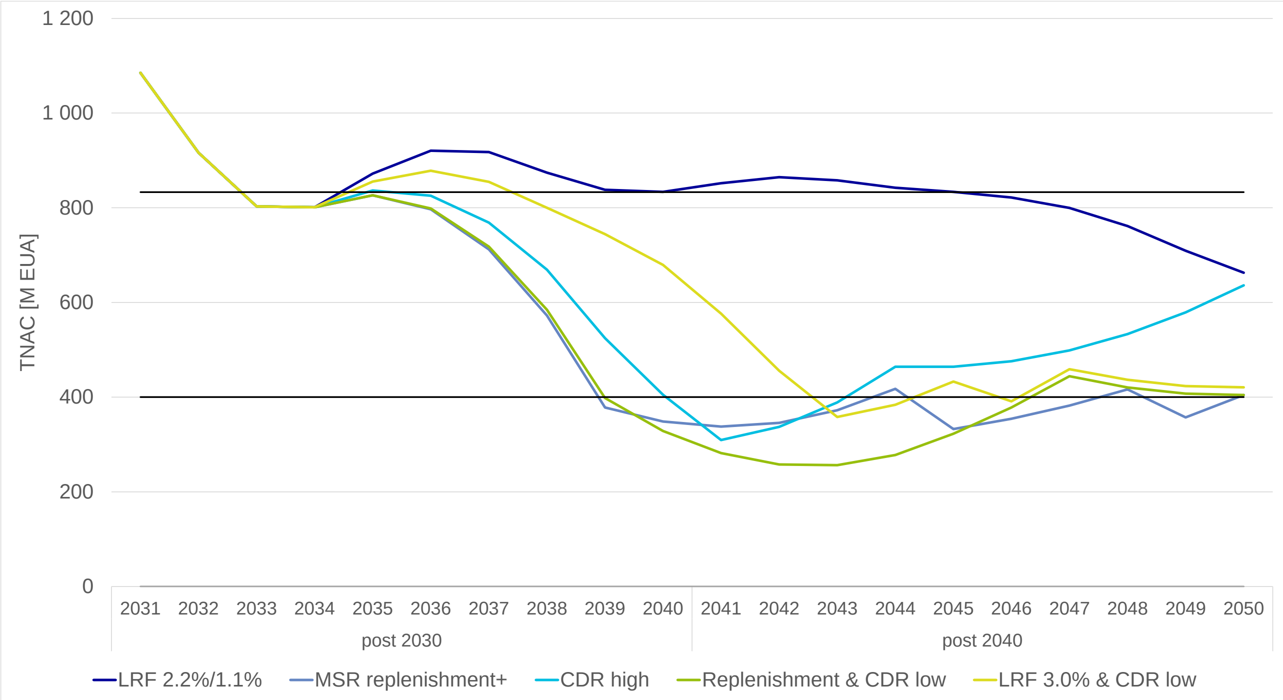
Notes: Total supply includes the quantities issued/withheld by the MSR and CDR.
Source: Oeko-Institut

Figure 5-1: Comparison of TNAC development in the CTP 2.5 scenario



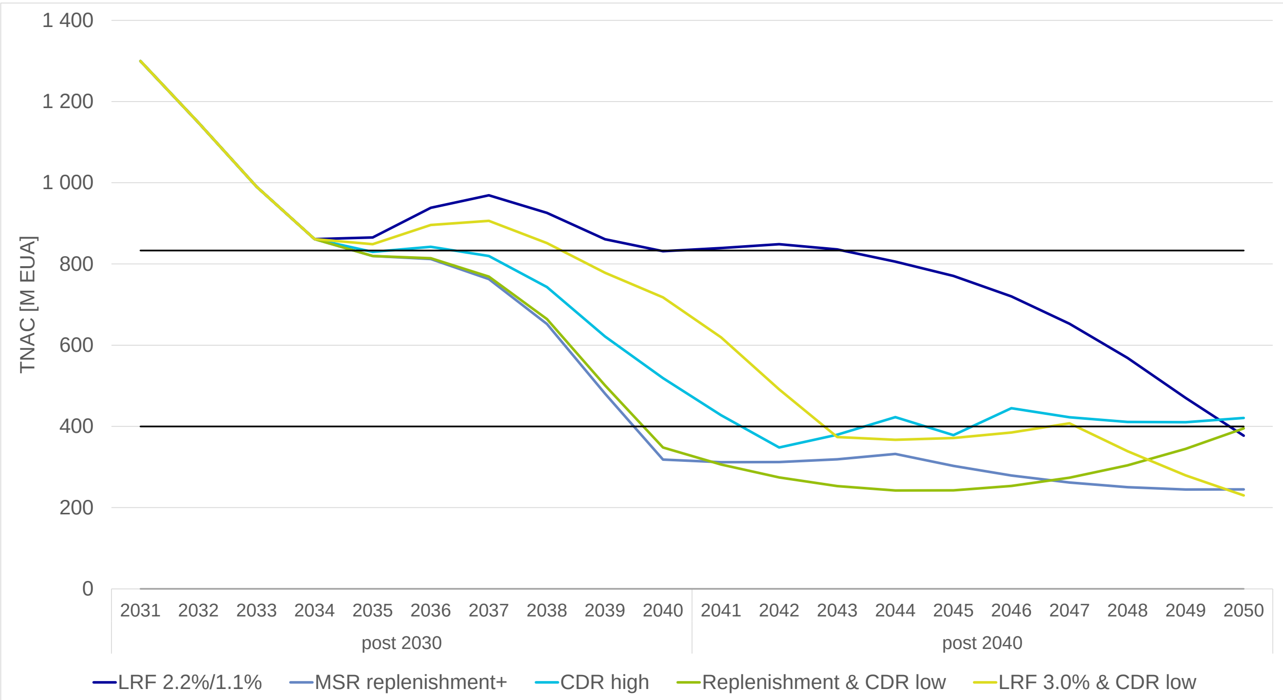
Source: Oeko-Institut

Figure 5-2: Comparison of TNAC development in the Gas Exit Pathway scenario



Source: Oeko-Institut

Figure 5-3: Comparison of TNAC development in the PAC scenario



Source: Oeko-Institut

6 Conclusions

- All three emission scenarios, including the most ambitious scenario aligned with the Paris Agreement, project emissions in both ETSs for 2040 and 2050. This indicates that emissions in the systems do not need to fall to zero in line with the emissions caps. The EU's 2050 climate neutrality target can still be achieved even without eliminating all emissions under the ETS. The remaining emission budget for sectors covered by the ETS needs to be shared between the ETS 1 and ETS 2. To achieve the net 90 % reduction target and climate neutrality, the non-ETS sectors can only emit the difference between the overall target and the emissions allocated to the ETS. This highlights the need for continuous pressure on the ESR to drive further emission reduction at Member State level. This could create a momentum to push for greater ambition outside the ETS framework.

- Without policy reforms or accelerated emission reductions, the ETS 1 and in some scenarios the ETS 2 are projected to reach a negative TNAC after 2035, which could trigger unsustainably high EUA prices. However, prior to 2035, there is no need to artificially rebalance supply and demand in the EUA market. Any measures that increase the supply in the system can be effective after 2035. Measures to reduce emissions – i.e. decreasing demand – are more urgent as their impact tends to be gradual.

- The effectiveness with which a merger of the EU ETS 1 and 2 can increase liquidity in the dried-up EUA market is highly sensitive to emission projections in both systems. Our result from analysing three different scenarios suggest that merging both systems cannot ease tension in the EUA market with certainty and administrative barriers to the merger are high. The cost-benefit ratio of merging the two systems might suggest that it is not the preferred tool to increase liquidity in the EU ETS endgame.

- Technical CDRs can provide some liquidity in the EU ETS endgame but their realistic abatement potential is uncertain. BECCS and DACCS cannot be treated as the only solution to the shortage of EUAs in the EU ETS. To maintain the environmental integrity of the EU ETS, it is crucial that CDRs are not directly allowed in the system. It is more efficient and will introduce less uncertainty into the EUA market to have two separate frameworks with separate targets.

- Allowing Art. 6 credits directly in the EU ETS poses significant risks to the functioning and environmental integrity of the system. There are major concerns around the quality and integrity of Art. 6 credits. Further, experience gathered with the CDM in the EU ETS showed how a surplus of cheap credits can cause EUA prices to collapse, negating any incentives for domestic climate action. If Art. 6 credits were to cause an oversupply of allowances in the EU ETS, it would severely harm the effectiveness of the instrument and delay urgently needed climate action. Article 6 credits should not be allowed into the ETS.

- Modifying the functioning of the MSR has the same effect as adjusting the LRF. Both can increase the EUAs supply when the market tightens. However, changing the LRF is generally perceived as a more significant intervention in the ETS. That means that adjusting the LRF would not only be more politically challenging but also carry greater risks than modifying the MSR. An excessively low LRF could weaken the system's ambition or even lead to the perception that the ETS has failed and that the EU is backtracking on its climate targets. A reform of the ETS should focus on potentially changing the functioning of the MSR before adjusting the LRF.

- Increasing supply by means of the MSR has the added advantage that additional units would only enter the market if there were a shortage. If emissions continue to decline faster than the cap, as has been the case in the ETS 1 to date, the MSR would remain inactive.

- The sectors regulated under the ETS 1 and ETS 2 are highly heterogenous. Achieving emission reductions in the ETS 1 may prove more challenging than in the ETS 2, in which abatement potential remains comparatively higher. This creates the opportunity for increased demand reductions in the ETS 2 that can help rebalance supply and demand during the most critical years after 2035. Complementary policies will be essential in driving emissions reductions and by that demand in those sectors.

- Emission projections for entities covered under the ETS 2 vary significantly, which shows the high degree of uncertainty around future emission levels. If a large surplus of TNAC materialises (as predicted in the PAC scenario), the current MSR will not be fit for purpose to absorb this surplus and reinstate a functioning allowance market. Given the high degree of uncertainty around the actual emission pathways, a few years of operation should be observed before making any adjustments to the systems’ flexibility mechanism.

List of References

2003/87/EC: Directive establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC. In: *Official Journal of the European Union*. Online available at http://eur-lex.europa.eu/LexUriServ/site/en/oj/2003/l_275/l_27520031025en00320046.pdf.

Abegg, M.; Clulow, Z.; Nava, L.; Reiner, D. M. (2024): Expert insights into future trajectories: assessing cost reductions and scalability of carbon dioxide removal technologies. In: *Front. Clim.* 6. DOI: 10.3389/fclim.2024.1331901.

Abhishek, K.; Shrivastava, A.; Vimal, V.; Gupta, A. K.; Bhujbal, S. K.; Biswas, J. K.; Singh, L.; Ghosh, P.; Pandey, A.; Sharma, P.; Kumar, M. (2022): Biochar application for greenhouse gas mitigation, contaminants immobilization and soil fertility enhancement: A state-of-the-art review. In: *Science of The Total Environment* 853, p. 158562. DOI: 10.1016/j.scitotenv.2022.158562.

Budai, A.; Zimmermann, A.; Cowie, A.; Masiello, C.; Andrade, C.; Kammann, C.; Rasse, D.; Marazza, D.; Balugani, E.; Santos, F.; Li, H.; Schmidt, H.-P. (2023): On the durability of biochar carbon storage, A clarification statement from researchers. Biochar Systems Research Group (ed.). Online available at https://biochar.systems/durability-statement/, last updated on 6 Dec 2024, last accessed on 11 Jun 2025.

Climact (2025): 2050 Pathways Explorer. In collaboration with Pauline Rohmer, Waïl Madrane Julien Goetghebuer Julio Tusumba Zinga Philippe Gillès Adriana Lazurca Jann Basso Guillaume Quet Simon Aerts. Online available at https://pathwaysexplorer.climact.com/pathways?visualisation=0&region=EU27&source=model&scenario=EU27%3A+%28Strategic+Perspectives%29+-90%25+Net+by+2040, last updated on 10 Apr 2025, last accessed on 10 Apr 2025.

CMW - Carbon Market Watch (2025): FAQ: Why separate carbon removals from other climate targets? Carbon Market Watch (ed.), last updated on 30 Jan 2025, last accessed on 2 May 2025.

Crook, J. (2022): COP27 FAQ: Article 6 of the Paris Agreement explained, Carbon Market Watch. Online available at https://carbonmarketwatch.org/2022/11/02/cop27-faq-article-6-of-the-paris-agreement-explained/, last accessed on 25 Apr 2025.

EC - European Commission (2024a): Securing our future, Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (COM/2024/63 final). Online available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2024%3A63%3AFIN, last accessed on 14 Oct 2024.

EC - European Commission (ed.) (2024b): Impact Assessment Report, Accompanying the document "Communication from the Commission to the EU. Securing our future Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society" (SWD(2024) 63 final). Strasbourg. Online available at https://climate.ec.europa.eu/document/download/768bc81f-5f48-48e3-b4d4-e02ba09faca1_en?filename=2040%20Climate%20Target%20Impact%20Assessment_en_0.pdf, last accessed on 14 Oct 2024.

Edenhofer, O.; Franks, M.; Kalkuhl, M.; Runge-Metzger, A. (2023): On the Governance of Carbon Dioxide Removal – A Public Economics Perspective. Munich Society for the Promotion of Economic Research (ed.). Online available at https://ideas.repec.org/p/ces/ceswps/_10370.html, last accessed on 10 Sep 2023.

Edmonds, J.; George, M.; Yu, S.; Forrister, D.; Bonzanini, M. (2023): Modelling the Economics of Article 6. IETA. Online available at https://www.ieta.org/wp-content/uploads/2023/09/IETAA6_CapstoneReport_2023.pdf.

ESABCC - European Scientific Advisory Board on Climate Change (2023): Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050. Online available at https://climate-advisory-board.europa.eu/reports-and-publications/scientific-advice-for-the-determination-of-an-eu-wide-2040, last accessed on 11 Aug 2023.

ESABCC - European Scientific Advisory Board on Climate Change (2025): Scaling up carbon dioxide removals, Recommendations for navigating opportunities and risks in the EU, last accessed on 10 Apr 2025.

Gores, S. and Graichen, J. (2024): Discussion of the results of the 2040 Impact Assessment. In collaboration with Cook, V. Oeko-Institut (ed.). Online available at https://www.oeko.de/publikation/diskussion-der-ergebnisse-der-folgenabschaetzung-fuer-2040-englische-version/, last accessed on 27 Oct 2024.

Graf, A.; Gagnebin, M.; Buck, M. (2023): Breaking free from fossil gas, A new path to a climate-neutral Europe. Agora Energiewende. Online available at https://www.agora-energiewende.de/en/publications/breaking-free-from-fossil-gas-1/, last accessed on 3 Sep 2023.

Graichen, J.; Graichen, V.; Wiegmann, K.; Scheffler, M. (2024): Next stop climate neutrality, Key questions for the 2040 climate target governance. Oeko-Institut. Online available at https://www.oeko.de//fileadmin/oekodoc/Next-Stop-climate-neutrality.pdf, last accessed on 18 Oct 2024.

Graichen, V.; Graichen, J.; Healy, S. (2019): The role of the EU ETS in increasing the EU's climate ambition, Assessment of policy options (Sitra Studies, 161). Oeko-Institut. Sitra (ed.). Helsinki, Finland. Online available at https://media.sitra.fi/2019/10/07112628/the-role-of-the-eu-ets-in-increasing-eu-climate-ambition.pdf, last accessed on 24 Oct 2019.

Höglund, R. (2024): Direct air capture is cheaper than you think, Milkywire. Online available at https://www.milkywire.com/articles/direct-air-capture-is-cheaper-than-you-think, last accessed on 4 Jun 2025.

Hünecke, K.; Schumacher, K.; Appenfeller, D.; Braungardt, S.; Bei der Wieden, M.; Cludius, J.; Graichen, J.; Graichen, V.; Hermann, H.; Keimeyer, F.; Kreye, K.; Mendelevitch, R.; Steinbach, I. (2025): Die Lenkungswirkung von Endenergiepreisen zur Erreichung der Klimaschutzziele (Climate Change, 14/2025). UBA - Umweltbundesamt (ed.).

JRC - Joint Research Center (2024): Aligning historical international aviation and maritime transport data to the scope of EU climate policies, A methodology to estimate activity, energy use, and emissions occurring within the boundaries of the European Union and European Economic Area. In collaboration with Jaxa-Rozen, M.; Rózsai, M. and Neuwahl, F. Online available at https://publications.jrc.ec.europa.eu/repository/handle/JRC139028, last accessed on 2 May 2025.

Kalcher, L. and Makaroff, N. (2023): Choices for a more Strategic Europe, The EU triple opportunity for energy security, reindustrialisation and competitiveness based on scenarios for 2040. Strategic Perspectives. Brussels. Online available at https://strategicperspectives.eu/wp-content/uploads/2023/07/Choices-for-a-more-Strategic-Europe.pdf, last accessed on 30 Aug 2023.

Komanoff, C. (2017): Don't Link Carbon Markets, Carbon Tax center. Online available at https://www.carbontax.org/blog/2017/04/06/dont-link-carbon-markets/, last accessed on 17 Apr 2025.

Lambert Schneider; John Holler; Pedro Martins Barata (2023): The Carbon Credit Quality Initiative, Transparent Scores for Carbon Credit Quality. Expanded Scores Launch. Online available at https://carboncreditquality.org/download/CCQI%20presentation%20on%20new%20scores%20released%20on%2031%20January%202023.pdf, last accessed on 6 Dec 2023.

Meyer-Ohlendorf, N.; Gores, S.; Graichen, J. (2025): Climate Targets for EU Member States after 2030: Functions and Options. Ecologic Institut; Oeko-Institut. Online available at https://www.oeko.de/publikation/climate-targets-for-eu-member-states-after-2030-functions-and-options, last accessed on 2 May 2025.

Nissen, C.; Cludius, J.; Gores, S.; Hermann, H.; Wissner, N. (2024): Trends and projections in the EU ETS in 2024, The EU Emissions Trading System in numbers (ETC-CM Report, 2024/09). European Topic Centre on Climate change mitigation. European Environment Agency (ed.). Online available at https://www.eionet.europa.eu/etcs/etc-cm/products/etc-cm-report-2024-09, last accessed on 2 May 2025.

Pinzuti, A. (2023): Biochar: Analysis and Economic potential with a focus on European Producers, Politecnico di Torino, 2023. Online available at https://webthesis.biblio.polito.it/28436/.

Schade, J. and Obergassel, W. (2014): Human rights and the Clean Development Mechanism. In: *Cambridge Review of International Affairs* 27 (4), pp. 717–735. DOI: 10.1080/09557571.2014.961407.

Schneider, L.; Jörß, W.; Böttcher, H.; Krob, F. (2024a): Assessment of the draft technical specifications for certification under the EU CRCF, Permanent carbon removals through DACCS/BioCCS. Oeko-Institut. Online available at https://www.oeko.de/fileadmin/oekodoc/Assessment-DACCS-and-BECCS.pdf, last accessed on 2 May 2025.

Schneider, L.; Siemons, A.; Fallasch, F.; Böttcher, H.; Henneberg, K.; Herold, A. (2024b): The EU Carbon Certification Removal Framework and its methodologies must be improved to deliver on their goals, Oeko-Institut. Online available at https://www.oeko.de/blog/the-eu-carbon-certification-removal-framework-and-its-methodologies-must-be-improved-to-deliver-on-their-goals/, last updated on 12 Dec 2024, last accessed on 2 May 2025.

Sultani, D.; Osorio, S.; Günther, C.; Pahle, M.; Sievert, K.; Schmidt, T.; Steffen, B.; Edenhofer, O. (2024): Sequencing Carbon Dioxide Removal into the EU ETS. In: *SSRN Electronic Journal. DOI:* 10.2139/ssrn.4875550.

Thrän, D.; Borchers, M.; Jordan, M.; Lenz, V.; Markus, T.; Matzner, N.; Oehmichen, K.; Otto, D.; Radtke, K. S.; Reshef, N.; Sadr, M.; Siedschlag, D.; Wollnik, R. (2024): BECCS –ein nachhaltiger Beitrag zur dauerhaften CO2-Entnahme in Deutschland?, Diskussionspapier (UFZ-Bericht, 2). Helmholtz Zentrum für Umweltforschung (ed.), last accessed on 11 Jun 2025.

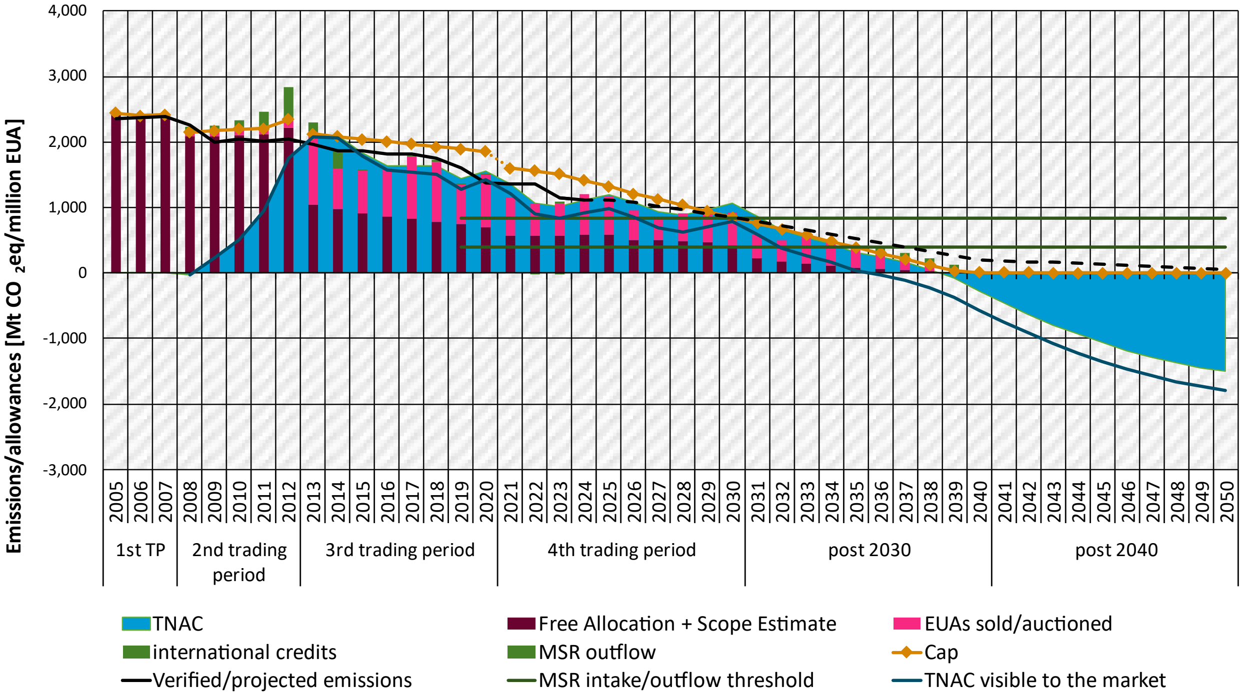
Tsekeris, D. and Karjalainen, J. (2024): Paris Agreement Compatible Scenarios (PAC) 2.0, last accessed on 13 Mar 2025.

UBA - Umweltbundesamt (2024): UBA refuses to approve certificates for eight UER projects, Defective certificates amounting to around 215,000 tonnes of CO2 do not reach the market. Umweltbundesamt (ed.). Online available at https://www.umweltbundesamt.de/en/press/pressinformation/uba-refuses-to-approve-certificates-for-eight-uer, last updated on 11 Jun 2025, last accessed on 11 Jun 2025.

Annex

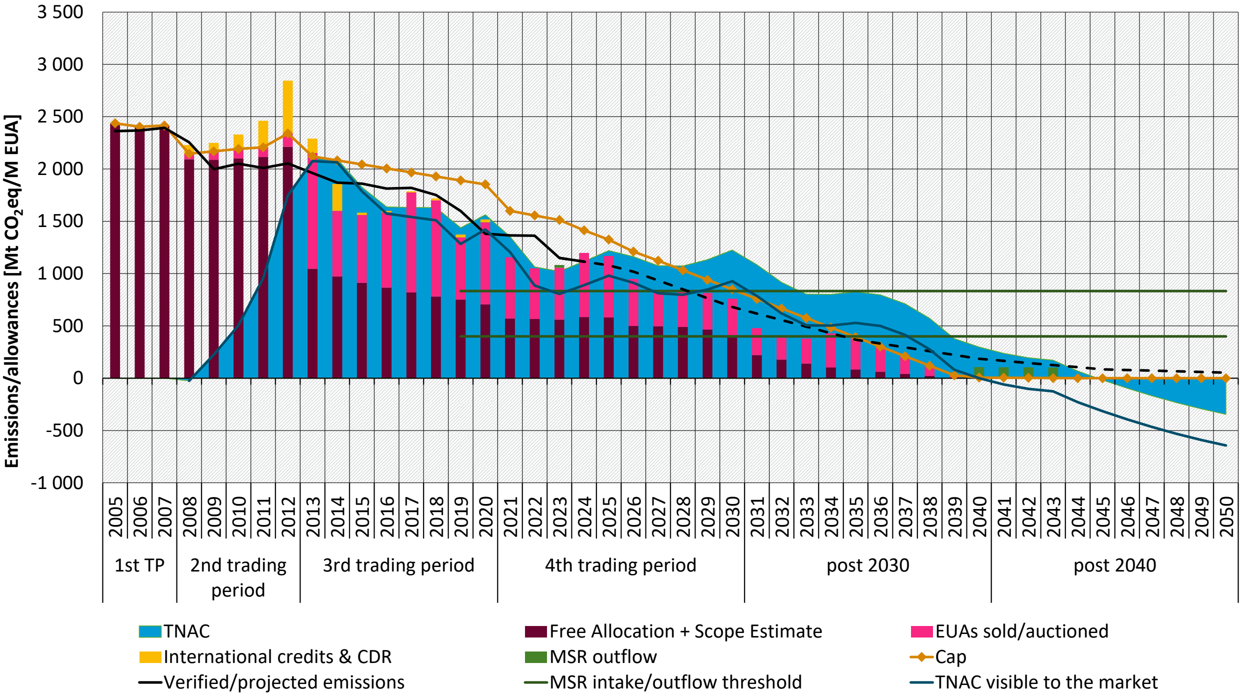
Annex I. TNAC development in the base case scenario for ETS 1 and ETS 2 for all three scenarios

Figure 6-1: TNAC development for the ETS 1 – CTP2.5 scenario



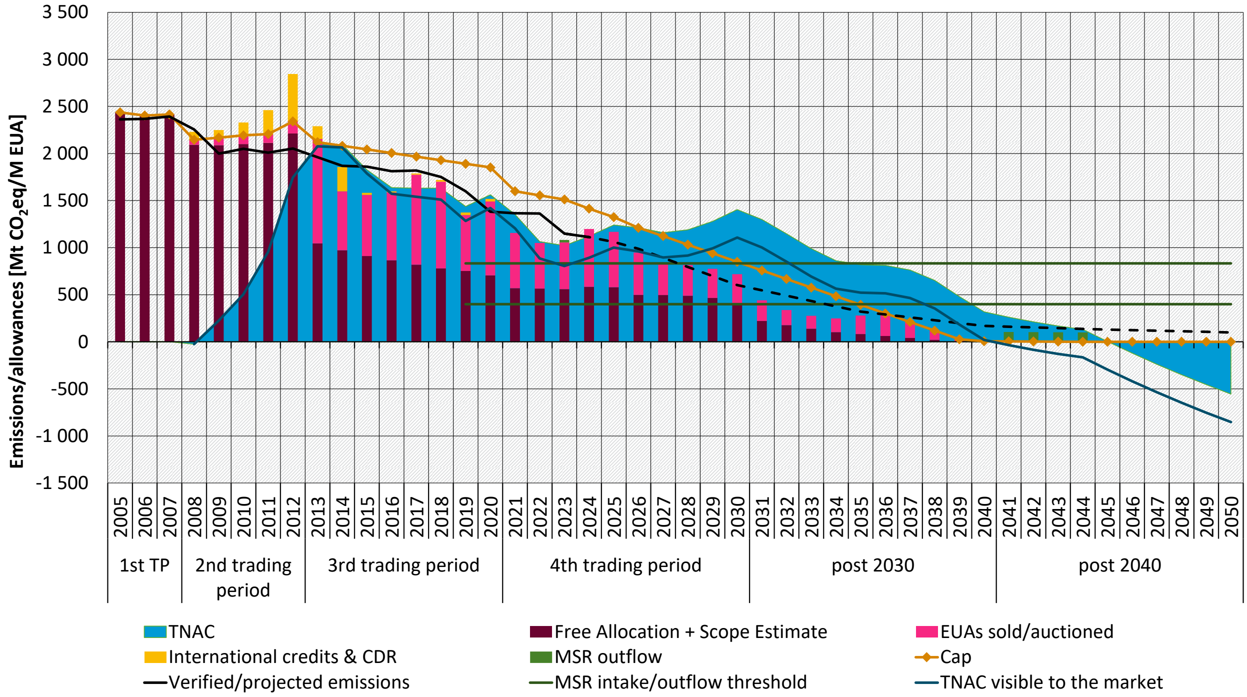
Source: Oeko-Institut based on EC (2024b)

Figure 6-2: TNAC development for the ETS 1 – Gas Exit Pathway scenario



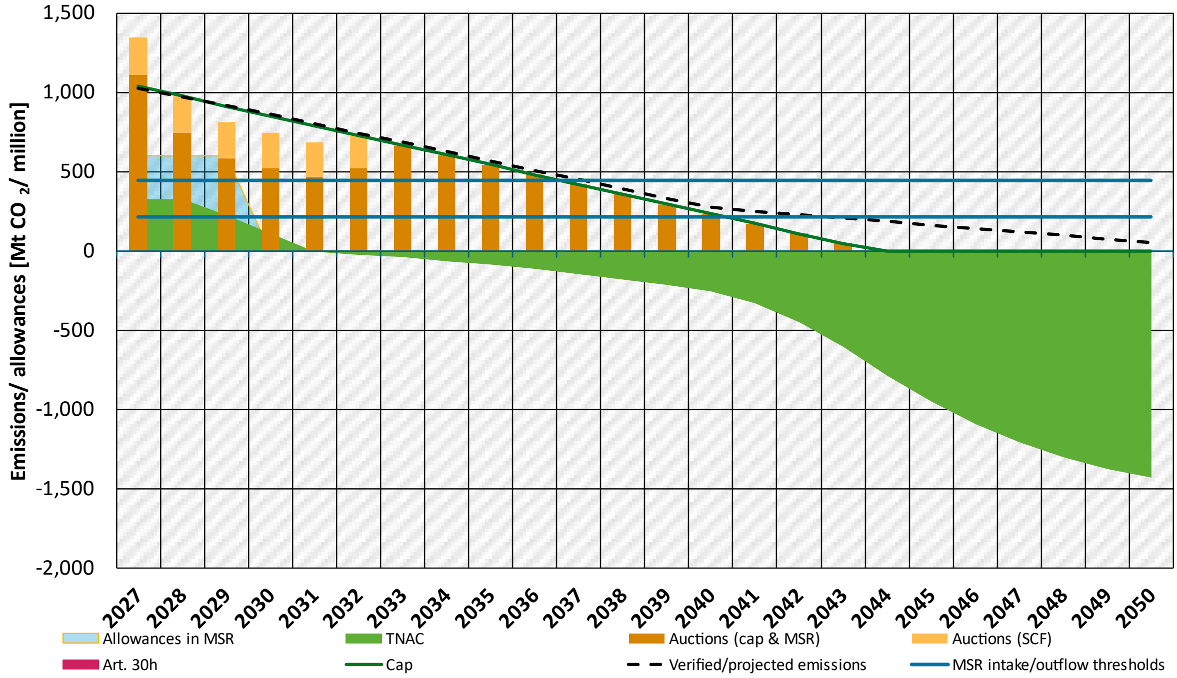
Source: Oeko-Institut based on Graf et al. (2023)

Figure 6-3: TNAC development for the ETS 1 –PAC scenario



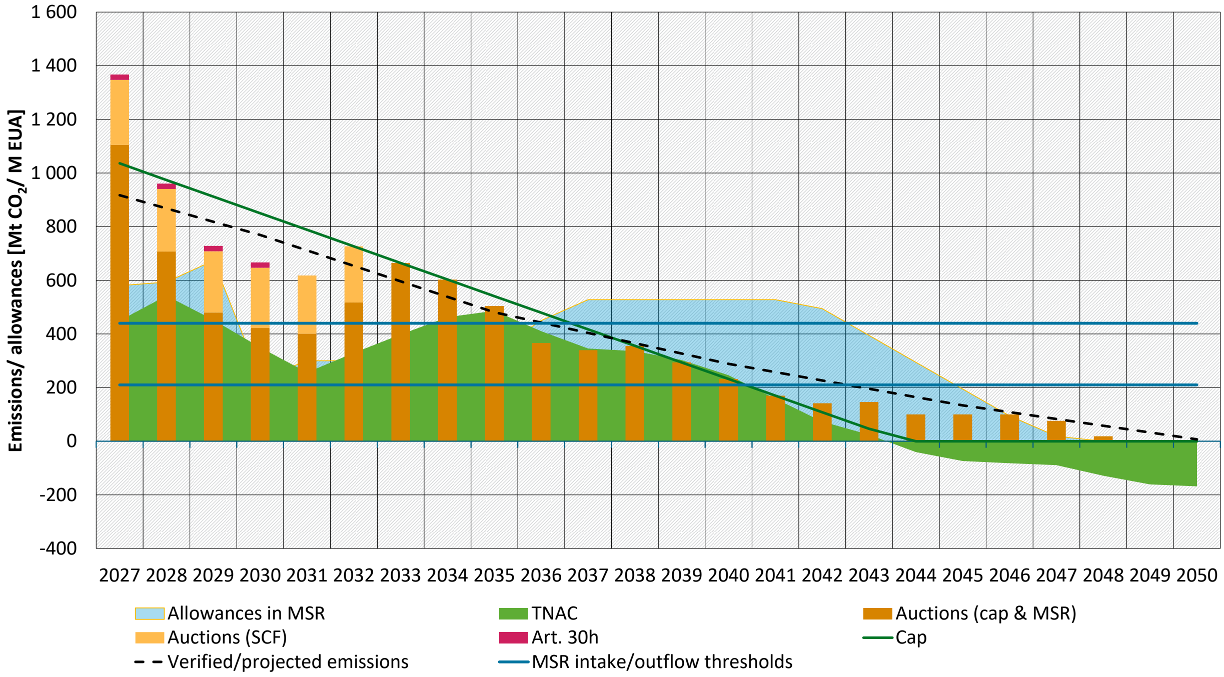
Source: Oeko-Institut based on Tsekeris and Karjalainen (2024)

Figure 6-4: TNAC development for the ETS 2 – CTP2.5 scenario



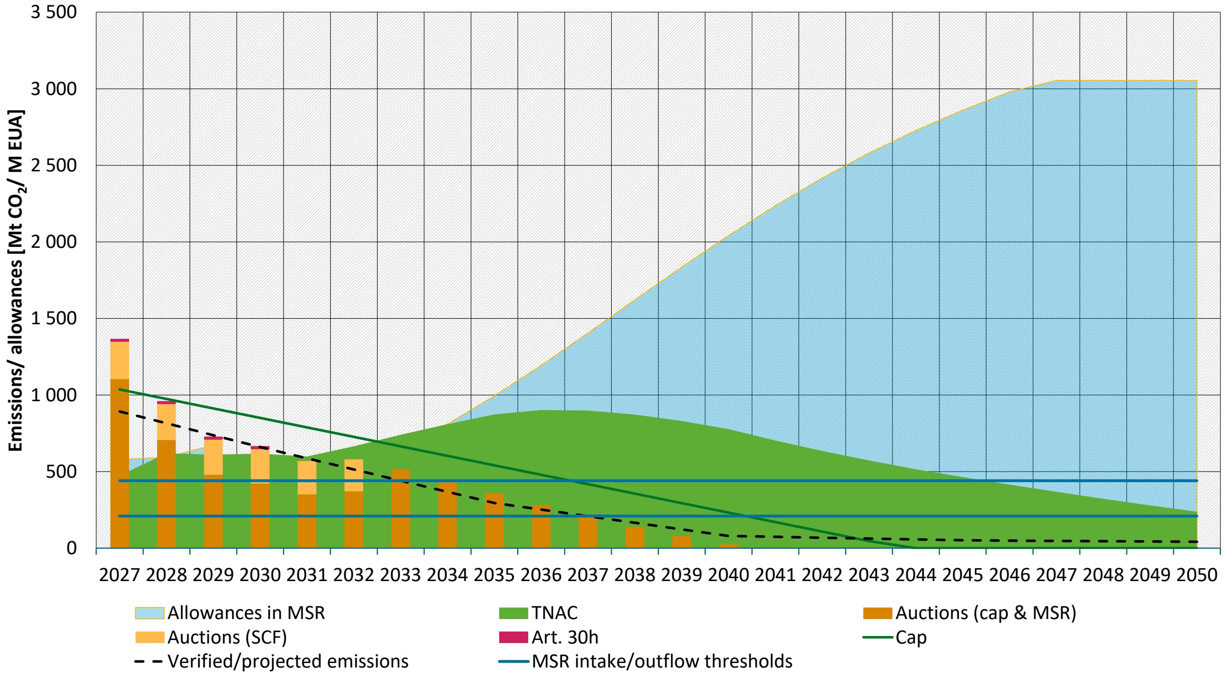
Source: Oeko-Institut based on EC (2024b)

Figure 6-5: TNAC development for the ETS 2 – Gas Exit Pathway scenario



Source: Oeko-Institut based on Graf et al. (2023)

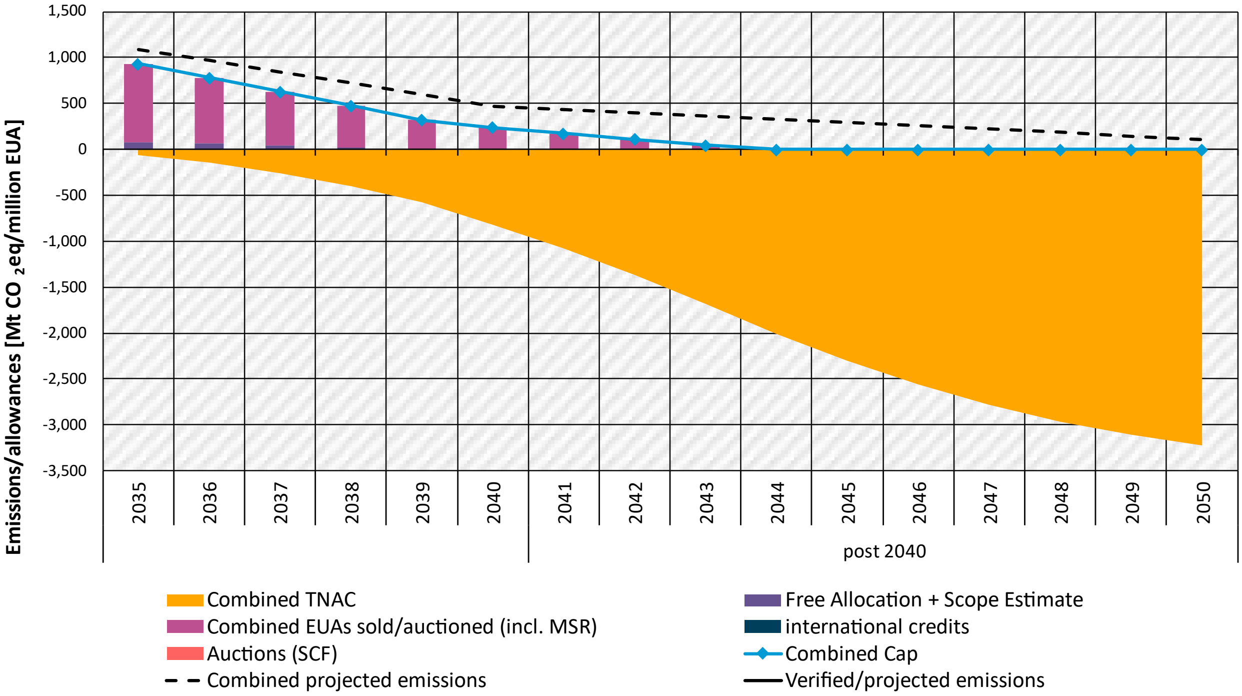
Figure 6-6: TNAC development for the ETS 2 – PAC scenario



Source: Oeko-Institut based on Tsekeris and Karjalainen (2024)

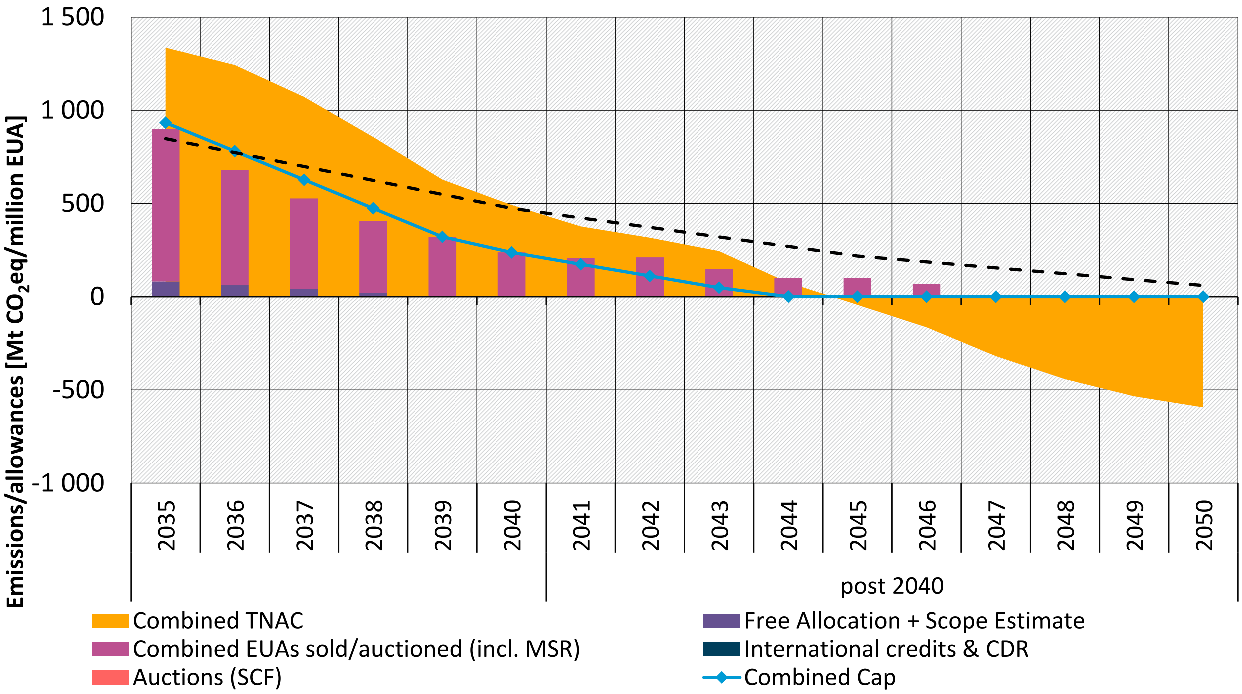
Annex II. TNAC development in all three scenarios for a merged ETS 1 and ETS 2

Figure 6-7: Combined EU ETS 1 and 2 under the COM CTP2.5 scenario



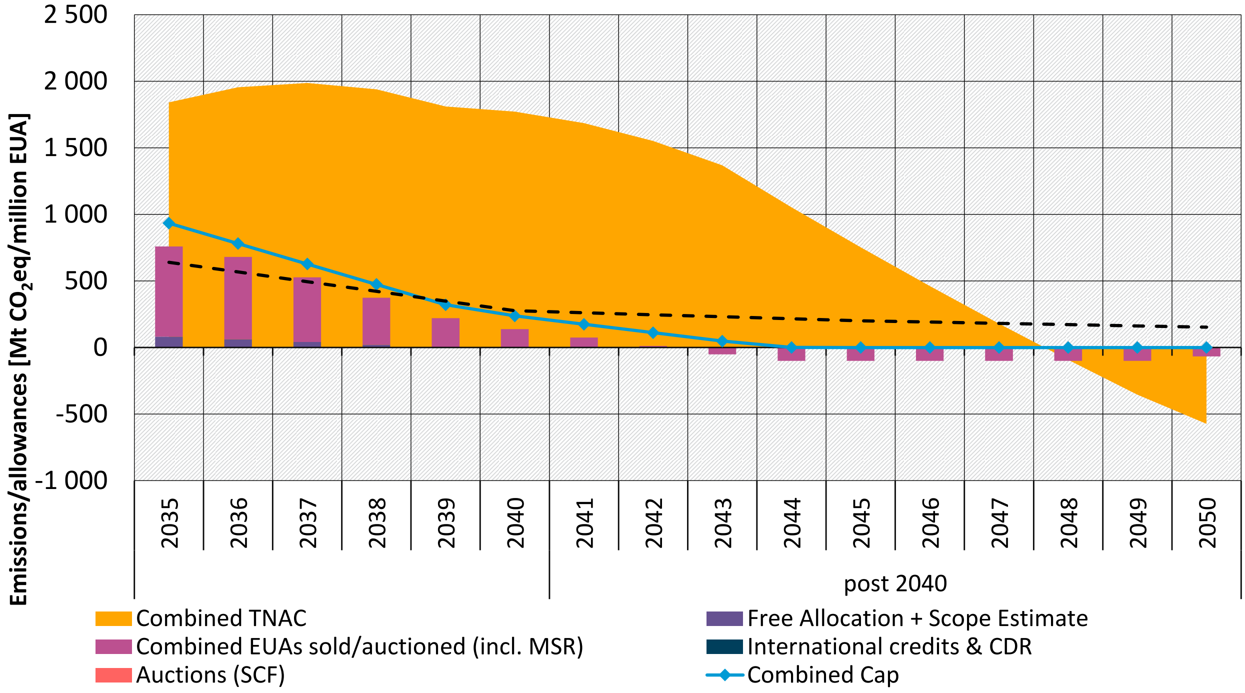
Source: Oeko-Institut based on EC (2024b)

Figure 6-8: Combined EU ETS 1 and 2 under the Gas Exit Pathway scenario



Source: Oeko-Institut based on EC (2024b), Tsekeris and Karjalainen (2024) and Graf et al. (2023).

Figure 6-9: Combined EU ETS 1 and 2 under the PAC scenario



Source: Oeko-Institut based on Tsekeris and Karjalainen (2024).