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EU ETS up to 2030: Adjusting the Cap in light of the IPCC1.5°C Special Report and the Paris Agreement

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Abstract: EU ETS up to 2030: Adjusting the Cap in light of the IPCC1.5 C Special Report and the Paris Agreement

We derive an EU ETS budget compatible with the Paris Agreement based on cost-effectiveness criteria, using a target of limiting global warming to 1.5 degrees Celsius with a 50 – 66% probability, and translate it into a cap reduction path. We derive a budget of about 30 Gt CO_{2e} for the EU ETS for 2016-2050. We show that already about 25 Gt CO_2e will be used until 2030 under current ETS parameters. We also show that cumulative GHG emissions of ETS sectors in the two most ambitious 1.5-degree-scenarios in the EU Commission's Strategic Vision amount to 33 Gt CO_{2e} until 2050, about 10% higher than our optimistic cost-effective budget. Thus, meeting the 2050 EU ETS budget under current 2030 parameters would require drastic – and probably unrealistic – additional efforts after 2030. A smoother and more credible emission pathway can be achieved through a cost-effective scenario reducing the cap by 61% until 2030, compared to 2005, corresponding to an LRF of 4.0% for 2021-2030 (5.8% if the LRF can only be adjusted in 2026). We show that a first step towards aligning the ETS cap with the Paris Agreement would be to use the potential for additional GHG savings due to recently increased EU targets for renewable energy and energy efficiency. The minimum required adjustment is to increase the reduction target for ETS sectors to at least 50% for 2030, compared to 2005, from currently 43%. This corresponds to a LRF of 2.9% for 2021-2030 or 3.5% if the LRF can only be adjusted in 2026. National coal-phase out policies planned in a number of EU member states until 2030 provide further cap adjustment potentials. If phased-out capacities are fully substituted by renewable electricity, emissions in ETS sectors could decline by 57% through 2030, approximating our cost-effective scenario and translating into an LRF of 3.6% for the period 2021-2030 or 4.9% if the LRF can only be adjusted in 2026.

Kurzbeschreibung: EU ETS up to 2030: Adjusting the Cap in light of the IPCC1.5 C Special Report and the Paris Agreement

Wir leiten ein mit dem Pariser Übereinkommen kompatibles EU-ETS-Budget auf Basis von Kosteneffizienzkriterien her mit dem Ziel, die globale Erwärmung mit einer Wahrscheinlichkeit von 50 bis 66% auf 1,5 Grad Celsius zu begrenzen und übersetzen es in einen Pfad der Cap-Reduktion. Unsere Berechnungen ergeben ein Budget von ca. 30 Gt CO_2e für das EU ETS für 2016-2050. Unter aktuellen ETS-Parametern werden bis 2030 bereits ca. 25 Gt CO_2e verbraucht. Wir zeigen, dass die kumulierten THG-Emissionen von ETS-Sektoren in den beiden ehrgeizigsten 1,5-Grad-Szenarien der Strategischen Vision der EU-Kommission bis 2050 33 Gt CO_2e betragen und damit etwa 10% höher liegen als unser optimistisches kosteneffizientes Budget. Das Einhalten des EU-ETS-Budgets bis 2050 unter den aktuellen Parametern für 2030 würde demnach drastische - und wahrscheinlich unrealistische - zusätzliche Anstrengungen nach 2030 erfordern. Ein glaubwürdigerer Emissionspfad kann durch ein kosteneffizientes Szenario erreicht werden, bei dem das Cap bis 2030 um 61% abgesenkt wird, im Vergleich zu 2005, was einem LRF von 4,0% für 2021-2030 entspricht (5,8%, wenn der LRF erst 2026 angepasst werden kann). Ein erster Schritt, um das ETS Cap mit dem Pariser Abkommen in Einklang zu bringen, ist die Potenziale für zusätzliche THG-Einsparungen zu nutzen, die sich aus kürzlich erhöhten EU-Zielen für erneuerbare Energien und Energieeffizienz ergeben. Dazu müsste das Reduktionsziel für die ETS-Sektoren bis 2030 von derzeit 43% auf mindestens 50% im Vergleich zu 2005 angehoben werden. Dies entspricht einem linearen Kürzungsfaktor (LKF) von 2,9% für 2021-2030 oder 3,5%, wenn der LKF erst 2026 angepasst werden kann. Die in einer Reihe von EU-Mitgliedstaaten bis 2030 geplanten nationalen Maßnahmen zum Ausstieg aus der Kohleverstromung bieten weitere Anpassungspotenziale. Wenn Kapazitäten vollständig durch Strom aus erneuerbaren Energien ersetzt werden, könnten die Emissionen in ETS-Sektoren bis 2030 um 57% sinken, was unserem kosteneffizienten Szenario nahe kommt und somit einem LKF von 3,6% für 2021-2030 bzw. 4,9%, wenn der LKF erst 2026 angepasst werden kann.

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CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent (measuring unit for greenhouse gas)
COP	Conference of the Parties
EU-ETS	EU Emissions Trading Scheme
GHG	Greenhouse gas
g/kWh	Gram per kilowatt hour (measuring units for emission intensity)
IPCC	Intergovernmental Panel on Climate Change
IPCC SR1.5	IPCC Special Report on the impacts of global warming of 1.5 degrees Celsius above pre-industrial levels
LRF	EU ETS linear reduction factor
LULUCF	Land Use, Land-Use Change and Forestry
NDC	Nationally Determined Contributions (in Paris-Agreement)
TWh	Terawatt hours (measuring units for energy)
Vision	A European Strategic Long-Term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy

Policy Brief

The main findings of this paper can be summarized as follows:

1) Deriving an adequate greenhouse gas (GHG) emissions budget for the EU ETS (or for the EU's overall GHG emissions) that may be regarded as compatible with the Paris Agreement's temperature goal is challenging from a technical and normative perspective. As the IPCC Special Report on Global Warming of 1.5 degrees Celsius (IPCC SR1.5) has shown, the remaining global CO_2 and GHG budgets are highly uncertain. Additionally, there are various options for splitting the global budget among countries or regions based on normative criteria. Despite these uncertainties, some orientation is needed with respect to adjusting the GHG-reduction pathway of the EU-ETS which is always directly linked to a corresponding GHG budget as the EU ETS is a strictly volume-based instrument. In this regard we are deriving an EU-ETS budget that may be regarded as compatible with the Paris Agreement and translate it into a cap reduction path.

2) As a starting point, we assess global long-term pathways to stay within the remaining emissions budget for limiting global warming to 1.5 degrees with a 50 – 66% probability and distribute it globally based on cost-effectiveness criteria. The selected global remaining emissions budget reflects an optimistic perspective for the EU in light of the large uncertainties associated with the budget. Moreover, the cost-effectiveness approach is the approach for deriving budget shares most favourable to developed economies. In this respect we underline, that it is not our task to make a recommendation for an EU share of the global budget which would be a highly normative undertaking. The resulting EU ETS budget should therefore purely be interpreted as an indicator for the very upper limit of an EU budget compatible with keeping global warming below 1.5 degrees. Again, it does not reflect a "fair share" of the budget or "an adequate contribution" to the Paris Agreement. Against this backdrop, our analysis shows that an emission budget of approximately 30 Gt CO_2e for the EU ETS during the period from 2016 to 2050, while achieving net-zero emissions in 2050 at the latest, is a reasonable basis for further discussions. Taking into account current emission trends in EU ETS, up to one third of this budget could already be used until 2020, and about 25 Gt CO_2e -or more than 80 percent - will be used by 2030 under current ETS parameters.

3) The EU Commission's Strategic Vision "A clean planet for all", published in November 2018, is intended to align the European emission pathway with the Paris Agreement. Estimated cumulative GHG emissions of ETS sectors in the two most ambitious 1.5-degree-scenarios of the Vision amounted to 33 Gt CO_2e until 2050. This is about 10% higher than the optimistic cost-effective budget we compute. In addition to that, estimated cumulative emissions reflecting the Commission Vision are so far not ensured by current ETS parameters for the fourth trading period (2021-2030).

4) Staying within the optimistic emissions budget of 30 Gt CO_2e for the EU ETS is theoretically possible without changing the ETS parameters up to 2030. However, it is not practical from an economic and political perspective, as meeting the EU ETS budget until 2050 under current 2030 parameters would require drastic additional efforts from ETS sectors after 2030. Keeping the linear reduction factor (LRF), the key parameter for setting the cap reduction path in the EU ETS, unchanged until 2030 at the current 2.2% would require a drastic – and probably unrealistic – increase in ambition after 2030 and net-zero emissions in 2040 already.

5) Our findings show that early action with respect to ETS parameters – in particular a change in the LRF in 2021 already – provides a smoother and more credible emission pathway for ETS sectors until 2050. In a cost-effective scenario the cap would be reduced by 61% until 2030 compared to 2005, corresponding to an LRF of 4.0% between 2021 and 2030 (5.8% if the LRF can only be adjusted in 2026). Net-zero emissions would be achieved in 2050.

6) A first step towards aligning the ETS cap with the Paris Agreement would be to use the potential for additional GHG savings due to recently increased EU targets for renewable energy consumption and energy efficiency. Such an adjustment would also help to ensure scarcity on the European carbon market and tap the full potential of the EU ETS as a climate protection instrument. In this regard, the minimum adjustment to the cap, i.e. the LRF, in order to ensure scarcity in EU ETS and to safeguard the consistency of the European climate and energy policy triad, is to increase the reduction target for ETS sectors to at least 50% for 2030, compared to 2005, from currently 43%. This corresponds to a LRF of 2.9% (2021-2030) or 3.5% if the LRF can only be adjusted in 2026. This additional potential for GHG savings from companion policies provides a political opportunity to adjust the cap in the direction required for a Paris compatible ETS, as underpinning measures and targets for their realization are already in place. While re-aligning the EU ETS with renewable energy and energy efficiency targets would lead to an almost complete decarbonisation of ETS sectors by 2050, simultaneously staying within the 30 Gt CO_2e budget would still require fairly drastic reduction efforts after 2030 and net-zero emissions around 2040 already.

7) Further potentials for accelerating the reduction of the cap up to 2030 stem from the effects of national coal-phase out policies planned in a number of EU member states until 2030. The effects of these national coal-phase-out policies are more uncertain than the European energy targets, as it is not yet clear how phased-out coal capacities will be substituted and to what extend the GHG-reduction effects will be additional to those that are linked to the renewable energy targets. Yet it is crucial that we analyze and account for such policies in order to maintain scarcity in the EU ETS and facilitate the political discussions on the cap adjustment with regard to the GHG abatement in the ETS sectors.

8) If phased-out coal capacities were fully substituted by renewable (zero-emission) electricity, emissions in ETS sectors could decline by 57% through 2030, which comes already very close to our cost-effective scenario and translates into an LRF of 3.6% for the period 2021-2030 or 5.0% if the LRF can only be adjusted in 2026. Our findings suggest that even if national policies are not implemented in the manner we assume or if coal power generation is not fully substituted by renewable energy, there is ample potential to increase the LRF to well above 2.9% (from 2021 on) or 3.5% (from 2026 on), which would be the minimum required adjustment to the cap in order to maintain consistency with EU's energy policy goals. By doing so the EU could start closing the gap between current ETS parameters and the requirements to stay within a cumulative emissions budget that can be considered compatible with the Paris Agreement's temperature goal, by reflecting the GHG abatement in ETS sectors occurring from planned or already implemented energy-related measures and targets.

1 Background and Introduction

Under the Paris Agreement, governments agreed to a long-term goal of keeping the global temperature increase to well below 2 degrees Celsius above pre-industrial levels, and aim to limit the increase to 1.5 degrees Celsius. The urgency to target the 1.5 degree goal has increased with the publication of the IPCC 1.5 degrees Celsius special report (short IPCC SR1.5), which clearly demonstrates that risks from temperature increases by 2 degrees are significantly more substantial than those of a warming by 1.5 degrees. The current EU's nationally determined contribution (NDC) implies a reduction of domestic GHG emissions by at least 40% compared to 1990. This is insufficient with regard to the requirements under the Paris Agreement (Wachsmuth et al., 2019).

In a recent position paper, the German Environment Agency (UBA) affirms the importance of re-calibrating European climate policy in view of IPCC SR1.5 (UBA 2018). According to UBA (2018) this should be achieved by defining a long-term strategy for 2050 and intermediate targets in NDCs that are consistent with limiting global warming to 1.5 degrees. There is only a very limited CO_2 budget remaining for limiting global warming to 1.5 degrees. Decisive early action is therefore required to minimize cumulative emissions and the risk of overshooting as well as the lock-in of high-emission technologies through long-lived assets due to policy uncertainty. To minimize cumulative emissions and to make achieving the long-term goals realistic, strong action will be required during the decade up to 2030 already. UBA (2018) stresses that in addition to its own climate action the EU should also support abatement outside the EU through technical assistance in establishing climate policies and cooperative approaches according to Article 6 of the Paris Agreement. Due to the requirement of achieving emission reductions both in Europe and beyond there is little scope for offsetting.

In the European Union, approximately 40% of emissions are covered by the European Emissions Trading Scheme (EU ETS). It is therefore important to calibrate EU ETS parameters to the requirements set by the Paris Agreement's temperature goals. The parameters determining emission reductions for sectors covered by EU ETS are set by the ETS Directive (EU 2018a). The so called "cap" defines the maximum emission level for ETS sectors. The linear reduction factor (LRF) determining the annual reduction of the EU ETS cap was set at 2.2% for the 4th Trading Period from 2021 to 2030 (EU 2018a). This corresponds to a 43% reduction of the cap by 2030 compared to the 2005 emission level. Together with a reduction target for non-ETS sectors of 30% by 2030, also vs. 2005, this implies a reduction of total EU's domestic GHG emissions by at least 40% compared to 1990, in line with the EU's NDC.

After adopting the overall GHG reduction target and determining the LRF of 2.2%, however, the stringency of key European energy policy targets was increased compared to the original goals from 2014, especially with respect to the share of renewable energy (from 27% to at least 32%) and improvements in energy efficiency (from 27% to at least 32.5%) in the "Clean energy for all Europeans" package (EU 2018e). Additionally, several EU member states are planning national phase-outs of coal-fired power generation. These recent policy initiatives have introduced inconsistencies between current EU ETS parameters and the overall climate and energy framework, which necessitate an adjustment of the EU ETS cap in order to avoid structural imbalances between supply and demand in the European carbon market. The objective of this paper is to contribute to the discussion on the long-term emission pathway for the EU ETS by considering the implications of the Paris Agreement's temperature goal and European and national energy policies for the EU ETS. Our analysis presupposes that the EU ETS should meet two basic requirements: first, it should be compatible with an appropriate European contribution to limit global warming to well below 2 degrees Celsius, preferably 1.5 degrees and second, there should be scarcity on the market in order to tap the full potential of emissions trading in an effective and efficient manner. With the cap being the crucial parameter for determining the level of stringency and ambition of any ETS, it is the central lever in deriving an EU-ETS budget and a cap reduction path for the period 2021-2100 that may be regarded as compatible with the Paris Agreement while ensuring market scarcity at the same time.

In Section 2, we use two documents as the framework for deriving a Paris compatible ETS budget: first, the IPCC SR1.5, which provides information on global remaining emission budgets compatible with different temperature goals and second, the "Strategic Long-Term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy (Vision)" proposed by the EU Commission in November 2018 (EU 2018c).

In Section 3 we derive exemplary emission pathways for ETS sectors that remain within the GHG budget for ETS sectors that we have calculated in Section 2. Moreover, we characterize how the emission reduction potential of interacting energy and climate policies should be reflected in the cap reduction path up to 2030 in order to safeguard the scarcity and effectiveness of the EU ETS. For this purpose, we develop scenarios incorporating both increased renewable and energy efficiency targets at the European level and national energy policies, in particular coal phase-out policies.

2 Deriving a budget for EU ETS in light of the Paris Agreement and the IPCC SR1.5

2.1 Cumulative emissions in the IPCC SR1.5 and the EU Commission's vision "A clean planet for all"

The Paris Agreement and the IPCC SR1.5 (IPCC 2018) constitute the international framework defining the required extent of European climate action. Under the Paris Agreement, governments agreed to a long-term goal of keeping the global temperature increase to well below 2 degrees Celsius above pre-industrial levels, and aim to limit the increase to 1.5 degrees. It was also agreed that emissions should peak as soon as possible and decline rapidly thereafter, in accordance with the best available science.[1] Parties regularly submit Nationally Determined Contributions (NDCs) declaring their emission mitigation targets.

IPCC SR1.5 indicates that risks from temperature increases by 2 degrees are significantly more substantial than those of a warming by 1.5 degrees, which strongly suggests that global climate action should avoid large overshoots of the 1.5 degree goal in addition to keeping the increase well below 2 degrees. How to achieve this in terms of mitigation pathways has been addressed by targeting global cumulative emissions of CO_2 until 2100 – a so called emission budget – and enhanced in recent studies on total GHG emissions. According to the IPCC SR 1.5, to limit warming to 1.5 degrees with a probability of at least 66% (with no temporary overshoot), a global budget of 420 to 570 Gt CO_2 remains – before accounting for other GHG gases and depending on which method is used (IPCC SR1.5, SPM C.1.3). However, for a variety of reasons there are large uncertainties associated with the budget, in the order of several hundreds of Gt CO_2 (IPCC SR1.5, SPM C.1.3). Therefore, the budget could also be substantially smaller, due to, among others, the impact and mitigation potential of non-CO_2 greenhouse gas emissions.[2]

The large uncertainty associated with a remaining global CO_2 budget makes it a challenge to derive an adequate budget for the ETS sectors. In addition to the uncertainty in the global budget, a fair distribution of this global budget between countries is a highly political and contentious issue. There are multiple approaches, each with their strengths and weaknesses. In particular, a distribution based solely on fairness approaches (including historical responsibility) may result in a politically, economically and technically infeasible emission pathway for the EU. Thus, deriving an emissions budget that is compatible with the Paris Agreement for a group of countries such as the EU or for EU ETS sectors is a challenge and will always be subject to reasonable criticism. Despite this, orientation is required to derive an EU-ETS budget that may be regarded as compatible with the Paris Agreement and translate it into a cap reduction path. The calculated budget should also be continuously monitored based on the latest scientific developments and – if required – adapted accordingly.

We therefore also consider the "Strategic Long-Term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy (Vision)" the EU Commission proposed in November 2018 (EU 2018c) to find a benchmark ETS budget. The EU Commission developed its Vision "A Clean Planet for All" with the goal of aligning the European emission pathway with the EU's required contributions under the Paris Agreement. The EU Commission assumes that this means

[1] Cf. https://ec.europa.eu/clima/policies/international/negotiations/paris_en for further details on the Paris Agreement.

[2] Chapter 2 of IPCC SR1.5 provides an overview of the most likely carbon budgets (i.e. excl. non-CO2 emissions) for different limits of global warming with associated probabilities.

reaching net-zero GHG emissions in 2050. The In-depth Analysis underlying the Vision features two scenarios targeting net-zero GHG emissions in 2050, the 1.5TECH and 1.5LIFE scenarios (EU 2018d). In addition to abatement action, both scenarios feature substantial negative emissions, to be achieved through LULUCF and carbon removal technologies. The In-depth Analysis also provides some information on the expected cumulative emissions between up to 2050 and 2100. Other than the IPCC SR1.5, the data include non-CO_2 emissions, which have large uncertainties, especially in the agriculture and waste sector, whereas in the ETS sectors, non-CO_2 emissions do not play a major role quantitatively.

For our assessment we consider the cumulative GHG emissions of the mean of the scenarios 1.5TECH and 1.5LIFE as a proxy for an emission budget target consistent with the Vision's goal of achieving net-zero emissions by 2050. We derive both total and ETS emissions of the net-zero GHG scenarios from the In-depth Analysis (EU 2018d).

For the EU ETS emissions, we assume that the reduction of EU ETS emissions by 49.8% until 2030 in the recent EUCO3232.5 scenario (EU 2019) applies to 1.5TECH and 1.5LIFE, as the scenarios 1.5TECH and 1.5LIFE are strongly in line with the EUCO3232.5 scenario until 2030. For 2050 emissions, we use the mean ETS emissions of 1.5TECH and 1.5LIFE as given in the In-depth Analysis (which is close to net-zero), while we estimate the 2040 value based on sectoral data from the In-depth Analysis. More details on the assumptions can be found in the technical annex to this study.

For the GHG emissions in EU ETS sectors in 2016-2050, we calculate cumulative emissions of 33 Gt CO_2e (see Table 1:). Note that the ETS emissions calculated in the In-depth Analysis are based on the assumption that emissions will decrease according to the revised renewable and efficiency targets for 2030. Without adjusting the LRF of the cap accordingly, annual and especially cumulative ETS emissions could be higher as the current requirement is only a reduction by 43% up to 2030 (compared to 2005).

Table 1: Annual and cumulated EU ETS GHG emissions of the EU Long-term Strategic Vision

Gt CO_2e	**2015**	**2030**	**2040**	**2050**	**2016-2050**
EU ETS GHG emissions, EU Long-Term Strategic Vision	2.0	1.2	0.3	0.0	**33**

Source: Own calculations. EU ETS emissions are calculated using the mean of the scenarios 1.5LIFE and 1.5TECH based on EU (2018d), Figures 60, 61, 90 and Table 9.

The scenarios 1.5TECH and 1.5LIFE were mainly based on the assumption that net-zero GHG emissions in 2050 are in line with limiting global warming to 1.5 degrees Celsius and the current EU 2030 framework. We ask whether these scenarios are also in line with the global budget requirements for the EU ETS implied by limiting global warming to 1.5 degrees. We tackle this question in the next subsection.

2.2 Calculating an EU ETS emissions budget based on globally cost effective pathways

To assess the cumulative ETS emissions of the EU long-term Vision in light of the IPCC SR1.5, we need to derive an emission budget for the EU ETS from the global GHG budget. However, deriving an emissions budget for the EU ETS is challenging, as it includes a normative choice about the probability to achieve a certain temperature goal and about how to split the corresponding global budget among countries. There are several different approaches present in the international debate, e.g. using the criterion of cost-effectiveness or a range of fairness criteria (e.g. Van Vuuren et al. (2017) and Matthes et al. (2018)).

A budget split according to the cost-effectiveness criterion allocates shares of the global budget in a way that the global cost of emission mitigation is minimized. Using the cost-effectiveness criterion leads to higher shares of the global emission budget for developed economies such as the EU. Using fairness criteria, e.g. based on population shares, considering economic capacities or accounting for historical emissions, decreases the share of the total emission budget available for the EU substantially. Using the cost-effectiveness criterion therefore yields an upper bound for the EU's share of the global emission budget. The EU's cost-effective budget thus indicates how much abatement should occur inside the EU, at a minimum. Targeting an EU budget based on fairness criteria would require further abatement or additional action outside the EU, e.g. by supporting mitigation efforts in emerging and developing economies through strengthened multi- and bilateral cooperation, capacity building, technology transfer and financial transfers (UBA 2018). We use the cost-effectiveness criterion here to derive the EU ETS share of the global emission budget as it sets the maximum available budget for the EU ETS that could be regarded as in line with the requirements of the 1.5 degree temperature goal. This allows us to assess whether the two scenarios leading to net-zero emissions by 2050 (1.5TECH and 1.5LIFE) of the "Vision" comply with the (domestic) emission reduction requirements in terms of cumulative emissions of the EU ETS.

Our calculations are based on the class of pathways called "below-1.5-degree pathways" in the IPCC SR1.5. This most ambitious class of pathways is defined as achieving a probability of 50 – 66% of staying below 1.5 degrees Celsius of warming for the entire 21st century. These pathways are, hence, as close as possible to the requirement of limiting global warming to 1.5 degrees Celsius with 66% probability, as stated by UBA (2018).[3]

We apply data from the POLES-Enerdata model (2018 version) to derive the globally cost-effective EU share of the global emission pathways. For the below-1.5-degree pathways, we derive the median evolution of global energy- and process-related CO_2 emissions from the IAMC 1.5 degrees Celsius scenario explorer[4]. We translate these into energy- and process-related GHG emissions by adding a fixed increase of 15% to the energy- and process-related CO_2 emissions[5] throughout the period with positive emissions. As the share of energy-related non-CO_2 emissions in the EU is substantially smaller, this might overestimate EU's emission budget slightly. Here, we also take into account non-CO_2 GHG emissions because both the data on the ETS in the Commission's In-depth Analysis (EU 2018d) and the data from the POLES-Enerdata model, which we will use in the following, include non-CO_2 emissions. We note that non-CO_2 emissions in the EU ETS have been reduced to less than 1% of the total cap already. So for the calculations regarding ETS sectors, non-CO_2 emissions do not play a major role quantitatively.

We translate the global energy- and process-related GHG emission pathways for the period 2016 – 2050 into national emission levels by applying a globally uniform shadow carbon price pathway that yields the globally required emission reductions in the POLES-Enerdata model. The globally uniform shadow carbon price is applied to all sectors in the EU as well. For the

[3] We note that Wachsmuth et al. (2019) assume an interim limited overshoot of 1.5 degrees Celsius as being in line with the Paris Agreement and consequently, the emission reduction levels for the EU would be somewhat less ambitious.
[4] The IAMC 1.5 degree Celsius scenario explorer is available online at: https://data.ene.iiasa.ac.at/iamc-1.5c-explorer/.
[5] This reflects the global 2015 share of energy- and process-related CO_2 emissions in total energy- and process-related GHG emissions of 87%.

years after 2030, the required emission reduction exceeds the reduction potential at the maximum carbon price level included in the POLES data. Therefore, we assume the existence of a backstop-technology (e.g. a negative emissions technology) and scale the minimum sectoral emission levels in POLES to the required level uniformly across sectors. The EU ETS emissions are derived by calibrating the emissions in the power sector and the energy-intensive industry sectors in the 2015 data from the POLES-Enerdata model to the ETS cap in 2015. More details on the methodology are provided in the technical annex.

The resulting annual emission levels for the EU ETS in 2030, 2040 and 2050 are given in Table 2. Our calculations yield a GHG budget of approximately 30 Gt CO_2e available for ETS sectors if the remaining global budget is split between countries and sectors based on cost-effectiveness as explained above.

Table 2: Annual and cumulated EU ETS GHG emissions in a globally cost-effective below-1.5-degree pathway and in the EU Long-term Strategic Vision

Gt CO_2e	2015	2030	2040	2050	2016-2050
EU ETS GHG emissions, **globally cost-effective** below-1.5-degree pathway	2.0	0.9	0.3	0.0	**30**
EU ETS GHG emissions, **EU Long-Term Strategic Vision**	2.0	1.2	0.3	0.0	**33**

Source: Own calculations. EU ETS emissions in the globally cost-effective below-1.5-degrees pathway are calculated based on data from the POLES-Enerdata model. EU ETS emissions are calculated using the mean of the scenarios 1.5LIFE and 1.5TECH based on EU (2018d), Figures 60, 61, 90 and Table 9.

We observe that even though the cost-effective budget – the effort-sharing approach most favorable to the EU – is relatively close to the mean of the two most ambitious scenarios in the EU's Vision, the budget implied by the Vision exceeds the cost-effective budget by around 10%. The estimated EU ETS budget in the EU Long-term Vision contains about 3 Gt CO_2e more than our calculated 30 Gt CO_2e budget.

However, the mismatch between the EU's current climate framework and the calculated GHG budget for ETS sectors is far more dramatic. The current ETS parameters (LRF of 1.74% up to 2020, from 2021 onwards 2.2%) implies total GHG emissions of about 25 Gt CO_2e in ETS sectors for 2016-2030 (sum of ETS caps in this period), so that only about 5 Gt CO_2e would remain for ETS sectors for the time after 2030 in the cost-effectiveness budget. Our calculations indicate that the EU ETS budget compatible with a temperature goal of 1.5 degrees remaining after 2030 would require drastic abatement action after 2030 if current policy parameters are not changed, which seems unrealistic from an economical, technical and political perspective.

Therefore, defining a more stringent pathway leading to an earlier deep decarbonization than envisioned in the current energy and climate framework up to 2030 and even earlier than in the long-term Vision is required to increase the credibility of the EU ETS being consistent with the Paris Agreement. As we show in Section 3, the ETS emission pathway implied by current ETS parameters would require unrealistically drastic action after 2030 and is therefore not compatible with the Paris Agreement. Stronger early action would increase the credibility of European climate action.

3 Deriving emission pathways for ETS sectors while staying within our assumed cost-effective budget

In this section, we present emission pathways for ETS sectors that remain within the budget of 30 Gt CO_2e for 2016-2050 we have derived from the global below-1.5-degree pathways by using data from the POLES-Enerdata model, based on the assumption of a global cost-effective splitting of the remaining emission budget. First, we compare the baseline scenario with constant ETS pathways as laid down in the current legal framework. In addition we consider two scenarios for which the 2030 target for the EU ETS is chosen based on the above introduced (global) cost-effective scenarios. This is equivalent to a reduction of ETS emissions of 61% by 2030 compared to 2005. We exclude emissions becoming net-negative in order to avoid the possibility of overshooting the target. Moreover, we assume that the LRF of the cap in its current design is the single ETS parameter to be changed.[6] We assume that changes in the LRF may only be undertaken at the beginning of each of the five year long ETS allocation periods in 2021, 2026, 2031, 2036 and 2041. As we have fixed a budget for 2016-2050 and assume no changes before 2021, the cumulative emissions in 2021-2050 are the same in all cases (about 20 Gt CO_2e).

We present the following three scenarios which are consistent with the 30 Gt CO_2e cumulative emissions between 2016 and 2050:

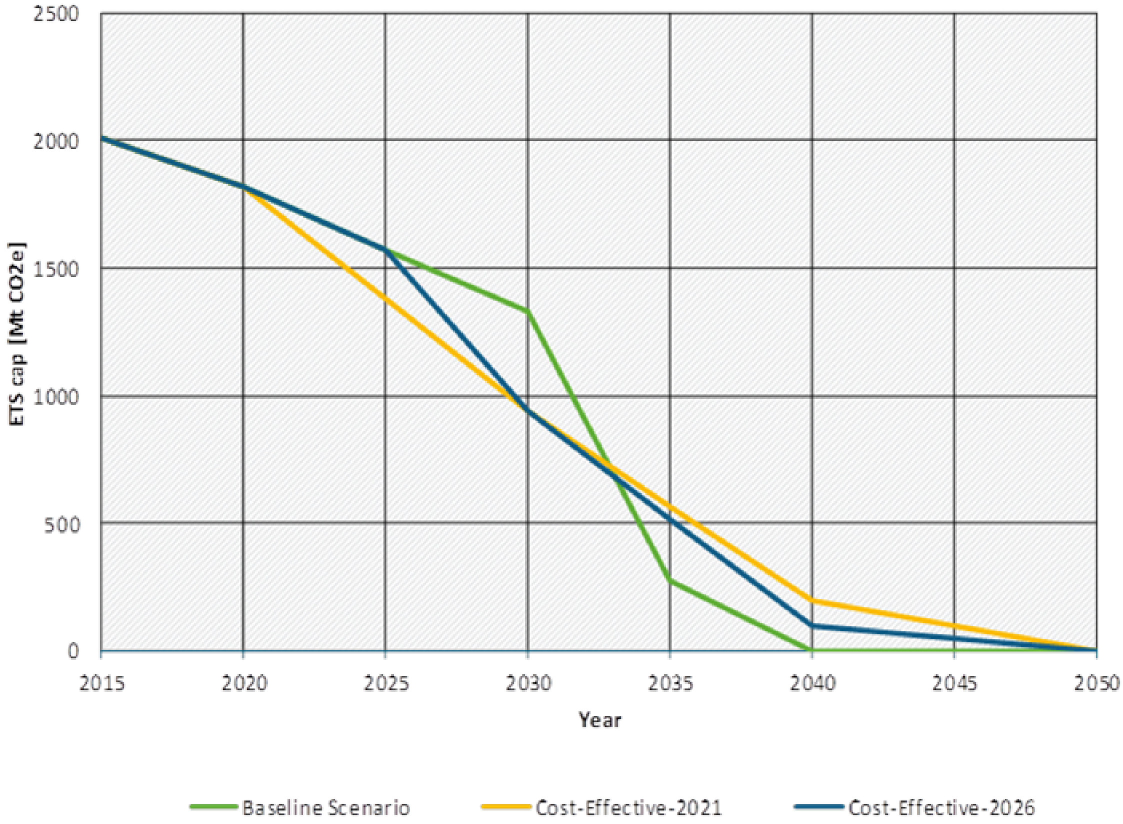
1. In the **Baseline** scenario (green line), the LRF stays at 2.2% until 2030, as under the current EU policy framework. In this case, 25.3 Gt CO_2e of the EU ETS budget are used during the period 2016-2030, with about 5 Gt CO_2e remaining for the time after 2030. Remaining within the Paris-consistent budget after 2030 would correspond to an LRF of 9.6% for 2031-2035, 2.5% for 2036-2040 and net-zero emissions by 2040.[7]
2. In the **Cost-Effective-2026** scenario (blue line), we assume that the LRF remains at 2.2% for 2021-2025 and can be adjusted in 2026. A concave reduction path is chosen for the time after 2026 to achieve cost-effectiveness (e.g. by avoiding technology lock-in) and achieve a 61% reduction in ETS sectors by 2030, compared to 2005 levels. This corresponds to LRFs of 5.8% for 2026-2030, 3.8 % for 2031-2040, 0.4% for 2041-2050 and net-zero emissions in 2050.
3. In the **Cost-Effective-2021** scenario (yellow line), we assume that the LRF can be adjusted in 2021 already. Again, we choose a concave reduction path to achieve a 61% reduction in ETS sectors by 2030, compared to 2005 levels. The Cost-Effective path in this scenario yields an LRF of 4.0% for 2021-2030, 3.4 % for 2031-2040, 0.9% for 2041-2050. Net-zero emissions are achieved in 2050.

The three scenarios are presented graphically in Figure 1.

[6] In EU ETS, the LRF is defined as the share of the cap in 2010, which is subtracted from the cap every year thereafter. An LRF of 2.2% corresponds to an annual reduction in the cap by approximately 48 million allowances.

[7] We divide the budget remaining after 2030 in a way that the maximum LRF is as low as possible, under the restriction that changes to the LRF can be made every five years only.

Figure 1: Base case and two alternative scenarios for the ETS cap 2021-2050 staying within a budget of 30 Gt CO_2e (2016-2050)



Source: Own calculations.

Maintaining an LRF of 2.2% until 2030 while staying within the 30 Gt CO_2e emissions budget as assumed in the **Baseline** scenario (green line), will lead to drastic abatement action after 2030, implying an LRF of almost 10% - a cap reduction of more than 200 million allowances each year - during the period 2031-2035. This would correspond to a decrease in the cap from about 1.3 billion allowances in 2030 to about 240 million allowances within five years. Staying within the budget of 30 Gt CO_2e while maintaining the current parameters up to 2030 would also require that net-zero GHG emissions are achieved by 2040 already.

If the LRF was adjusted in 2021 already as assumed in the **Cost-Effective-2021** scenario (yellow line), an emission pathway consistent with the 30 Gt CO_2e budget could be achieved in a more balanced way. The cap would be reduced from 1.8 billion allowances to about 930 emission allowances within 10 years (2021-2030, with an annual reduction of about 90 million allowances or a LRF of about 4%). If such an adjustment is only possible starting in 2026 as assumed in the **Cost-Effective-2026** scenario (blue line), the post-2026 LRF must temporarily be at almost 6% (that means the cap must be reduced by 130 million allowances each year) to stay within the 30 Gt CO_2e budget. In both Cost-Effective scenarios, net-zero emissions will be necessary by 2050, with some scope for emissions between 2040 and 2050.

We conclude that keeping the LRF unchanged until 2030 and remaining within the 30 Gt CO_2e emissions budget (2016-2050) that we deem to be roughly in line with 1.5 degrees will require drastic change in later years, which seems unrealistic from an economical, technical and political perspective. Adjusting the LRF in 2026 only would still require a very strong increase of emission reductions between 2026 and 2030 in order to remain in line with this budget. Only early action – raising the LRF to 4% in 2021 already – yields a relatively smooth emission pathway.

3.1 Minimum adjustment of the EU ETS cap reflecting interacting EUs energy and national climate policies

Having defined the **Baseline** scenario and the two **Cost-Effective** scenarios above, we now introduce minimum requirements for the EU ETS to restore consistency of GHG reduction and energy policies up to 2030. This would be necessary anyway to maintain the scarcity signal of EU ETS in the context of interacting EU level and national energy policies. This approach also allows us to develop an intuition of the extent of the required ambition raising in EU ETS that can already be addressed by accounting for those interacting policies.

The EU ETS cap must be sufficiently stringent in terms of market scarcity to maintain incentives for emission reductions by covered entities. If additional emission reductions in ETS sectors occur due to interacting climate and energy policies while the EU ETS cap is determined without taking these additional reductions into account, the allowance price will decline, leading to a loss in the effectiveness of the EU ETS and the additional emission reductions might not occur due to the "waterbed effect". To avoid such a loss in effectiveness, the ETS cap should take additional reductions from EU-level and national-level interacting climate and energy polies into account.

In the period up to 2030, there are two main sources of emission reductions in ETS sectors not accounted for by the current LRF of 2.2%:

1. More stringent binding energy policy targets until 2030, as defined in the *Clean energy for all Europeans package* (EU 2018e). In particular, the target for the share of renewable energy (RE) was revised from 27% to 32%, while the target for energy efficiency (EE) was increased from 27% to 32.5%. We consider the potentials for EU ETS cap adjustment due to EU energy policies in Section 3.2.
2. Several EU Member States are planning phase-outs of coal-fired power generation by 2030. If implemented fully as currently planned and coal-fired capacities are being replaced by renewable energies, these phase-outs may lead to emission reductions of up to 300 Mt CO_2 in the year 2030, compared to 2018. The potential for cap adjustment due to these national policies is evaluated in Section 3.3.

Both EU and national policies require an adjustment of the cap to maintain scarcity and avoid losses in the effectiveness of the EU ETS. We consider a cap adjustment reflecting the policies outlined above as a minimum in order to ensure scarcity, i.e. a proper functioning of the ETS by 2030. Additional adjustments must occur to bring the ETS cap in line with the required European contributions under the Paris Agreement. However, the potential for GHG savings coming from the energy measures also provide a clear political opportunity to adjust the cap in the direction which is required for a Paris compatible ETS as there are already underpinning measures and targets for their realization in place.

In Sections 3.2 and 3.3 we estimate the potentials for cap adjustment due to the respective policies. Note that reductions due to the adjusted European energy policy targets may be considered as more certain, as these targets are part of the EU governance process. In contrast, at this stage, we consider the reduction potentials from national policies to be less certain as it is not sure how much coal power will be replaced by renewable energy or by other fossil fuels. Moreover, EU level and national climate and energy policies interact, so that it is uncertain how much reduction potential will be realized from national policies in addition to the EU level targets. For these reasons we consider the additional reduction potential from European targets as a lower bound for the necessary cap adjustment in the EU ETS. National policies are likely to further increase the potential for lowering the cap, however, the magnitude of the aggregate reduction potential from the combination of EU level and national policies is not yet clear.

3.2 Potential for raising ambition in the EU ETS - Interacting EU energy policies

This section outlines the implications for EU ETS up to 2030 from aligning ETS parameters with the additional emission reductions from interacting EU energy policies introduced in the *Clean energy for all Europeans package* (EU 2018e). In particular, the targets for the RE share (32%) and the improvement in EE (32.5%) were increased compared to 2014, when the ETS parameters were adopted. It is assumed – both in the Clean energy package and in the Vision – that fully implementing all measures in the package will lead to a reduction in GHG emissions of at least 45% by 2030, compared to 1990 levels (EU 2018c, EU 2018e). This would translate to an emission reduction in the EU ETS by 49.8% in 2030, compared to 2005 levels (EU 2019).

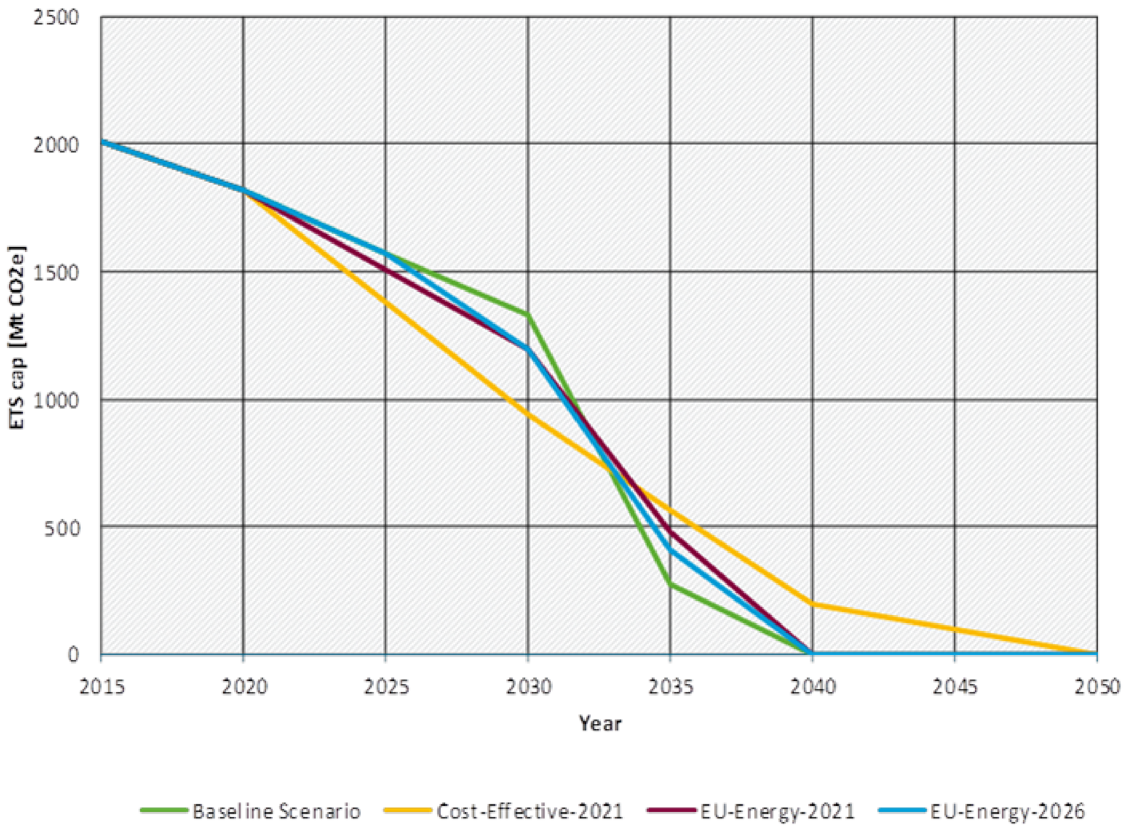
This reduction would be in excess of the current 40% emission reduction target for 2030, which implies a 43% reduction in the EU ETS by using an LRF of 2.2%. As the EU ETS cap has not yet been updated to reflect the effect of these interacting policies, keeping the LRF unchanged at 2.2% until 2030 would lead to a diminished scarcity signal and lower allowance prices in the EU ETS. This would threaten the effectiveness of the EU ETS and of the EU's target triangle consisting of emission reduction, renewable energy and energy efficiency targets. The more stringent energy policies therefore necessitate a concurrent tightening of the cap to maintain the balance of the European target triangle.

We now compare our **Baseline** and **Cost-Effective-2021** scenarios with two scenarios that take into account the potential for a tighter emission target for 2030 in ETS sectors from implementing the more stringent EU energy policies. As before, all scenarios remain within their Cost-Effective budget of about 30 Gt CO_2e for 2016-2050 which is deemed to be in line with a cost-effective contribution of EU to limiting global warming to 1.5 degrees.

1. **Baseline** scenario (green line), as in Section 3.
2. **Cost-Effective-2021** scenario (yellow line), as in Section 3.
3. In the **EU-Energy-2026** scenario (blue line), the LRF is chosen to achieve a reduction of around 50% in ETS sectors by 2030, compared to 2005 levels. Simultaneously, the EU ETS sectors remain within their Cost-Effective budget of about 30 Gt CO_2e for 2016-2050. We assume that the LRF cannot be changed before 2026. This corresponds to an LRF of 2.2% for 2021-2025, 3.5% for 2026-2030, 7.0% for 2031-2035, 3.8% for 2036-2040 and net-zero emissions by 2040.
4. The **EU-Energy-2021** scenario (red line) satisfies the same parameters as the **EU-Energy-2026** scenario, except that we assume that the LRF can be changed in 2021 already. In this case, the LRF is 2.9% for 2021-2030, 6.3% for 2031-2035, 4.5% for 2036-2040 and net-zero emissions are again achieved by 2040.

The four scenarios are presented in Figure 2.

Figure 2: Scenarios accounting for the EU Energy policy targets adopted in 2018



Source: Own calculations.

We observe that accounting for the revised energy policy targets somewhat alleviates the need for a drastic increase in ambition after 2030 of the **Baseline** scenario. However, the **EU-Energy-2026** scenario still requires a reduction of the cap by 780 million allowances within only 5 years (corresponding to an LRF of about 7%) after 2030 and net zero emissions in 2040, while the corresponding **EU-Energy-2021** scenario requires a reduction of the cap by 710 million allowances (LRF of 6.5%) between 2030 and 2035 and net zero emissions in 2040 also. Both scenarios require much more drastic emission reductions after 2030 than the **Cost-Effective-2021** scenario, which additionally leaves some remaining budget for emissions in the decade of 2040-2050.

Overall, incorporating the revised 2030 energy policy targets helps alleviating, but not avoiding the unrealistic drastic post-2030 effort of the **Baseline** scenario. To achieve a more realistic pathway towards fulfilling the EU's required contributions under the Paris Agreement, not only the new EU-level energy targets should be incorporated in an adjusted LRF, but further potentials for cap reduction should be investigated as soon as possible, ideally from 2021 already. Moreover, a reduction by 50% in ETS sectors by 2030 would no longer be in line with the updated aim of the incoming European Commission, which is planning to decrease overall EU emissions by minimum 50%, up to 55% in 2030, compared to 1990 levels (von der Leyen 2019). Due to their lower abatement costs ETS sectors would be required to abate more than proportionately to achieve cost effectiveness.

3.3 Potential for raising ambition in the EU ETS - Interacting national energy policies

Apart from energy policies at the EU level, national climate and energy policies providing additional emission reductions by 2030 must also be accounted for as a minimum requirement when adjusting the cap of the EU ETS for the period 2021/2026 to 2030 and beyond. Several member states are currently planning policies to phase out coal-fired power generation. Such national policies further increase the potential for more abatement in ETS sectors than foreseen in the current 2030 framework. As with tighter EU level energy policies, disregarding additional national measures would weaken the scarcity signal of the EU ETS, lead to lower allowance prices in the future, foster technology lock-in and decrease the likelihood of staying within an emissions budget that is compatible with limiting global warming to1.5 degrees. However, in the context of this paper, these policies are in particular also an argument that there are short term potentials available that allow for an adjustment of the ETS cap that can close the gap between the current ETS framework and an emissions budget that can be regarded as compatible with limiting global warming to 1.5 degrees.

Several member states are planning to phase out coal by 2030, with Germany planning to decommission a portion of its coal-fired capacity before 2030 and the remaining capacity until 2038 at the latest.

Table 3: Coal power generation in 2018 in countries with planned phase-outs of coal-fired power generation

TWh in 2018	Lignite	Hard Coal	Total
Phase-out before 2030	**108**	**208**	**316**
Full phase-out by 2025 (AT, BE, FR, IE, IT, SE, SK, UK)	3	58	61
Full phase-out by 2030 (DK, EL, ES, FI, HU, NL, PT)	25	96	121
Partial phase-out by 2030 (Germany)	80	54	134

Source: own calculation based on Agora (2019). Coal phase-out in Germany is based on the proposal by the WSB (2019)
Note: The estimate for Germany assumes that power generation in phased-out plants (both lignite and hard coal) is proportional to the capacity. This is an optimistic estimate, as phased-out plants are likely to have fewer full load hours and moreover remaining capacities may partially compensate the phase-out.

Table 3 summarizes national plans to phase out coal-fired power generation in TWh by 2030 compared to coal power generation in 2018 according to Agora (2019). We assume that the 316 TWh of electricity generated by coal in 2018 will be fully substituted by zero-emission electricty (i.e. renewable energy) with unchanged demand and therefore an unchanged quantity of electricity production.[8] By doing so, we show the maximum potential for adjustments of the ETS cap coming from national energy policies that are currently under discussion. If these policies are implemented as currently discussed, this would likely imply the need for a further increase

[8] In case the phased-out coal capacity is (partially) substituted by other fossil-based capacity, the emission savings will be less, depending on the substitute.

in renewable energy and improvements in energy efficiency up to 2030 compared to the current minimum targets at EU level.

We observe that the largest potential for emission reductions comes from the German phase-out of its coal-fired generation capacity. It constitutes about 42% of the planned phase-out prior to 2030. Assuming a mean carbon intensity of 1142 g/kWh for lignite and 815 g/kWh for hard coal plants (Icha 2019), we obtain about 300 Mt CO_2 emission reductions by 2030 compared to 2018 due to national policies (Table 4).[9] Again, the largest contribution to emission reductions based on national policies comes from the German coal phase-out. Due to its large share of lignite capacity, the German phase-out represents about 46% of the total European emission reduction thanks to phase-outs of coal-fired capacity.

Table 4: Planned national phase-outs of coal-fired power generation – Potential emissions reductions

Mt CO_2 compared to 2018	Lignite	Hard Coal	Total
Phase-out before 2030*	**124**	**176**	**300**
Full phase-out by 2025 (AT, BE, FR, IE, IT, SE, SK, UK)	3	49	53
Full phase-out by 2030 (DK, EL, ES, FI, HU, NL, PT)	29	81	110
Partial phase-out by 2030 (Germany)	92	46	138

Source: own calculation based on Agora (2019) and Icha (2018).

*Note: The estimate for Germany assumes that power generation in phased-out plants (both lignite and hard coal) is proportional to the capacity. This is an optimistic estimate, as phased-out plants are likely to have fewer full load hours and moreover remaining capacities may partially compensate the phase-out.

We now compare our **Baseline** scenario and the **Cost-Effective-2021** scenario with two scenarios that take into account the potential for additional reductions by 2030 in ETS sectors due to national energy policies phasing out coal-fired generation. More precisely, we assume that the 300 Mt CO_2e emission reductions from phasing out coal-fired power generation are realized in addition to the current parameters in 2030, by subtracting 300 Mt CO_2e from the ETS cap in 2030. Doing so leads to an emission reduction of 57% in ETS sectors by 2030, compared to 2005 levels, instead of approximately 43% in the Baseline and 50% in the EU-energy scenarios. As previously, all scenarios remain within their Cost-Effective budget of 30 Gt CO_2e for 2016-2050:

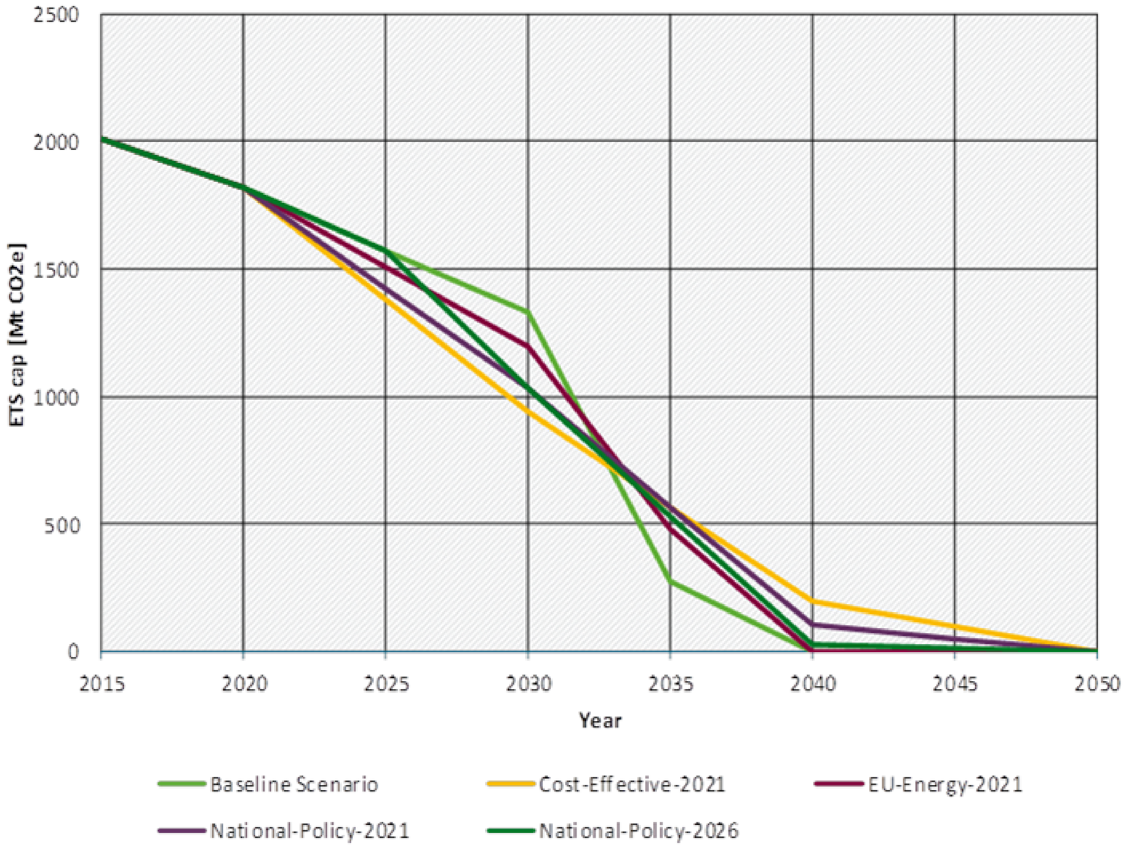
1. **Baseline** scenario (green line), as in Section 3.
2. **Cost-Effective-2021** scenario (yellow line), as in Section 3.
3. **EU-Energy-2021** scenario (red line), as in Section 3.2.
4. In the **National-Policy-2026** scenario (dark green line), we assume that the estimated emission savings of 300 Mt CO_2e from phasing out coal-fired power are realized fully by 2030, and that they are fully substituted by emission-free renewable energy. Doing so

[9] Note that the cumulative emission reductions due to the national policies in the period 2021 – 2030 are in the order of 1 Gt CO_2e, under the assumption that the phase-out of power plants occurs on average five years earlier than without the national policies and is streched over a five-year time period.

leads to an emission reduction of about 57% in ETS sectors by 2030, compared to 2005 levels. We assume that the LRF can only be changed starting in 2026. This corresponds to an LRF of 2.2% for 2021-2025, 5.0% for 2026-2030, 4.5% for 2031-2040, 0.2% for 2041-2050 and net-zero emissions by 2050.

5. The **National-Policy-2021** scenario (purple line) uses the same assumptions as the **National-Policy-2026** scenario, except that we assume that the EU ETS cap can be changed in 2021 already. In this case we compute an LRF of 3.6% for 2021-2030, 4.1% for 2031-2040, 0.5% for 2041-2050 and net-zero emissions by 2050.

Figure 3: Scenarios accounting for national coal phase-outs by 2030



Source: Own calculations.

We observe that fully accounting for the potential effects of national coal-phase out policies until 2030 – under the crucial assumption that coal-based power will be fully substituted by renewable energy – brings us close to the cost-effective solution if we assume that the LRF can be changed in 2021 already (Figure 3). The emission pathway in the **National-Policy** scenario is very similar to the **Cost-Effective-2021** scenario. The 57% decline in ETS emissions by 2030, compared to 2005, substantially exceeds the 50% decrease foreseen in the **EU-Energy** scenarios. It is closer to the 61% decline in ETS emissions, compared to 2005, achieved in the **Cost-Effective** scenarios. If the LRF can only be adjusted in 2026, we still face a steep increase in ambition after 2026. Emissions strongly decline after 2026 and we reach net zero emissions by 2040 to remain within the cost-effective budget.

However, we note that the effects of national policies on EU ETS emissions are far more uncertain than the effect of EU energy policies, since it is not clear how phased-out coal capacities will be substituted. For this reason the **National-Policy** scenarios could be considered as an optimistic scenario showing the potentials for cap adjustments coming from national policies. Our assumption that coal-based power will be fully substituted by RE likely implies that the RE targets must increase beyond the shares determined under current EU-level energy policy for 2030. However, determining precise shares of RE is beyond the scope of this paper. In a leaked version of an unpublished EC report, a so-called Non-Paper (EU 2018b), an assessment of various combinations of RE and EE targets is provided. A RE target of 45% combined with an EE target of 40% leads to a reduction of ETS emissions by 58%. This suggests that an ETS emission reduction of 57% could be roughly in line with an increase of the RE target to around 45%.

Recall that the latest analysis of the Commission (EU 2019) shows that a 50% decrease in ETS emissions by 2030, compared to 2005, is achievable if 2030 EU-level energy policy targets for 2030 are accounted for. Based on the analysis in this paper, we conclude that the 50% decrease in ETS emissions by 2030 – that is also assumed as baseline in the Vision (2018d) - should be viewed as certain only when adjusting the cap (corresponding to an LRF of 2.9% from 2021 on). Given the scale of the national coal phase-outs, the cap adjustment should also account for some additional abatement effect from national policies to maintain the integrity of the EU ETS scarcity signal. If the additional effects of national policies are fully substituted by RE, ETS emissions could decline by 57% by 2030, compared to 2005 – which is close to our **Cost-Effective-2021** scenario (61% reduction).

Even if the national policies are not fully implemented as currently discussed, or if coal-based power generation is not fully substituted by RE, the potential for adjusting the cap and the corresponding LRF is substantially larger than a 50% emission reduction by 2030 which only reflects the current targets for EE and RE at the EU level. The LRF should therefore be increased well beyond 3% in any case just in order to guarantee a scarcity signal by the EU ETS. For providing an adequate contribution to the increased overall GHG reduction target for 2030 that has been proposed by the new head of the Commission (minus 50 up to minus 55% compared to 1990, von der Leyen 2019), the LRF must be increased further, up to at least 4%.

4 Conclusions for Cap-setting in the 4th Trading Period

In this paper we derive an emission budget for EU ETS sectors consistent with the goal of keeping global warming below 1.5 degrees throughout the entire 21st century, according to the IPCC SR1.5 classification of emission pathways. We derive the share for EU ETS sectors based on assumptions favourable to the EU, in particular using the cost-effectiveness criterion for global effort-sharing. We stress that this should not be interpreted as a "fair share" or "an adequate contribution of EU ETS to the Paris Agreement". We made this choice as it allows us to compute the maximum EU budget that is still in line with the Paris goals. In this respect, the derived budget is an indicator for the appropriateness of proposals for adjusting the GHG-reduction pathway of the EU ETS which is a strictly volume based climate protection instrument. Our analysis shows that the main parameter of the EU ETS, the linear reduction factor (LRF) of its cap – set at 2.2% for the period 2021-2030 – is substantially out of line with respect to its requirements in two key dimensions:

- The LRF is too low to deliver a long-term emission path in line with the EU's required contributions under the Paris Agreement. The current LRF until 2030 would require drastic and unrealistic action after 2030 to remain within an emissions budget based on cost-effective international effort sharing (let alone an emissions budget that considers fairness criteria).
- The LRF no longer reflects a changed climate and energy policy framework at the European and national levels: At the European level, stricter targets for renewable energy and energy efficiency have been set in 2018, while several EU member states plan to phase out coal-fired power generation. An unadjusted LRF – in the context of concurrently more stringent companion policies – diminishes the scarcity signal of the EU ETS and threatens its effectiveness as an integral component of the European climate policy framework.

In our analysis we find that an appropriate increase in the LRF can re-align the EU ETS along both dimensions.

- An increase to 2.9% for the period 2021-2030 or to 3.5%, if the adjustment can only take place in 2026, is the minimum that will bring the EU ETS in line with already-set renewable energy and energy efficiency targets at the European level. However, such a minimal adjustment does not reflect additional emission reductions from national coal-phase out policies. Moreover, it would still require drastic – and likely unrealistic – additional abatement efforts in ETS sectors after 2030 to remain within an emission budget consistent with a cost-effective below-1.5-degrees pathway.
- An adjustment in the LRF to 3.6% for the period 2021-2030 or 5.0%, if the LRF can only be adjusted in 2026, would additionally ensure consistency with national coal phase-out policies, under the assumption that coal-fired power generation capacity will be fully replaced by a combination of renewable energy and gains in energy efficiency. However, remaining within an emission budget consistent of a cost-effective below-1.5-degree pathway would still require strong additional action after 2030.
- Fully aligning the LRF with the cost-effective emission budget consistent with a below-1.5-degree pathway and safeguarding the emission pathway set out in the EU's long-term Vision (2018) would require an LRF of 4.0% between 2021 and 2030, or 5.8% if the LRF can only be adjusted in 2026. Such a budget would result in more realistic climate action requirements after 2030 and set the EU ETS on a credible long-term course.

We conclude that alleviating the deficiencies in the LRF with respect to already decided EU and member-state-level policies will go a significant way towards ensuring that EU ETS sectors will deliver the emission reductions required under the EU's international climate policy commitments. It would also safeguard the effectiveness of the EU ETS with respect to other European climate policies and the long-term reliability of the EU ETS. Doing so should therefore be a priority in the forthcoming debate on raising ambition in the period up to 2030.

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A Technical annex

A.1 Detailed methodology for deriving cumulative emissions associated with the European Commission's Long-term Strategic Vision

While Article 15 of the EU Governance Regulation (EU 2018b) requires the Commission's Long-term Strategic Vision (EU LTS) to address the scenarios' implications with regard to the remaining global and Union carbon budget, the budget considerations in the Commission's Long-term Strategic Vision (in the following we use "draft EU LTS") are rather limited. For the scenarios considered in the In-depth Analysis (EU 2018d), cumulative net carbon emissions (incl. LULUCF) are presented in Table 9 without discussing the implications.

To assess the implications of a pathway consistent with a global warming of 1.5 degrees Celsius for the EU ETS, we derive cumulative emissions for the EU ETS. The EU LTS includes two scenarios that are stated to be consistent with a global pathway limiting warming to 1.5 degrees Celsius namely 1.5TECH and 1.5LIFE (EU 2018c). For our assessment of the EU ETS budget, we thus consider the cumulative GHG emissions of the mean of the scenarios 1.5TECH and 1.5LIFE as a proxy for an emission budget target consistent with the Vision's goal of achieving net-zero emissions by 2050. The total GHG emissions given there include GHG emissions from international transport, but exclude LULUCF. For a comparison with similar estimates, we consider total GHG emissions without LULUCF and remove GHG emissions from international transport based on data from the In-depth Analysis. Here, we assume that 10% of aviation is domestic and that the scenario 1.5LIFEMar for international transport is used in both 1.5TECH and 1.5LIFE.

The emission reduction in the scenarios 1.5TECH and 1.5LIFE is strongly non-linear between 2020 and 2050. We, hence, cannot estimate the cumulative emissions based on a linear pathway. However, the EU LTS does not provide information on the emission levels between 2030 and 2050 except for sectoral emissions of the scenarios 1.5TECH and 1.5LIFE in Figure 90 of the In-depth Analysis. The data underlying this figure has been published on the EC website as supplementary information. We use this data to derive the total 2040 emission levels and estimate the EU ETS emissions in 2040 based on remaining emissions in the energy and the industry sector as well as negative emission from the use of CCS.

The In-depth Analysis provides information on the GHG emissions in the scenarios 1.5TECH and 1.5LIFE in 2030 and 2050 but for the EU ETS only in 2050 (in Table 9). However, all scenarios considered in the EU LTS differ only very little before 2030. They are all based on the policies and regulations currently in place, in particular the RES 2030 target of 32% and the energy efficiency 2030 target of 32.5%. The same assumptions are the basis for the scenario EUCO3232.5 considered in a recent technical note (EU 2019). Moreover, all scenarios are based on the model PRIMES. Therefore, we assume that the data on the EU ETS emission in the scenario EUCO3232.5 for 2026 and 2030 applies to the scenarios 1.5TECH and 1.5LIFE as well. The EUCO3232.5 scenario specifies ETS emissions for the 2013 scope including aviation. Here, we work with the 2013 scope excluding aviation. Therefore, we apply the relative reductions in the scenario EUCO3232.5 (–32.8% by 2026 and -49.8% by 2030) instead of the absolute values. For 2015 and 2020, we assume that the current cap applies.

As no information for further intermediate years is available, we assume a linear decline in 2015-2020, 2020-2025, 2025-2030, 2030-2040 and 2040-2050 in the calculation of the cumulative emissions for the period 2016 to 2050. For the calculation, we multiply the mean of the end and start year of the various periods with the corresponding number of years, and add up the results for all periods. Afterwards, we add half of the value in 2050 and reduce the result by half of the value in 2015. The final results can be shown to be equivalent to the cumulative emissions for 2016-2050 after a linear interpolation to all intermediate years. For the total cumulative GHG emissions in 2016-2050 (excl. LULUCF and international transport), we end up with 78 Gt CO_2e[10]. For the GHG emissions in EU ETS sectors in 2016-2050, we find cumulative emissions of 33 Gt CO_2e (see Table 5).

Table 5: Annual and cumulated GHG emissions of the EU Long-term Strategic Vision (mean of the scenarios 1.5LIFE and 1.5TECH)

[Gt CO_2e]	2015	2020	2030	2040	2050	2016-2050
Total GHG (excl. LULUCF incl. international transport)	4.6	4.1	3.1	1.2	0.4	85
Total GHG (excl. LULUCF and international transport)	4.3	3.8	2.8	1.0	0.3	76
EU ETS GHG emissions	2.0	1.8	1.2	0.3	0.0	33

Source: Own calculations (Fraunhofer ISI) based on EU (2018d), Figures 60, 61, 90 and Table 9. Emission levels are calculated using the mean of the scenarios 1.5LIFE and 1.5TECH

A.2 Detailed methodological considerations for deriving emission budgets for the EU ETS

In the main report, we present a globally cost-effective EU ETS share of the global 1.5 degree Celsius emission pathways based on data from the IPCC SR1.5, the corresponding scenarios and the POLES-Enerdata model and the 2018 Enerfuture global energy scenarios[11]. Our calculations are based on the class of pathways called below-1.5-degrees pathways in the IPCC SR1.5. This most ambitious class of pathways is defined as achieving a probability of 50 – 66% of staying below 1.5 degrees Celsius of warming for the entire 21st century. These pathways are, hence, as close as possible to the requirement of limiting global warming to 1.5 degrees Celsius with 66% probability, as stated by UBA (2018). Here, we describe the technical details how we translate the global budget into an emission budget for the EU ETS step by step.

Step 1: Derive a global pathway for energy- and process-related CO_2 emissions based on below-1.5-degree pathways in the IPCC SR1.5 and the corresponding data in the IAMC 1.5 degrees scenario explorer

As the marginal abatement cost curve data from the ENERDATA-Poles model we use applies to the energy- and process related emissions only, we require these for the below-1.5-degrees pathways. Therefore, we derive the median level of global energy- and process-related CO_2 emissions (called fossil fuel and industry emissions in the IPCC SR1.5 and the IAMC 1.5 degrees Celsius scenario explorer) for the years 2025, 2030, 2040 and 2050 from the IAMC 1.5 degrees

[10] The In-depth Analysis lists cumulative CO_2 emissions of 48 – 49 Gt CO_2 for 2018-2050. We note that these include LULUCF and exclude non-CO_2 GHG emissions. Moreover, the period considered differs from ours by two years characterized by high emissions.

[11] See https://www.enerdata.net/solutions/poles-model.html for a description of the POLES model and https://www.enerdata.net/research/forecast-enerfuture.html for a description of the Enerfuture global energy scenarios

Celsius scenario explorer (see Table 6). The figures for 2030 and 2050 are consistent with those provided for the below-1.5 degrees Celsius pathways in Table 2.4 of the IPCC SR1.5.

Table 6: Global energy- and process related CO_2 emissions in the median below-1.5 degrees Celsius pathways in the IAMC 1.5 degree scenario explorer

[Gt CO2]	2025	2030	2035	2040	2050
Median of the below-1.5-degrees pathways	25.6	16.4	9.8	6.0	1.0

Source: Own calculations (Fraunhofer ISI) based on the IAMC 1.5 degree scenario explorer

Step 2: Derive a global pathway for energy- and process-related GHG emissions by estimating non-CO_2 energy- and process-related emissions

Next, we need to take into account non-CO_2 GHG emissions because both the data on the ETS in the Commission's In-depth Analysis (EU 2018d) and the data from the POLES-Enerdata model we use include non-CO_2 emissions. We note that while there are large uncertainties about the reduction of non-CO_2 emissions from agriculture and waste, non-CO_2 emissions in the EU ETS have been reduced to less than 1% of the total cap already. Hence, for the calculations regarding ETS sectors, non-CO_2 emissions do not play a major role quantitatively. We translate the energy- and process-related CO_2 emission levels into energy- and process-related GHG emission levels by adding a fixed increase of 15% to the energy- and process-related CO_2 emissions[12] throughout the period with positive emissions. In particular, this results in 18.9 Gt of CO_2e energy- and process-related emissions globally in 2030 and 1.1 Gt CO2e in 2050. As the share of energy-related non-CO_2 emissions in the EU is substantially smaller, this may lead to a slight overestimation of the EU emission budget in the end.

Step 3: Derive corresponding regional and sectoral emission pathways by applying a global carbon price pathway based on the POLES-Enerdata model (2018 version)

We translate the global energy- and process-related GHG emission pathways for the period 2016 – 2050 into national emission levels by applying a globally uniform shadow carbon price pathway that yields the globally required emission reductions in the POLES-Enerdata model. The required carbon price level is 220 USD/t in 2025, 800 USD/t CO2e in 2030. For the years after 2030, the required emission reduction exceeds the reduction at the maximum carbon price of 1200 USD/t in POLES-Enerdata. Therefore, we assume the existence of a backstop-technology (e.g. a negative emissions technology) and scale the minimum sectoral emission levels in POLES to required level uniformly across sectors. Then the globally uniform shadow carbon price is applied to derive a cost-effective share of the global emission pathway for the EU. The described scaling of the emissions after 2030 is applied here as well. This results in energy- and process-related GHG emission level in the EU of 1.7 Gt CO_2e in 2030, 0.5 Gt CO_2e in 2040 and 0.1 Gt CO_2e in 2050 (see Table 7).

Table 7: Annual energy- and process-related GHG emissions of the EU in a cost-effective pathway compatible with a global below-1.5-degrees pathway

[Gt CO_2e]	2025	2030	2035	2040	2050
EU energy- and process-	2.7	1.7	1.0	0.5	0.1

[12] This reflects the global 2015 share of energy- and process-related CO2 emissions in total energy- and process-related GHG emissions of 87%.

[Gt CO_2e]	2025	2030	2035	2040	2050
related GHG emissions					

Source: Own calculations (Fraunhofer ISI) based on data from the ENERDATA-Poles model

Step 4: Derive consistent evolution of the emission cap for the EU ETS sectors

The ENERDATA-Poles model provides data on the level of sub-sectors for the electricity sector as well as for the steel, the cement and the chemical industry. We use the sum of these four sectors as a basis for the estimate of the emissions under the stationary ETS. To this end, we calibrate their sum for 2015 to the EU ETS emissions, where they made up roughly three quarters of the EU ETS emissions. Other options here would be to use the total industry emissions or the total energy-sector emissions from ENERDATA-Poles for the calibration. This changes the estimate by less than 2%. Our choice is based on the fact that the selected sectors include almost no non-CO_2 emissions, thereby leading to less uncertainty in this regard. Then, the globally uniform shadow carbon price is applied to derive a cost-effective share for all the sectors in the EU. The emissions of the electricity, the steel, the cement and the chemical industry are used to estimate the EU ETS emission levels based on the calibration for 2015. This results in EU ETS emissions of 0.9 Gt CO_2e in 2030, 0.3 Gt CO2e in 2040 and net-zero emissions in 2050 (see Table 8).

Step 5: Derive a cost-effective EU ETS budget by calculation the cumulative emissions of the EU ETS sectors in a cost-effective pathway

Analogously with the calculation for the draft EU LTS, we assume a linear decline in 2015-2020, 2020-2025, 2025-2030, 2030-2040 and 2040-2050 in the calculation of the cumulative emissions for the period 2016 to 2050. For the calculation, we again multiply the mean of the end and start year of the various periods with the corresponding number of years, and add up the results for all periods. Afterwards, we add half of the value in 2050 and reduce the result by half of the value in 2015 to obtain the result for the period 2016 to 2050. In this way, the cost-effective GHG emission budget for the EU ETS is calculated to be about 30 Gt (see Table 8).

Table 8: Annual and cumulated GHG emissions of the EU ETS in a cost-effective pathway compatible with a global below-1.5-degrees pathway

[Gt CO_2e]	2015	2020	2030	2040	2050	2016-2050
EU ETS GHG emissions	2.0	1.8	0.9	0.3	0.0	30

Source: Own calculations (Fraunhofer ISI) based on data from the ENERDATA-Poles model