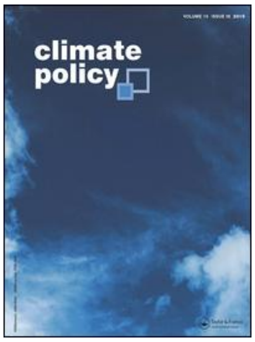

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RESEARCH ARTICLE

The EU ETS to 2030 and beyond: adjusting the cap in light of the 1.5°C target and current energy policies

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ABSTRACT

The Paris Agreement calls on countries to pursue efforts to limit global average temperature rise to 1.5°C. We derive a 2016–2050 emission budget for the EU Emissions Trading System (EU ETS) based on cost-effectiveness criteria aimed at achieving the 1.5°C target with a 50%–66% probability, and translate it into a cap reduction path. We show that, under current ETS parameters, the vast majority of this budget will be consumed by 2030. Meeting the budget under current 2030 EU ETS parameters would require drastic – and probably unrealistic – additional efforts after 2030. We derive a cost-effective scenario delivering a smoother and more credible emission pathway. We show that recently increased EU targets for renewable energy and energy efficiency, along with national coal phase-out policies up to 2030 provide cap adjustment potential. If the cap is adjusted to reflect these policies and if phased-out coal capacities are fully substituted through renewable energy, emissions in ETS sectors could decline by 57% through to 2030. This approximates our cost-effective scenario and translates into a linear reduction factor (LRF) for the cap of 3.6% for the period 2021–2030.

Key policy insights:

- Paris Agreement-compatible emission budgets can serve as a guideline to define the minimum requirement for emission reductions in the EU ETS.
- The globally cost-effective emissions budget for EU ETS sectors in line with limiting global warming to 1.5°C is about 30 Gt CO_2e for 2016–2050.
- During the next decade the annual emissions cap must decrease much faster than currently planned to meet the cost-effective budget.
- Achieving a globally cost-effective emissions path requires that the linear reduction factor (LRF) of the EU ETS cap for 2021–2030 is raised from currently 2.2% to at least 4%.
- Incorporating EU targets for renewable energy and energy efficiency, as well as national coal phase-outs, enables an increase of the LRF for 2021–2030 to 3.6% without an additional abatement burden on EU ETS installations.

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1. Introduction

Under the Paris Agreement (UNFCCC, 2015), governments agreed to a long-term goal of keeping the global temperature increase to well below 2°C above pre-industrial levels, and pursuing efforts to limit the increase to 1.5°C. The urgency to target the 1.5°C goal has increased with the publication of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C (IPCC SR1.5), which clearly demonstrates that risks from a 2°C global temperature increase are significantly greater than those of 1.5°C warming

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(IPCC, 2018). This long-term challenge has largely remained unchanged in the context of the human and economic fallout of the COVID-19 pandemic, including a likely short-term drop in greenhouse gas (GHG) emissions.

This paper focuses on the European Union, one of the relatively more ambitious regions in terms of climate policy. Specifically, we consider the GHG emissions covered under its Emissions Trading System (EU ETS). Approximately 40% of European and 4% of global GHG emissions are covered by the EU ETS (Ellerman et al., 2016).[1] Given the centrality of the EU ETS to European climate policy, it is important to set EU ETS parameters in line with the requirements set by the Paris Agreement's temperature goals. The EU ETS cap defines the maximum emission limit for ETS sectors. The linear reduction factor (LRF) determining the annual reduction of the EU ETS cap is currently set at 2.2% for the fourth Trading Period from 2021 to 2030 (EU, 2018a). This corresponds to a 43% reduction of emissions by 2030 compared to the 2005 emission level. Together with a reduction target for non-ETS sectors of 30% by 2030, also from 2005, this implies a reduction of total EU domestic GHG emissions by at least 40% compared to 1990, in line with the EU's Nationally Determined Contribution (NDC). However, this level of European commitment to GHG mitigation was insufficient with regard to the requirements under the Paris Agreement (Wachsmuth et al., 2019). Recently, the EU's NDC was updated to a decrease in overall EU emissions by 55% by 2030, compared to 1990 levels (EU, 2020b); this has, however, not been translated into an updated EU ETS target yet.

Moreover, the EU ETS is not the only policy in Europe affecting GHG emissions. At the European level it forms a policy triad together with renewable energy and energy efficiency targets, while further policy initiatives occur at the national and even local level. While addressing these policy overlaps is required from an effectiveness perspective (e.g. Böhringer et al., 2009), their existence also offers potentials to improve the overall level of ambition in ETS sectors and better align them with the Paris targets (Schlomann & Eichhammer, 2014). Recent policy initiatives at the EU level have increased the stringency of EU level renewable energy and energy efficiency targets (EU, 2018b), while several EU member states are planning to phase out coal-fired power generation and may voluntarily cancel allowances as a result. These changes necessitate an adjustment of the EU ETS cap to avoid a surplus of emission allowances, which leads to market inefficiencies, e.g. a diminished scarcity signal in the European carbon market such as observed after the financial crisis in 2009 (Joltreau & Sommerfeld, 2019). For example, as we show in this paper (Section 3.3), cumulative emission reductions due to national coal phase-out policies in the period 2021–2030 are in the order of 1 Gt CO_2e. A significant allowance surplus would therefore develop if the cap is not adjusted to reflect this emission reduction due to interacting policies. The literature has developed a variety of proposals on how to maintain scarcity in the EU ETS, from delegating cap setting power to an independent authority akin to a central bank (De Perthuis & Trotignon, 2014) to introducing a price collar (Fuss et al., 2018) and flexibility in the cap (Meunier et al., 2018).

The objective of this paper is to enrich the debate on cap setting for the EU ETS by considering the implications of the Paris Agreement's temperature goals as well as European and national energy policies for the EU ETS, and deriving recommendations on setting an appropriate cap pathway going forward. As the cap is the crucial parameter for determining the level of ambition of any ETS, it is the central lever for enforcing an EU ETS budget and an emissions reduction pathway for the period 2021–2030 and beyond that may be regarded as compatible with the Paris Agreement while ensuring scarcity on the allowance market at the same time.[2]

We further contribute by taking up one important point so far often neglected in the policy literature on national target setting – contrary to economic intuition – and only slowly making its way from scientific circles to political decision makers: we apply a budget approach to remaining emissions instead of considering figures for specific target years only, the approach currently prevailing in discussing national reduction targets (see e.g. Höhne et al. (2014) for an overview). It is clear from a climate-science perspective that the determining factor for climate change is not the GHG emissions in one particular year, but cumulative GHG emissions over long time periods due to the long lifetime of GHGs in the atmosphere (see e.g. IPCC, 2013). This is why IPCC reports refer to remaining GHG or carbon budgets in addition to discussing emission targets for specific years and regions (e.g. IPCC, 2013; IPCC, 2018). The importance of following an emissions budget approach is thus well-established in climate science and budgets are – of course – a common concept in economics. However, so far emissions budgets have not featured strongly in the climate policy debate.

We derive an EU-wide emission budget compatible with a 1.5°C target and split it between ETS and non-ETS sectors based on the cost-effectiveness criterion (cf. Höhne et al., 2014).[3] This means that the emission reduction of globally cost-minimizing mitigation pathways is split in such a way that the marginal abatement cost is the same across countries and sectors (see Annex A.2 for details). It is well-known that there is great uncertainty about future abatement cost developments and thus about cost-effective mitigation pathways. For the globally cost-minimizing pathways, we therefore rely on the IPCC SR1.5 and the associated database that covers the existing range of integrated assessment models. As that database, however, does not include regional data for the EU, our regional and sectoral split of emissions is based on data from the POLES-Enerdata model. This limits the use of a single model to a step with lower uncertainty, given the better-founded evidence on sectoral and regional differences. While using other models and budget splitting approaches will still result in certain changes to the EU's emission budget, an important observation is that using criteria other than cost-effectiveness will lead to (much) lower emission budgets for the EU (cf. Wachsmuth et al., 2019). Therefore, the cost-effective emission budget derived in this paper provides a lower bound for the required level of EU ambition.

We take the analysis further by analyzing concrete policy consequences for EU ETS cap setting. In addition, we use the results of our analysis to assess what national policies such as a coal phase-out or the increase in the EU's targets for energy efficiency and renewable energies for 2030 could mean with regard to an increase in ambition for the EU ETS cap and in relation to a 1.5°C-compatible EU ETS budget. The policy-driven cap pathways for 2030 and beyond are compared to a pathway with a 2030 target in line with the global pathways, which we also derive from the POLES data based on the cost-effectiveness criterion. For reasons of consistency of the EU pathway with the global IPCC pathways, we do not carry out an inter-temporal cost minimization based on the POLES data.

The remainder of this article consists of three sections and a technical annex. In the first section we derive a Paris Agreement-compatible EU ETS emission budget using two main documents as the framework: First, the IPCC SR1.5 provides information on global remaining emission budgets compatible with different temperature goals. Second, the 'Strategic Long-Term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy (Vision)' proposed by the EU Commission in November 2018 derives scenarios targeting net emission neutrality by 2050 (EU, 2018c). In the second section, we derive a set of emission pathways for ETS sectors that all remain within the allotted GHG budget, while achieving different 2030 objectives. 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 to safeguard the scarcity signal and thus effectiveness of the EU ETS over the next decade. For this purpose, we develop scenarios incorporating both increased renewable energy and energy efficiency targets at the European level and national energy policies, in particular coal phase-out policies. The third section contains a summary and our main conclusions. The annex provides detailed information on our methodology for deriving emission budgets and cumulative emissions for the EU ETS.

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

2.1. Cumulative emissions under the IPCC SR1.5 and the EU Commission's long-term strategic vision

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°C above pre-industrial levels, and pursuing efforts to limit the increase to 1.5°C. It was also agreed that emissions should peak as soon as possible and decline rapidly thereafter, in accordance with the best available science.[4] Parties have to regularly submit Nationally Determined Contributions (NDCs) declaring their emission mitigation targets or actions.

IPCC SR1.5 indicates that risks from a 2°C temperature increase are significantly more substantial than those of 1.5°C warming, which strongly suggests that global climate action should avoid large overshoots of the 1.5°C goal in addition to keeping the increase well below 2°C. How to achieve this in terms of mitigation pathways is addressed by targeting global cumulative emissions of GHG/CO_2 up to 2100 – a so called emission budget. According to the IPCC SR1.5, to limit warming to 1.5°C with a probability of at least 66%, with no temporary overshoot, a global carbon budget of 420–570 Gt CO_2 remains – depending on the assumed emission pathway for other GHGs and the method used (IPCC, 2018). However, there are large uncertainties associated with the budget, in the order of several hundreds of Gt CO_2 (IPCC, 2018). Therefore, the budget could also be substantially smaller, due to, among others, the impact and mitigation potential of non-CO_2 GHG emissions.[5]

As a benchmark for our analysis, we 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). 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, assuming that this means reaching net-zero GHG emissions in 2050. We derive EU ETS emissions of the net-zero GHG scenarios from the In-depth Analysis accompanying the Long-Term Vision (EU, 2018d). We consider the cumulative GHG emissions of the mean of the scenarios 1.5TECH and 1.5LIFE, both targeting net-zero GHG emissions in 2050, as an emission budget target consistent with the Vision's goal of achieving net-zero emissions by 2050. Details regarding our calculations and the underlying assumptions can be found in the technical annex (Section A.1).

Our calculations yield cumulative GHG emissions of 33 Gt CO_2e (see Table 1) in EU ETS sectors for 2016–2050. 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 only a reduction by 43% up to 2030 (compared to 2005) will be delivered by current EU ETS parameters:

The scenarios used to derive the emission budget according to the Vision (EU, 2018c) are mainly based on the current EU 2030 framework and the assumption that net-zero GHG emissions in 2050 are in line with limiting global warming to 1.5°C. However, we need to evaluate whether cumulative emissions implied by these scenarios are also in line with the global budget requirements for limiting global warming to 1.5°C. We tackle this question in the next subsection.

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

In this section, we derive an emission budget for the EU ETS from a specified global GHG budget. However, deriving an emissions budget for the EU 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 such that the global cost of emission mitigation is minimized. Using fairness criteria, e.g. based on population shares, considering economic capacities, accounting for historical emissions, or other metrics, decreases the share of the total emission budget available for the EU substantially. 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 inside the EU 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). Applying the cost-effectiveness criterion to derive the EU's share of a specified global emission budget and using this budget as basis for deriving EU ETS share of the global emission budget, sets the available budget for the EU ETS at the maximum of what could be regarded as being in line with the requirements of the 1.5°C temperature goal. This allows us to assess

Table 1. Annual and cumulated EU ETS GHG emissions in a globally cost-effective below-1.5°C pathway and in the EU Long-term Strategic Vision.

Gt CO2e	2015	2030	2040	2050	2016–2050
EU ETS GHG emissions, globally cost-effective below-1.5°C 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°C pathway are calculated based on data from the POLES-Enerdata model. EU ETS emissions are calculated using the average of the scenarios 1.5LIFE and 1.5TECH based on EU (2018d), Figures 60, 61, 90 and Table 9.

whether the two relevant scenarios in the EU's Vision leading to net-zero emissions by 2050 (1.5TECH and 1.5LIFE) are in line with the mitigation requirements in terms of cumulative emissions of the EU ETS.

Our calculations are based on the class of pathways called 'below-1.5°C pathways' in the IPCC SR1.5. This class of pathways is defined as achieving a probability of 50%–66% of staying below 1.5°C of warming for the entire twenty-first century. We apply data from the POLES-Enerdata model to derive the globally cost-effective EU share of the global emission pathways in each time step and translate the global energy- and process-related GHG emission pathways for the period 2016–2050 into national emission levels. EU ETS emissions are derived by matching the historical emissions in the power sector and the energy-intensive industry sectors of the POLES-Enerdata model to the ETS emission level. More details on the methodology and the model data are provided in the technical annex (Section A.2).

The resulting annual emission levels for the EU ETS in 2030, 2040 and 2050 are also shown in Table 1. 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.

We observe that even though the cost-effective budget – the effort-sharing approach most favourable 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%, that is 3 Gt CO_2e.

However, the mismatch between the EU's current climate framework and the calculated GHG budget for ETS sectors is far more dramatic. Too large a share of the emission budget is allocated to the decade 2021–2030, with the remaining share being too small for a credible pathway toward staying within the 1.5°C budget: Summing up the EU ETS cap for each year of the period 2016–2030 shows that current ETS parameters (LRF of 1.74% up to 2020, 2.2% from 2021 onwards) imply total GHG emissions of about 25 Gt CO_2e in ETS sectors for 2016–2030. Only about 5 Gt CO_2e would remain for ETS sectors for the time after 2030 in the cost-effective budget.

Our calculations in Section 3 suggest that the EU ETS budget compatible with a temperature goal of 1.5°C remaining after 2030 would require drastic – and politically unlikely – abatement action after 2030, unless current policy parameters for 2021–2030 are changed. Therefore, defining a more stringent pathway leading to an earlier deep decarbonization than envisioned in the current European energy and climate framework up to 2030 and even earlier than in the long-term Vision is required to increase the likelihood that the EU ETS will be consistent 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 the assumed cost-effective budget

In this section, we present emission scenarios for ETS sectors that remain within the cost-effective budget of 30 Gt CO_2e for 2016–2050. Current legislation defines ETS trading periods of ten years with a possible revision after five years. For all scenarios, we therefore 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 the budget for 2016–2050 is fixed[6] and we assume that there are no changes in emissions before 2021, cumulative emissions for 2021–2050 are the same in all cases (about 20 Gt CO_2e). In all scenarios, we divide the budget remaining after 2030 such that the *maximum* per-period LRF is as low as possible. The choice to minimize the maximum LRF is motivated by political feasibility, as minimal per-period LRFs are more likely to be politically acceptable.[7] Note that relaxing the restriction that the LRF needs to be constant in each five-year period gives a solution in which the LRF is constant until an endpoint with zero emissions that normally lies within a 5-year period. We additionally derive the required year of net-zero emissions for all scenarios, if the LRF is taken to be constant after 2030.

3.1. The current 2030 framework compared to a cost-effective pathway for the EU ETS cap

First, we establish a baseline scenario with EU ETS pathways as defined through to 2030 in the current legal framework and a cap decrease in line with the remaining cost-effective budget after 2030. In addition, we consider a scenario for which the 2030 target for the EU ETS is chosen based on cost-effectiveness (cf. Höhne et al., 2014). This means that we fix a median global emissions pathway derived from the category of below 1.5° C pathways, and the required emission reduction is then split across countries and sectors in 2030 such that the marginal abatement costs are the same (see Annex A.2 for details). Note that this does not necessarily correspond to a cost-minimizing pathway over time. In fact, an inter-temporal cost minimization can be expected to lead to even faster emission reductions before 2030. However, the current legislation foresees a cap for 2030 only and the policy debate is also centred around an update of the 2030 target. Therefore, we see our pathway as a lower bound for necessary ambition, which all other scenarios can be compared to, in order to check whether they could in principle be in line with a cost-minimizing approach to global effort-sharing under the Paris Agreement or not.

Both the baseline and the cost-effective scenario are consistent with achieving 30 Gt CO_2e cumulative emissions between 2016 and 2050:

> 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. Dividing the remaining budget after 2030 such that the LRF is held constant until net-zero emissions are reached would require an LRF of 8.7% and achieving net-zero emissions in 2037. In the Cost-Effective-2021 scenario (yellow line), we assume that the LRF can be adjusted in 2021 already. The resulting cost-effective emission path achieves 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. Analogously to the Baseline scenario, applying a constant LRF to the budget remaining after 2030 would require an LRF of 2.9% after 2030. Net-zero emissions would need to be achieved in 2045. The two scenarios are presented graphically in Figure 1.

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 per 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

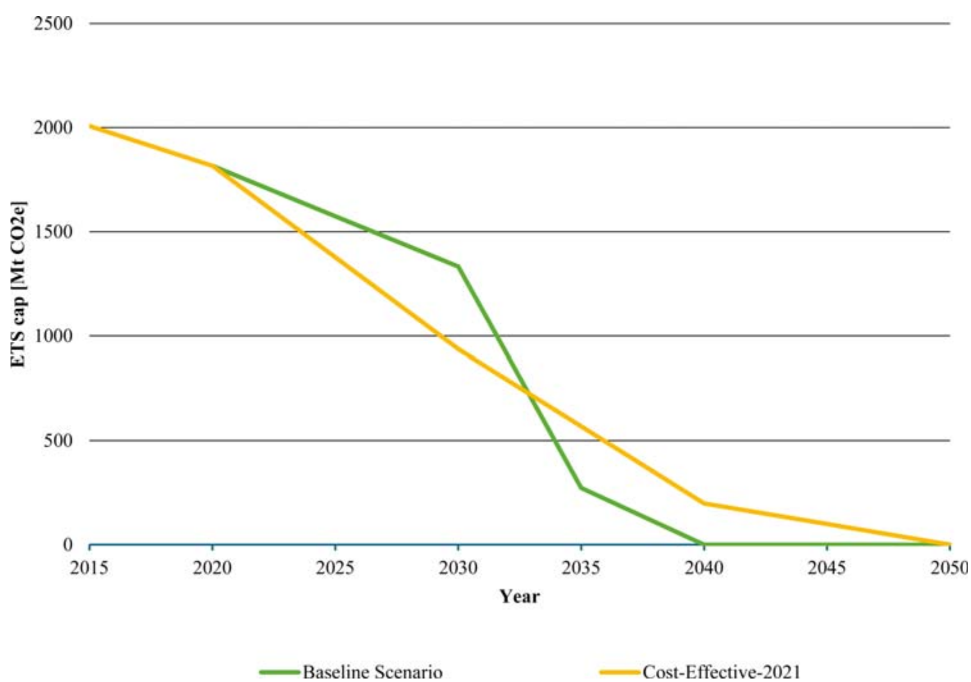

Figure 1. Base case and two alternative scenarios for the ETS cap 2021–2050 staying within a budget of 30 Gt CO_2e (2016–2050). Source: Own calculations.

five years. Minimizing the maximum LRF while staying within the budget of 30 Gt CO_2e would also require achieving net-zero GHG emissions by 2040 already.

If the LRF is adjusted in 2021, 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 from 2021 to 2030, with an annual reduction of about 90 million allowances corresponding to a LRF of about 4%. In the Cost-Effective scenario, net-zero emissions will not be required before 2050, with scope for some remaining emissions between 2040 and 2050.

We conclude that both keeping the LRF unchanged until 2030 and remaining within the 30 Gt CO_2e emission budget that we deem to be roughly in line with 1.5°C will require drastic change after 2030, which appears to be unrealistic from an economic, technical and political perspective. The earlier an increase in ambition occurs, the smoother the emission pathway after 2030 will be.

3.2. Adjustment potentials for the EU ETS cap reflecting interacting EU energy and national climate policies

Having derived the Baseline and Cost-Effective scenarios, we now consider adjustment potentials for the cap due to interacting EU level and national policies already enacted or planned for the period up to 2030. According to basic economic theory, 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, threatening the effectiveness of the EU ETS. The additional emission reductions in ETS sectors may not occur due to the 'waterbed effect' (Perino, 2018; Rosendahl, 2019). To avoid such a loss in effectiveness, the ETS cap should take additional reductions from interacting EU level and national climate and energy policies into account in any case. Doing so also provides potential to deliver a more credible emission pathway than in the Baseline scenario. Evaluating potentials for cap adjustment from interacting policies thus allows us to develop a sense of the extent of the required increase in ambition in the EU ETS that may already be addressed by accounting for interacting policies.

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 up to 2030, as defined in the 'Clean energy for all Europeans' package (EU, 2018e). In particular, the target for the share of renewable energy was revised from 27% to 32%, while the target for energy efficiency was increased from 27% to 32.5%.
2. Several EU Member States are planning phase-outs of coal-fired power generation by 2030. If implemented fully as currently planned, and if coal-fired capacities are replaced by a combination of renewable energy and increased energy efficiency, these phase-outs may lead to emission reductions of up to 300 Mt CO_2 in the year 2030, compared to 2018.

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 and the avoidance of high-carbon technology lock-in. However, the potential for GHG savings coming from the energy measures also provide a political opportunity to adjust the cap in the direction required for a Paris Agreement-compatible EU ETS achieving abatement at minimal cost.

In Sections 3.2 and 3.3, we determine the potentials for cap adjustment due to the respective policies. We view the reductions due to the adjusted European energy policy targets as more certain, as these targets are enshrined in the EU governance process. In contrast, at this stage, we believe the reduction potentials from national policies are less certain as it is not clear 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.

3.3. Potential for raising ambition in the EU ETS: interacting EU energy policies

This section outlines the implications for the EU ETS from aligning ETS parameters with the additional emission reductions interacting with recently introduced EU energy policies (EU, 2018e). In its projections, the EU Commission assumes 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 of 49.8% by 2030, compared to 2005 levels (EU, 2019a). This reduction would be in excess of the 40% emission reduction target for 2030, which implies a 43% reduction in the EU ETS by using an LRF of 2.2%.

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 by accounting for more stringent EU energy policies. These four scenarios are presented in Figure 2. As before, all scenarios remain within the cost-effective budget of about 30 Gt CO_2e for 2016–2050. For the EU energy policy scenarios, we again choose the cap pathway after 2030 such that the LRF is minimal. The LRFs for the baseline and Cost-effective scenarios are the same as in Section 3.

For 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. Setting a constant average LRF after 2030 would require an LRF of 6.4% and net-zero emissions in 2038. 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 already be changed in 2021. 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. A constant LRF applied to the remaining budget after 2030 would require net-zero emissions in 2039 and an LRF of 6.0%.

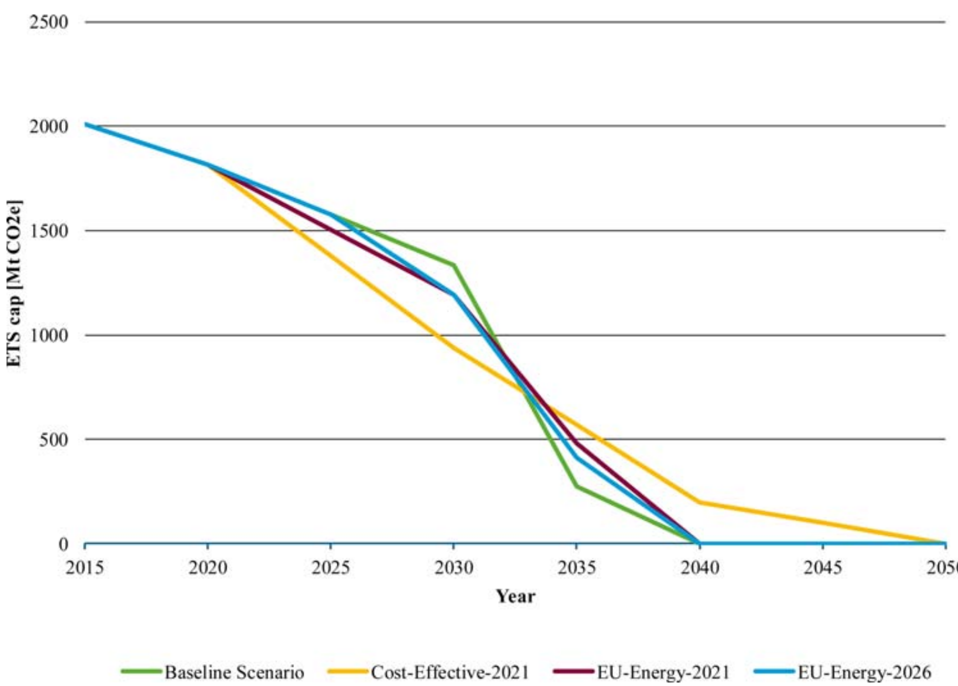

Figure 2. Scenarios accounting for the EU Energy policy targets adopted in 2018. Source: Own calculations.

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 involves a reduction of the cap by 780 million allowances within just 5 years (an LRF of about 7%) after 2030 and reaching net-zero emissions by 2040, while the EU-Energy-2021 scenario involves a reduction of the cap by 710 million allowances (LRF of 6.5%) between 2030 and 2035 and reaching 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 during the decade of 2040–2050. Overall, incorporating the revised 2030 energy policy targets helps decrease, but not avoid, the unrealistic drastic post-2030 effort of the Baseline scenario.

Note that a reduction by about 50% in ETS sectors by 2030 is no longer in line with the updated EU climate targets for 2030. The proposal by the European Commission to target a decrease in overall EU emissions by 55% in 2030, compared to 1990 levels (von der Leyen, 2019; EU 2019b), has been agreed to by the European Council (EU, 2020a) and submitted to the UN Climate Change secretariat as an update to the EU's NDC. The 55% target for 2030 can therefore be considered as the lower bound with respect to the final target. Due to their lower abatement costs ETS sectors will need to abate more than proportionately to achieve cost-effectiveness. Once the updated targets are fully enacted both the need and potentials for cap adjustment due to changes in EU policies will increase further.

3.4. 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 when adjusting the cap of the EU ETS for the period up to 2030 and beyond. Several member states are currently planning policies to phase out coal-fired power generation. Such national policies lead to more abatement in ETS sectors than foreseen under 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 high-carbon technology lock-in and decrease the likelihood of staying within an emission budget that is compatible with limiting global warming to 1.5°C. However, as in the case of EU level policies, addressing this issue provides short-term potential for adjusting the ETS cap to close the gap between the current ETS framework and an emission budget compatible with limiting global warming to 1.5°C.

Table 2 summarizes national plans to phase out coal-fired power generation in TWh by 2030 compared to 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 electricity (i.e. renewable energy) with unchanged demand and therefore an unchanged quantity of electricity production.[8] This shows the maximum potential for adjustments of the ETS cap from currently planned national climate and energy policies. If these policies are implemented as currently discussed, this would likely imply the need for a further increase in renewable energy and improvements in energy efficiency compared to the current EU level 2030 targets.

The largest potential for emission reductions comes from the German phase-out of its coal-fired generation capacity, representing about 42% of the capacity phased-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

Table 2. 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.

reductions by 2030 compared to 2018 due to national policies (Table 3).[9] Due to its large share of lignite capacity, the share of the German phase-out is even larger in terms of emissions. It represents about 46% of the total European emission reduction due to phase-outs of coal-fired capacity.

We now compare our Baseline scenario and the Cost-Effective-2021 scenario with two scenarios taking into account the potential for additional reductions by 2030 in ETS sectors due to national policies phasing out coal-fired power generation. We assume that the 300 Mt CO_2e emission reductions from phasing out coal will be realized in addition to the current ETS 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. As before, all scenarios remain within the Cost-Effective budget of 30 Gt CO_2e for 2016–2050 and minimize the speed of decarbonisation after 2030:

> Baseline (green line) and Cost-Effective-2021 (yellow line) scenarios, as in Section 3. In the National-Policy-2026 scenario (dark green line), 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. Applying a constant LRF to the post-2030 budget would require net-zero emissions in 2041, with an LRF of 4.4%. The National-Policy-2021 scenario (purple line) relies on the same assumptions as the National-Policy-2026 scenario, except that we allow for a change in the EU ETS cap 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. Here, using a constant post-2030 LRF leads to net-zero emissions in 2042 and an LRF of 3.9%.

We observe that accounting for the potential effects of national coal phase-out policies up to 2030 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-2021 scenario is similar to the Cost-Effective-2021 scenario. The 57% decline in ETS emissions by 2030 substantially exceeds the 50% decrease foreseen in the EU-Energy scenarios, and is close to the 61% decline in ETS emissions achieved in the Cost-Effective scenario. If the LRF can only be adjusted in 2026, a steep increase in ambition is still needed after 2026 and minimizing the maximum LRF while remaining within the cost-effective budget requires reaching net-zero emissions by 2040.

However, 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, we consider the National-Policy scenarios to be optimistic. Our assumption that coal-based power will be fully substituted by renewable energy likely implies that the renewable energy targets must increase beyond the shares determined under current EU level energy policy for 2030, which would in turn increase cap adjustment potentials from interacting EU policies. Determining precise shares of renewable energy is beyond the scope of this paper. However, in a leaked version of an unpublished EC report, a so-called Non-Paper (EU, 2018b), an assessment of various combinations of renewable energy and energy efficiency targets is provided. A renewable energy target of 45% combined with an energy efficiency target of 40% leads to a reduction in 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%.

An analysis by the European Commission (EU, 2019a) shows that a 50% decrease in ETS emissions by 2030, compared to 2005, is achievable if EU level energy policy targets for 2030 are accounted for. Based on our analysis the cap adjustment should also account for some additional abatement effect from national policies. Even if the national policies are not fully implemented as currently discussed, or if coal-based power generation is not fully substituted by renewable energy, the potential for adjusting the cap is certainly larger than a 50% emission

Table 3. Planned national phase-outs of coal-fired power generation – Potential emissions reductions.

Mt CO2 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	52
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 (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.

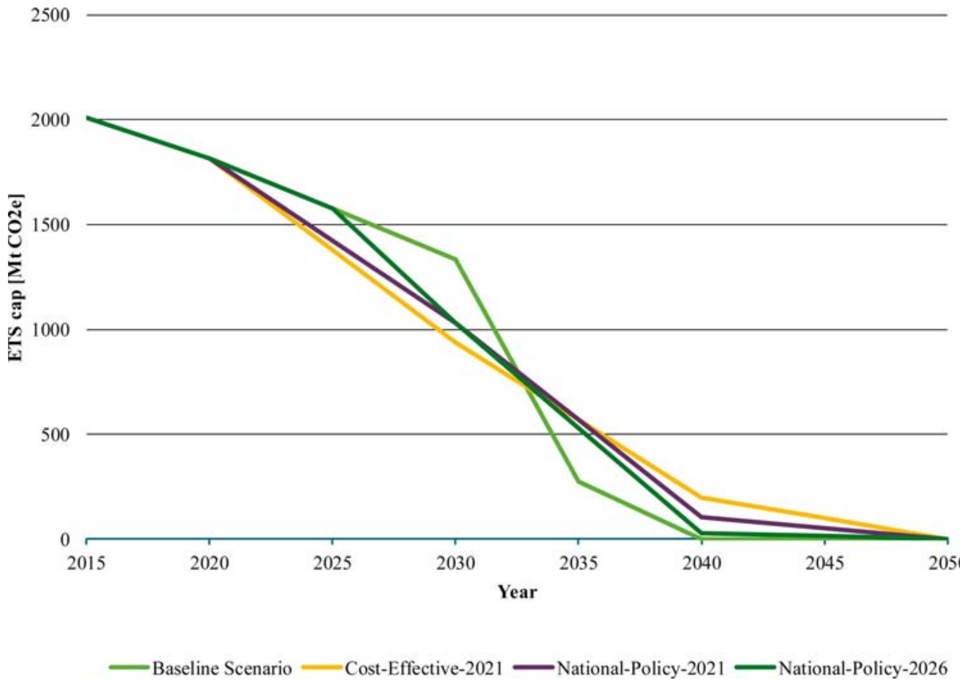

Figure 3. Scenarios accounting for national coal phase-outs by 2030. Source: Own calculations.

reduction by 2030, which only reflects the current targets for energy efficiency and renewable energy at the EU level. The LRF will therefore need to be increased to well beyond 3% to guarantee a scarcity signal by the EU ETS. To provide an adequate contribution to the strengthened overall GHG reduction target for 2030 of at least minus 55% compared to 1990, the LRF must be increased further, to a level that at least reflects the current national coal phase-out policies.

4. Conclusions

In this paper, we derive an emission budget for EU ETS sectors consistent with the goal of limiting global warming to 1.5°C throughout the entire twenty-first 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. This should not be interpreted as a 'fair share' or 'an adequate contribution of EU ETS to the Paris Agreement'. Rather, this choice allows us to compute the maximum EU budget still in line with the Paris goals. The budget we derive for the EU ETS requires a faster-than-linear decrease of the cap on the way to the 2050 net-zero target. If the 2030 cap is set at a less stringent level than the cost-effective one, its path needs to become strongly concave after 2030. This is not only costlier, but may also lead to stranded assets given the long investment cycles in the industrial sector (cf. Bertram et al., 2015; Johnson et al., 2015). This is another argument for setting a stringent 2030 cap, thereby providing a clear long-term investment signal. In contrast, setting the 2030 cap in excess of the cost-effective one, e.g. leading to a linear cap trajectory, could result in high investments in premature technologies. This suggests that an ambition level prior to 2030 beyond the cost-effective one should be avoided.

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. First, the LRF is too low to deliver a long-term emission pathway in line with the EU's required contributions under the Paris Agreement. Maintaining a 2.2% 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. Second, the LRF no longer reflects the changed climate and energy policy framework at the European and national levels: At the European level, stricter targets for renewable energy and energy efficiency were 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, as implied by the EU energy scenarios, 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°C 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. However, remaining within an emission budget consistent with a cost-effective below-1.5°C 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°C pathway would require an LRF of 4.0% between 2021 and 2030. Such a budget would result in more realistic climate action requirements after 2030 and set the EU ETS on a credible long-term course. It would also make sure that the ETS sectors provide an adequate contribution to the recently confirmed overall EU GHG emission reduction target for 2030 of at least 55%.

We conclude that alleviating the deficiencies in the LRF with respect to already-decided EU and national 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 long-term credibility of the EU ETS, and its effectiveness with respect to other European climate policies.

Our analysis shows that a significant adjustment in the cap trajectory is required during the decade 2021–2030 to set ETS sectors on a credible path towards meeting the 1.5°C goal. Targeting a short-term increase in ambition should therefore be a priority in order to safeguard the credibility of European climate policy. This implies a need for short-term adjustment in the European 2030 climate framework. To implement the required adjustment, European policy makers should place a high priority on cap adjustment in the discussions on structural reform of the EU ETS going into Trading Phase IV, also in the context of dealing with the fallout from COVID-19 with respect to the EU ETS.

Notes

1. The analysis in this paper focuses on the stationary EU ETS, assuming that its scope will remain unchanged. While scope extensions may occur in the future, the assumption of constant scope allows us to keep the analysis in this paper at a manageable length. An extension of this analysis for changes in ETS scope is a fruitful avenue for future research.
2. The effective stringency of the EU ETS cap is also influenced by the Market Stability Reserve (MSR), specifically by its cancellation mechanism (e.g. Perino, 2018; Osorio et al., 2020; Quemin, 2020). The cap may therefore also be adjusted implicitly by increasing the likelihood of allowance cancellations through the MSR, either in addition to or instead of adjusting the LRF. However, interactions between the cap and the MSR are complex and final cancellations highly uncertain (Osorio et al., 2020), so that adjustments to the MSR's cancellation mechanism cannot deliver the same long-term incentives to market participants as explicit adjustments to the cap. For this reason, this paper focuses on explicit cap adjustments through the LRF only.
3. Note that the same emission budget and the same sector split is used in all scenarios in this paper.
4. See https://unfccc.int/sites/default/files/english_paris_agreement.pdf for further details on the Paris Agreement.
5. Chapter 2 of IPCC SR1.5 provides an overview of the most likely carbon budgets (i.e. excl. non-CO_2 emissions) for different limits of global warming with associated probabilities.
6. We exclude that emissions may become net-negative during this period, i.e. we eliminate the option of overshooting the target. Moreover, we assume that the LRF of the cap in its current design is the only ETS parameter to be adjusted. In the 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. Note that this min-max approach is pursued instead of an intertemporal equalization of marginal abatement costs.

8. If phased-out coal capacity is (partially) substituted by other fossil-based capacity, the emission savings will be less, depending on the substitute.`
9. Note that the cumulative emission reductions due to 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.

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