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Carbon prices on the rise? Shedding light on the emerging second EU Emissions Trading System (EU ETS 2)

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ABSTRACT

As of 2027, the EU will implement a second Emission Trading System (EU ETS 2) to cap emissions in buildings, road transport and small industries not covered by the already existing European Emissions Trading System. Substantial uncertainty remains regarding potential price trajectories and their underlying drivers. In light of this, we explore EU ETS 2 price paths using the energy system model PRIMES. We focus on the effect of complementary efficiency policies (EPs), as earlier research suggests they could have a profound impact. Indeed, analyzing three scenarios with different EPs stringency, we find that they make EU ETS 2 prices vary between 71 EUR/tCO_2 and 261 EUR/tCO_2 in 2030. Despite different instruments driving emission abatement, comparable emission reductions at the EU level (−41%) are achieved in all three scenarios.

Key policy insights

- Energy efficiency policies at both EU and national levels are expected to significantly impact EU ETS 2 price levels
- The more stringent energy efficiency policies are, the lower the EU ETS 2 price
- Modeled EU ETS 2 prices lie in the range of 71–261 EUR/tCO_2, depending on the stringency of complementary energy efficiency policies assumed in scenarios
- Fundamentally modeled EU ETS 2 prices point to the possibility of price stability mechanisms of EU ETS 2 being triggered

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Carbon pricing; emission trading; energy efficiency; abatement cost; EU ETS; climate policy

Introduction

In 2027, a new European Emissions Trading System 2 (hereafter EU ETS 2) will be launched. While the existing EU ETS 1 regulates combustion emissions from the power sector and large industry, the new system is designed to cover the buildings and road transport sectors, as well as small industrial emitters not included in EU ETS 1 (Parliament & Council, 2023). A distinctive feature of the EU ETS 2, compared to its sibling system, is a more elaborate system to dampen prices in the event of sharp price increases (see Art. 30 h of the Directive 2023/959). In particular, for the initial years of the new system, multiple price stability mechanisms have been included to prevent carbon prices from rising strongly (see recital 91 of the Directive). Nevertheless, concerns about high carbon prices have been voiced since it remains unclear how high the pressure on prices will be, and whether price stability mechanisms will be effective (Packroff & Carroll, 2023). This is especially relevant since citizens will be more directly affected by carbon prices in the EU Emissions Trading System for buildings and road transport than by EU ETS 1, raising distributional concerns (Görlach et al., 2022).

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Extensive empirical and numerical research on EU ETS 1 prices exists, spanning two decades, during which the system has undergone multiple structural reforms. In contrast to this abundance, relatively few studies have been conducted on EU ETS 2 price drivers for two reasons: the novelty of the EU ETS 2 and the heterogeneity of emitters covered by the system. Some preliminary conclusions on potential price paths can be drawn from Abrell et al. (2024), European Commission (2021a) and European Climate Foundation et al. (2021). However, all of these studies were conducted before the final EU ETS 2 design was agreed upon in 2023 (Parliament & Council, 2023).[1] All studies abstract from the actual EU ETS 2 scope and partially lack detail in the underlying country and sector modeling. Moreover, these studies do not provide EU ETS 2 price sensitivities (except for European Commission (2021a)) with regard to complementary energy efficiency and renewable energy policies, which we show to be very important.

This paper aims to address the identified research gap via two contributions. First, we discuss price formation for the EU Emissions Trading System for buildings and road transport from a conceptual point of view, identifying key drivers and assessing the novel EU ETS 2 price stabilization mechanisms. Second, we present results from our scenario analysis with the PRIMES model, which features bottom-up modeling of all EU ETS 2 sectors, in line with the design and scope of EU ETS 2 recently agreed upon. Across three scenarios, we vary the assumptions on the stringency of primarily energy efficiency policies and associated renewable energy policies. This setup allows us to assess the impact of energy efficiency policies in the buildings and road transport sectors on EU ETS 2 prices.

Revisiting EU ETS 2 price formation

EU ETS 2 price drivers

Functioning as a cap and trade system, each EU ETS 2 allowance grants the right to emit one tonne of CO_2, with the total number of allowances decreasing over time. To understand the formation of prices in the EU Emission Trading System for buildings and road transport, it is helpful to start with the most fundamental aspects of firm behavior in emission trading systems established by Rubin (1996). His model states that the initial price level of emission certificates is determined by future marginal abatement costs on the demand side, accounting for intertemporal trading. Subsequently, the price increases at the interest (discount) rate, provided firms can bank allowances and act rationally, and market failures are absent. This price evolution is also known as the Hotelling rule (Hotelling, 1931). Correspondingly, demand in each year is a function of the marginal abatement costs and the value of allowance banking. Supply is simply the volume of allowances issued in a year, also called the cap.[2] This is commonly referred to as market fundamentals.

However, the formation of prices in real-world emission trading systems, such as EU ETS 2, is more complex for two primary reasons. First, marginal abatement costs are inherently uncertain and can vary substantially over time. Structural changes in energy prices or sudden technological advances can cause abatement costs to deviate from previous expectations. Second, even if fundamentals were certain, future prices would remain difficult to predict since price formation is influenced by several additional factors beyond the fundamentals. These factors shift prices away from the simple fundamental model explained above. From the literature, we identify four such factors, as listed in Table 1 and explained below.

Complementary policy measures at the EU or national level could substantially influence the prices within the EU ETS 2, particularly if their scope directly overlaps with these sectors. For instance, energy performance standards for buildings, which decrease energy demand for heating and cooling, would reduce the demand for EU ETS 2 allowances and, consequently, decrease EU ETS 2 prices (ceteris paribus). The extent to which this effect occurs depends on the effectiveness of the policy measures and the expectations of market participants.

A second important factor for EU ETS 2 price expectations is the potential linking with other systems. Sooner or later, the EU ETS 2 may be linked with the EU ETS 1 or other international carbon systems. This could lead to price convergence even before the actual (physical) linking takes place: Depending on how and to what extent

[1]The original version of Abrell et al. (2024) was published in 2022 (Abrell et al., 2022).
[2]In the absence of other quantity-based adjustment mechanisms.

Table 1. EU ETS 2 Price drivers beyond marginal abatement cost.

Factor	Impact on EU ETS 2 Prices	Examples
Complementary policies	Effective complementary policies reduce EU ETS 2 prices	Subsidies for energy efficiency or renewable energy, efficiency standards in buildings and transport
ETS linking	Price effect depends on carbon price expectation of other ETS	Linking of EU ETS 1 and EU ETS 2
Credibility of cap	Low trust in EU ETS 2 cap and climate policy can result in lower EU ETS 2 prices	Low credibility of EU ETS 1 in Phase 1 and Phase 2
Non-homogeneous behavior of market participants	Can distort prices away from fundamentals upwards and downwards	Short-term EU ETS 1 price fluctuations

market actors anticipate this, the fungibility rules of allowances,[3] and allowance scarcity in the other system, the EU ETS 2 price may shift upwards or downwards.

Third, prices in the EU Emissions Trading System for buildings and road transport may deviate if market actors expect political adjustments to the cap. For example, they might expect such adjustments if prices are perceived as politically unsustainable or excessively high, impacting the system's credibility. This could be particularly relevant if the implemented social compensation mechanisms prove inadequate, leading to political pressure from end consumers.

The fourth factor relates to behavior of market participants. Fundamental models typically assume homogeneity across all market actors, including a uniform discount rate, the absence of transaction costs, rational behavior, and perfect foresight. In contrast, end-consumers and small-scale industry, which play a much greater role in EU ETS 2, may exhibit heterogeneous behavior, for example, in terms of discount rates. If firms face high interest rates as an opportunity cost of cash flows or act myopically, their actions will be driven much more by short-term EU ETS 2 prices rather than the expected long-term price increase (Sitarz et al., 2024). Another novel aspect of the EU ETS 2 is its upstream structure. Firms participating in the allowance market are not the ones making abatement decisions (as is the case in the EU ETS 1). This dichotomy between regulated entities, on the one hand, and consumers making abatement decisions, on the other, could distort prices away from fundamentals.

EU ETS 2 price stabilization mechanism

Apart from the factors mentioned above that influence demand, there are also policy-related factors that affect supply. More specifically, the new ETS Directive 2023/959 introduces three price stabilization mechanisms to prevent excessive price increases or excessively high initial prices (Parliament & Council, 2023).

First, the EU ETS 2 includes a quantity-based adjustment of the cap (Art.1a(5,6)): If the total number of allowances in circulation (TNAC2) falls below 210, 100 million allowance certificates are released from the Market Stability Reserve (MSR2) to the market. Vice versa, 100 million allowances are placed into the MSR2 and deducted from auction volumes if TNAC2 exceeds 440 million.

Second, until 2029, a price level above 45 EUR/tCO_2 may trigger the release of allowances (Art. 30h(2)).[4] Through this mechanism, 20 million certificates would be distributed up to twice per year if the price rises above 45 EUR/tCO_2 for at least two consecutive months. The first distribution is automatic, and the second distribution requires a proposal from the EU Commission and the consent of the Member States (Art. 30h(7)). In total, up to 40 million additional allowances could be released per year under this rule.

The third and last mechanism is an injection of allowances in the event of a rapid price increase (Art. 30h(1, 3)). This mechanism includes two variants, depending on the magnitude of the price increase. The first variant results in the distribution of 50 million allowances if the average auction price for three months is twice (1.5 times until the end of 2028) as high as the average price of the previous six months (Art. 30h(1)). The second variant involves the distribution of 150 million certificates if the average auction price over three months is three times higher than the average price of the previous six months Art. 30h(3).

[3]Price convergence could be limited if allowances issued before the linking takes place arenot eligible for linked emission coverage.
[4]The 45 EUR/tCO_2 threshold is inflation-adjusted based on the European index of consumer prices for 2020 according to Art. 30 h(2).

An important limitation of all price trigger mechanisms is that only one of them can be triggered once every 12 months[5] (Art. 30h(6)). This means that a maximum of 150 million allowance certificates can be distributed per year (Art. 30h(4, 6)). Another important implication arises from Article 30h(2) for the start of the trading system: If EU ETS 2 prices rise to over 45 EUR/tCO_2 immediately in 2027, only a total of 40 million allowances could be released from the MSR2 that year, since triggering Art. 30h(2) would inhibit the activation of other price measures (Art. 30h(6)).

To understand the impact of the price stabilization mechanism, a closer look at the MSR2 volumes is necessary. All price stabilization measures are based on the release of allowances from the new MSR2, which are then brought to the market via auctions. For this purpose, the MSR2 is provided with an initial volume of 600 million emission allowances, the remainder of which will be canceled at the beginning of 2031 (Art. 30d(2), Art. 1a(3)). The 600 million allowances are thus the maximum quantity that could be released to the market to stabilize prices until 2030. This corresponds approximately to a maximum supply increase of 18% with respect to the cumulative cap between 2027 and 2030.[6]

To summarize, the EU ETS 2 has multiple stabilization mechanisms in place but they can mitigate high EU ETS 2 prices only to a limited extent, as the extra supply of allowances to the market is capped at 18% and because the release of additional allowances occurs with a delay.[7] This is important to keep in mind for the following analysis, which clearly shows that pressure from fundamentals could be high.

Methodology

Numerical model analysis

To explore EU ETS 2 price pathways and, in particular, the impact of energy efficiency policies, we conduct a numerical scenario analysis using the well-established PRIMES model. The PRIMES model has been implemented for the assessment of EU-wide and national policies. Recent applications of PRIMES include the official evaluation of the Fit-for-55 legislative packages, which aim to reduce greenhouse gas (GHG) emissions to 55% below 1990 levels by 2030 (European Commission, 2021a), as well as the impact assessment of the Climate Target Plan of 2030 (European Commission, 2020). The PRIMES model is an energy system model designed to provide long-term energy system projections and transformation pathways, both on the demand and supply sides. The modeling suite is based on models representing the entire energy system, with detailed models for the power, heat and alternative fuels generation sectors on the supply side, and dedicated models for industrial, transportation, residential, and services sectors. The model formulates the energy-related decisions on the supply and demand sides as structural microeconomic optimization problems, involving minimization of costs or maximization of consumer utility under technical, economic, and policy constraints. The modeling is enhanced with elements that represent behavioral aspects. For example, the PRIMES Buildings Model (PRIMES BuiMo) is based on the formulations of discrete choice theory to capture the preferences of representative agents. The model is calibrated to the available Eurostat statistics for historical periods. The detailed model description is given in (E3-Modelling, 2018).

PRIMES is equipped with a detailed representation of policy instruments ranging from economic policies and measures (e.g. taxes or subsidies) to regulatory instruments (such as emissions or performance standards), and institutional policies that act as facilitators of investments but not as direct incentives (e.g. information and education policies). Therefore, the model is suitable for assessing alternative EU ETS 2 price paths and analyse the cross-sectoral impacts of complementary policies. The model applies the concept of Generalized Price-driven Equilibrium and is formulated as a mixed complementarity problem to handle system-wide targets (e.g. emission reduction, energy efficiency, renewables) that influence all demand and supply model outcomes, hence the market equilibrium.

[5]With the exception of the second optional distribution of allowances if 45 EUR/tCO_2 is exceeded (Art. 30 h(7)).
[6]According to our estimates based on the cap stated in European Commission (2021b).
[7]However, the price stabilisation mechanisms might be altered in the upcoming reviews mentioned in the Directive 2023/959 (Art. 30i, Art. 30 h(5)).

The energy efficiency targets, which are particularly relevant for the current analysis, are formulated as constraints in the model: the model meets the energy efficiency constraint by varying the associated shadow price (dual variable).

A non-zero value of the dual variable, proportional to the ambition of the energy efficiency targets, influences the decision-making as a penalty factor adding to energy consumption costs for all consumers representing the different demand sectors. Subsequently, investment in energy efficiency (e.g. for building renovation) becomes more profitable. Similarly, the choice of highly efficient but more expensive equipment becomes attractive. The value of the dual variable varies until the required energy savings on a system level are achieved.

The dual variables associated with energy efficiency targets can represent a variety of concrete policy measures with different stringency or ambition. These include subsidies for energy efficiency investment, penalties aimed at enforcing energy efficiency performance, prices in a white certificate trading mechanism, among others. In essence, the effect is similar to the price signal affecting energy efficiency decisions.

A similar approach is applied to renewable energy and greenhouse gas emission reduction targets, which are treated as constraints to ensure the achievement of the proposed renewable energy (RES) and GHG emission reduction targets in line with each scenario.

Scenario framework

The three scenarios presented in the analysis are aligned with the climate objectives within the Fit-for-55 EU policy package and therefore achieve the 55% greenhouse gas emissions reduction by 2030 (compared to 1990 levels) at the EU level. To align with recent economic and political developments, the projections of international fossil fuel prices, which are being used as input to the model, take into account the effects of COVID-19 and Russia's war of aggression against Ukraine (see Table A1 for details on the modeling assumptions). For the EU ETS 1, all scenarios include the latest reform in line with the July 2021 proposal (European Commission, 2021b).[8] As for other legislation, the scenarios are based on the 2021 proposal for Energy Efficiency Directive (EED) (European Commission, 2021d), the proposal for Renewable Energy Directive (RED) (European Commission, 2021c), but do not include the proposal for Effort Sharing Regulation (ESR) (European Commission, 2021e) or recent updates, such as the revised Energy Efficiency Directive (European Parliament and Council, 2023). An overview of the considered policies can be found Table B1.

The modeled scenarios reflect pathways to meet the overall EU GHG emissions reduction target based on the expectations about the pace of technology development in the end-use sectors, associated costs, and specific economic and policy framework conditions. As such, they do not represent the current stance of Member States' climate and energy policies or EU ETS 2 price forecasts. Instead, these scenarios provide insights into the cost-effective sectoral developments needed to achieve the climate targets and the required EU ETS 2 price trajectories.

Policy scenarios

We model three scenarios: the *Strong Efficiency Policies (EP)* scenario, characterized by the strong effectiveness of energy efficiency (EE) policies; the *Limited EP* scenario, which assumes moderate effectiveness of these policies; and the *Weak EP* scenario, reflecting low effectiveness of measures. The differences between the scenarios are based on the effectiveness and/or ambition of policies aimed at enhancing energy efficiency (through e.g. waste heat recovery in the industrial sectors, renovations of buildings, and electrification in the heating and cooling sectors), as well as renewable energy uptake (such as biofuels use in the transport sector, hydrogen deployment in industrial uses and specific transport segments, promotion of heat pumps (HP) in the buildings sector). The increase in EU ETS 2 prices becomes essential in scenarios lacking ambitious complementary policies (*Limited EP* and *Weak EP*) to ensure compliance with emission reduction targets. This scenario setup allows us to focus on the challenges faced by the EU ETS 2 sectors. The description of the scenarios, as well as the associated energy system targets, is presented in Table 2.

[8]The July 2021 proposal is very similar to the adopted revision in 2023, with the main difference being a slightly tighter 2030 cap (Parliament & Council, 2023).

Table 2. Overview of scenarios and relevant policy targets.

Acronyms	Strong Efficiency Policies *Strong EP*	Limited Efficiency Policies *Limited EP*	Weak Efficiency Policies *Weak EP*
Brief description	EU GHG emission reduction and energy efficiency 2030 targets are met. Policies for energy efficiency are effective in all sectors. Targets assumed reflect the framework of the Fit-for-55 July 2021 proposals.	2030 EU GHG emission reduction target is met by design but other targets can be missed or overachieved. *Limited* and *Weak EP* scenarios differ in the level of effectiveness of the energy efficiency policies. In the *Weak EP* scenario, the effectiveness of energy efficiency policies is lower compared to the *Limited EP* scenario.	
GHG emissions	Achievement of the 2030 EU GHG emission reduction target of – 55%.		
EU ETS 1	Achievement of the 2030 EU ETS 1 target of −62% (European Commission, 2021b).		
ESR, EU ETS 2	Achievement of the 2030 target for ESR of −30% (European Commission, 2018a) at the EU level and the proposed EU ETS 2 target of -43% (European Commission, 2021b).		
Energy efficiency dimension	Final energy reduction target of −9% (relative to the respective year in EU Reference scenario 2020) EED proposal (European Commission, 2021d) is met or overshot.	Meeting the EED target as in the *Strong EP* scenario is not mandatory.	
	High Ambition of EE policies: Enforcement of EPBD (European Commission, 2018b), Minimum EU requirements for energy performance of new buildings (MEPS); Effective policies supporting HP, deep renovation and thus lowering risk of energy efficiency (EE) investments; Expansion of district heating and cooling; High exploitation of waste heat recovery, Best Available Techniques compliance.	Medium Ambition: MEPS but limited policies supporting penetration of HP and deeper renovation; Compared to *Strong EP*, lower expansion of district heating and cooling; lower exploitation of waste heat recovery, lower Best Available Techniques compliance.	Low Ambition: Compared to *Limited EP*, even lower policies supporting deeper renovation and penetration of HP; lower district heating infrastructure expansion; lower waste heat recovery in industry.
Renewable energy dimension	The EU 40% RES target of RED 2021 proposal (European Commission, 2021c) is met or overshot.	Meeting of the RES target as in the *Strong EP* scenario is not mandatory.	
	Energy efficiency measures are tightly connected to the deployment of renewables in the buildings, transport and industry sectors: The renewables share increases with penetration of HP, expansion of district heating and cooling.	Compared to *Strong EP*, lower penetration of HP, district heating and cooling; and subsequently less renewables in buildings.	Compared to *Limited EP*, lower penetration of HP, district heating and cooling; and subsequently less renewables in buildings.
Transport	Respecting the biofuel blending mandates for aviation and maritime from the ReFuelEU and FuelEU, as well as CO_2 standards.	No changes to mandates for aviation and maritime from the ReFuelEU and FuelEU, as well as CO_2 standards compared to *Strong EP* scenario. For electric cars, lower infrastructure development, lower use of electric vehicles for long-distance transportation.	
Scope	Changes to the scenario framework are implemented EU-wide (compare to the implementation in European Commission (2021a)).		

The *Strong EP* scenario assumes full effectiveness of regulatory and institutional policy measures as indicated in Table 2. In contrast, the *Limited and Weak EP* scenarios reflect less effective energy efficiency and renewable policy measures, with the *Weak EP* scenario embodying the least effective policies of all.

In both alternative scenarios, the analysis focuses on the EU ETS 2 sectors, with no changes applied to the EU ETS 1 price. We keep the cap and design for the EU ETS 1 unaltered in all scenarios and do not assume policy spillover effects. This means that the EU ETS 1 price path (reaching 119 EUR/tCO_2 in 2030, 279 in 2040, 463 in 2050[9]) does not vary between scenarios. We assume no linking, and model the two ETS systems separately in all three scenarios.

Results

In this section we first report the main results (carbon prices and energy efficiency gains). Next, we highlight selected sectoral results. The PRIMES data related to the figures can be accessed as supplementary material

[9]All model results are stated in EUR2022/tCO_2.

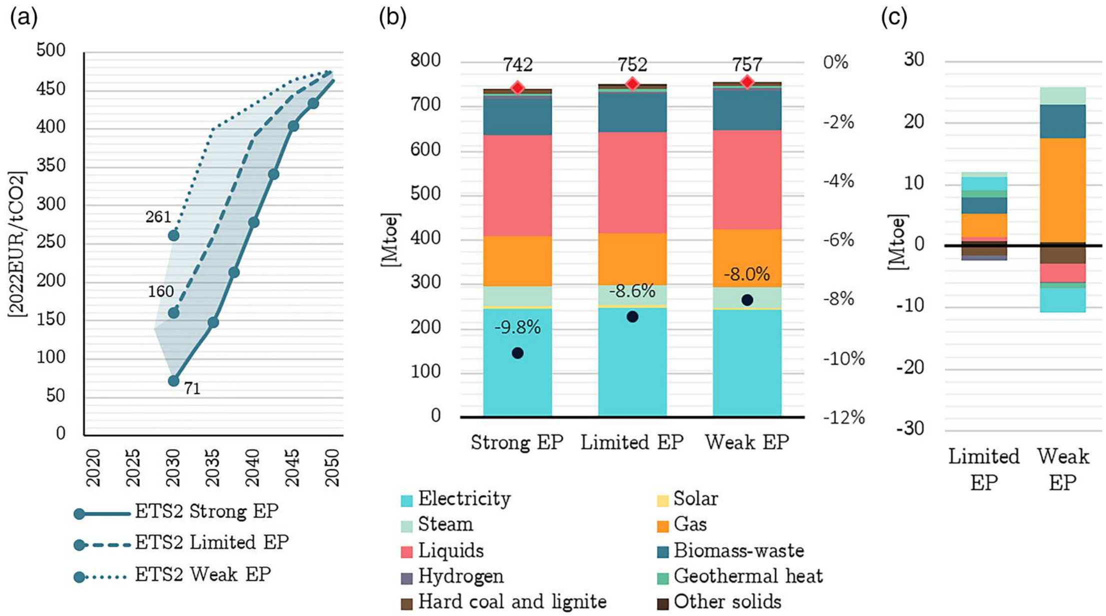

Figure 1. EU ETS 2 price pathways and final energy consumption across Efficiency Policies (EP) scenarios. (a) EU ETS 2 carbon price pathways across scenarios in EUR2022/tCO_2. (b) 2030 EU final energy consumption per energy carrier (left axis) and final energy consumption reduction relative to the year 2030 of the 2020 EU Reference Scenario (right axis). (c) Final energy consumption reduction by energy carrier relative to *Strong EP* scenario.

in the public repository (Günther et al., 2025). Finally, we compare our results on the EU ETS 2 price projections with other studies.

Main results

Figure 1 provides an overview of the main results for all three scenarios. Starting with prices, panel (*a*) highlights that there are substantial differences across scenarios. The *Strong EP* scenario features an EU ETS 2 price of 71 EUR/tCO_2. As expected, due to the comprehensive complementary policies in place, only relatively low prices are needed to induce the additional emission savings required to meet the 2030 emissions reduction target. In contrast, the price in the *Limited EP* scenario rises to 160 EUR/tCO_2 in 2030, while the *Weak EP* scenario shows a price as high as 261 EUR/tCO_2. Furthermore, over time, prices across scenarios reach a level of around 475 EUR/tCO_2 by 2050. The reason for this strong increase is that currently implemented complementary policy measures and targets are defined over the short to medium term. In the long-term, a price increase is necessary to eliminate remaining emissions.

Notwithstanding the stark differences in EU ETS 2 prices, the scenarios achieve comparable emission reductions by design.[10] In other words, the high carbon price of 261 EUR/tCO_2 in the *Weak EP* scenario yields similar emission reductions to those achieved in the other two scenarios. This suggests that abatement costs of stronger efficiency policies (per ton of emissions reduced) must roughly be those of the EU ETS 2 price in the *Weak EP* scenario.[11] Thus, there is a trade-off between higher EU ETS 2 prices and reliance on complementary energy efficiency policies, both of which involve greater public or private expenditure. We come back to this issue in the discussion below.

Finally, it must be noted again that the modeled prices only consider fundamental demand factors and abstract from future regulatory changes that would change the supply of allowances. Notably, potential

[10]See Figure D1 and D5 in the Appendix for a sectoral breakdown of emissions.

[11]The PRIMES model embeds in the modelling formulation elements to capture consumer behaviours and the effects of market and non-market barriers in the investment decisions of individuals. Thus, abatement costs are not directly comparable.

policy responses related to the feasibility of very high prices are not taken into account. We revisit this issue in the discussion section. Moreover, the EU ETS 2 price stabilization mechanisms are also not included in the modeling since their impact on long-term prices is negligible (Graichen & Ludig, 2024).

Moving on to energy efficiency impacts, Figure 1 (*b*) illustrates the variation in final energy consumption across scenarios. Two findings are common across all three scenarios. First, final energy consumption is reduced at a high rate that exceeds historically observed levels.[12] Second, electrification plays a crucial role, with the share of electricity in final energy consumption rising from roughly a quarter to a third between 2020 and 2030.

What is more, the amount of energy efficiency gains in different scenarios varies, as shown in the panel 1 (*c*). Under the *Strong EP* scenario, the targeted energy efficiency policies lead to a reduction in final energy consumption that is two percentage points higher compared to the *Weak EP* scenario. In the *Limited* and *Weak EP* scenarios, energy efficiency gains are driven by higher EU ETS 2 prices. However, these higher prices cannot achieve the same level of energy efficiency as the *Strong EP* scenario. The emission reduction, despite higher energy demand, in *Limited and Weak* scenarios is achieved by a fuel switch to natural gas, which has a lower emission intensity compared to other fossil fuels (liquids, hard coal and lignite).

Selected sectoral results

Buildings

In the *Strong EP* scenario, renovations of buildings significantly reduce overall energy consumption. The *Strong EP* scenario achieves annual renovation rates of 1.9%, doubling the historically observed EU average in 2020. In contrast, the *Limited* and *Weak EP* scenarios maintain renovation rates at currently observed levels (0.9%–1%), resulting in higher final energy consumption. Despite EU ETS 2 prices rising over time, consumers opt more for fuel switching instead of expensive renovations. Thus, final energy consumption for heating and cooling in the buildings sector is higher in *Limited EP* and *Weak EP* scenarios compared to the *Strong EP* scenario. Moreover, electrification of the buildings sector progresses through the rapid deployment of heat pumps. In 2030, the stock of heat pumps ranges between 35 and 46 million across scenarios (see Table C1).[13]

Industry

In the absence of effective bottom-up policies in the *Limited* and *Weak EP* scenarios, there is lower uptake of heat recovery practices as a means of reducing energy consumption, and at the same time, there is slower shift to more advanced technologies and processes compared to the *Strong EP* scenario.

Transport

Electrification plays a pivotal role in transport. Electric vehicles (EVs) make up for 9% to 11% of total road transport stock in 2030 (see Table C2). EV adoption is highest in the *Strong EP* scenario, driven by the rapid expansion of charging infrastructure. In the *Limited and Weak EP* scenarios, slower build-out of charging infrastructure for electric vehicles and higher fuel prices (resulting from EU ETS 2 prices) lead to lower electric vehicle sales and lower road transport activity compared to the *Strong EP* scenario (see Table C2).

Comparison with other EU ETS 2 price modeling

A final issue worth considering for validation is how modeled prices in our study compare to other existing EU ETS 2 model studies. This is shown in Figure 2. After harmonizing all price projections to 2022 as the base year, estimates for 2030 vary between 51 and 391 EUR/tCO_2. We identify two reasons for the large discrepancy of estimates: Different scenarios and study designs, based on various modeling approaches, as well as distinct assumptions regarding the EU-wide implementation and effectiveness of complementary policies. Divergent views regarding the abatement costs of sectors covered by EU ETS 2 may also contribute; however, the

[12]See Figure D3 in the Appendix for an overview of final energy consumption in the *Strong EP* scenario over time.
[13]See section A.3 in the Appendix for a detailed explanation of sector dynamics.

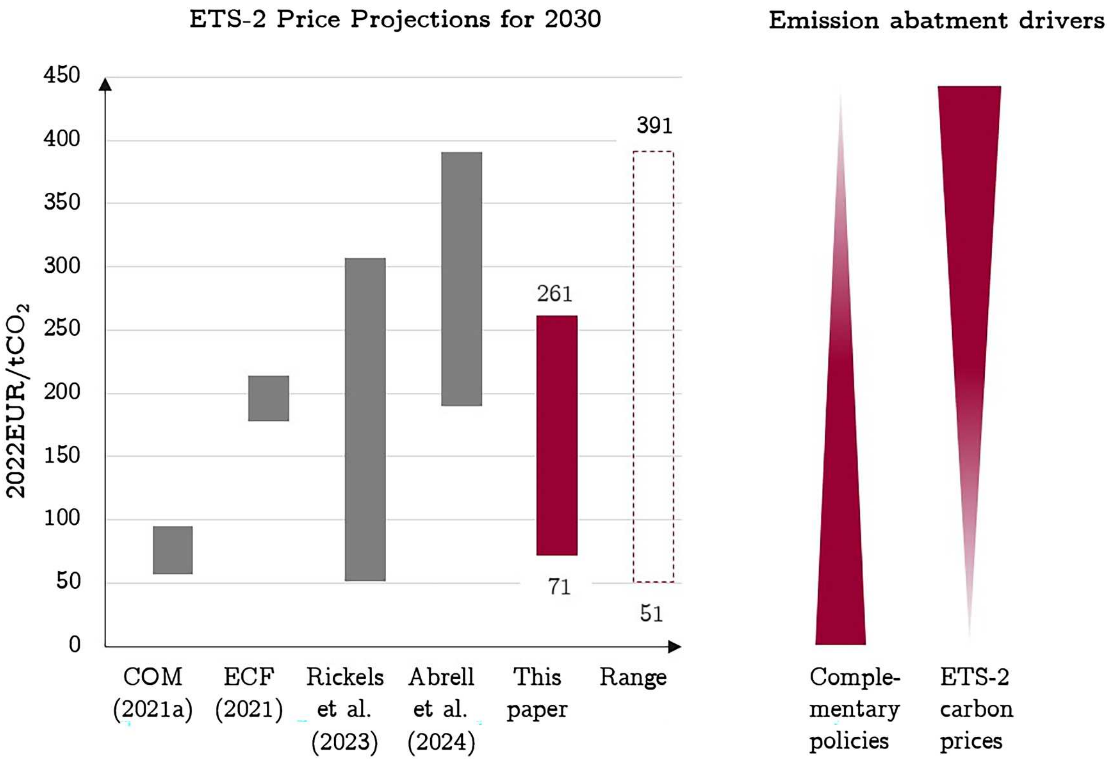

Figure 2. Review of numerical EU ETS 2 price projections.

listed studies lack transparency on these assumptions. A detailed overview of reviewed studies can be found in Table D1 in the Appendix.

The comparison corroborates our main finding that the degree of comprehensiveness of complementary policies is a major determinant of price levels. More specifically, European Commission (2021a),[14] Rickels et al. (2023)[15] project rather moderate prices similar to our *Strong EP* scenario. In contrast, scenarios with less ambitious complementary policies, namely those in Abrell et al. (2024), European Climate Foundation et al. (2021), Rickels et al. (2023), and European Commission (2021a)[16] report relatively high prices as in our *Weak EP* scenario. Notably, the orders of magnitude are similar across different study designs and modeling approaches, implying this is a relatively robust finding.

Discussion

The first aspect that merits further discussion is the finding that emissions reductions in all scenarios are roughly the same, implying that the (shadow) cost of complementary policies to reduce the marginal ton of emissions is roughly equal to the (high) EU ETS 2 price in the *Weak EP* scenario. In other words, reducing the marginal ton of carbon is costly regardless of the policy instrument used. This is important because transformation scenarios with relatively high carbon prices are often challenged on the grounds that they might not be politically feasible. Indeed, political acceptability is a concern because carbon prices make climate policy costs very salient for consumers, and distributional implications can be substantial and need to be managed properly (see e.g. Görlach et al. (2022) for a discussion of these topics in the context of the EU ETS 2).

[14]See the MIX scenario in the impact assessment.

[15]Their scenario with the lowest EU ETS 2 price of 51 EUR/tCO_2 is characterized by an upper price bound on EU ETS 2 prices, while national complementary policy takes the form of national carbon prices.

[16]See the MIX-CP scenario in the Impact Assessment, which reflects less effective regulatory policies compared to the MIX scenario.

However, it is important to recognize that scenarios with lower EU ETS 2 prices are not devoid of significant challenges. To begin with, at least in the mid- to long-term the costs of non-pricing policies will become very salient too, especially when they need to be stringent enough to close the emission reduction gap. A case in point is the heavy push-back against Germany's new de-facto ban on fossil heating systems, underlining the difficulty of implementing strict complementary policies. Ultimately, costs matter, whether they are reflected in costs associated with the EU ETS 2 or complementary policies. What is more, the broader distributional impacts of policies – not just the level of carbon pricing – are crucial to consider. Often it is claimed that such policies could be designed to be socially fair, e.g. subsidies primarily for lower-income households and mandates for higher-income households. Yet so far the track record of policymakers in accomplishing this seems to be mixed at best. Furthermore, carbon pricing revenues could also be redistributed in a way to achieve fair outcomes (Feindt et al., 2021). Hence the actual challenge is targeting policies effectively to ensure fair distributional outcomes, which arises for all policy instrument choices alike. Arguably, both issues deserve more attention in policy discussion and making, where they are frequently sidelined.

A second aspect that merits further discussion is a potential sequencing of the different types of policies. The general idea of sequencing is that certain policies implemented at an early stage can remove barriers for the effectiveness of more stringent policies at a later stage (Pahle et al., 2018). In this case, energy efficiency policies could be used to trigger (deep) renovations that pave the way for the subsequent installation of heat pumps, for which a high carbon price provides a financial incentive. For such a sequencing to be cost-effective, energy efficiency policies should be designed according to the 'decarbonization first' principle, which prioritizes targeted measures to make buildings 'heat pump ready' over measures for deep renovations that only target energy efficiency and may turn out to be overly costly (Levesque et al., 2023).

A third important consideration is that policy developments have advanced since the design of our scenarios. All our scenarios are based on legislation adopted in 2018 and the Commission's 2021 legislative proposals (see Table B1). Thus, the scenarios do not include the final adopted revisions of RED, EED, and ESR. Correspondingly, in more up-to-date versions of our scenarios, EU ETS 2 prices would tend to be lower. Another policy that could also have a substantial effect on the possible development of EU ETS 2 prices is the Energy Performance of Buildings Directive, which was still under revision at the time of writing. We leave the analysis of the reformed EPBD and other policies (RED, EED, ESR) to future research.

Conclusion

This analysis highlights the crucial role of complementary energy efficiency and renewable energy policies in determining prices in the new EU Emissions Trading System (EU ETS 2). Our findings suggest that carbon prices of the EU ETS 2 in 2030 could be nearly four times as high if such policies were implemented at much weaker levels compared to those proposed under the Fit-for-55 package. Specifically, modeled EU ETS 2 prices lie in the range of 71–261 EUR/tCO_2 in 2030 across scenarios, depending on the stringency level of energy efficiency and renewable energy policies.

The high EU ETS 2 price reported for 2030 in the *Weak EP* scenario might mistakenly lead one to conclude that stringent complementary policies result in lower total costs. However, across all three scenarios, similar EU-wide emission reductions (−41%) are achieved, indicating that marginal abatement costs are at least 261 EUR/tCO_2 (the carbon price in the *Weak EP* scenario), regardless of which policy instrument is in place. The high carbon price merely makes these costs more visible initially.

The fundamentally modeled carbon prices indicate the possibility of price stability mechanisms, which are part of the new EU ETS 2, being triggered. However, in addition to fundamental drivers, speculation regarding regulatory changes, market intervention or market linking could shift prices up or down. This underscores the importance of credible policy commitments to EU ETS 2 and complementary policies to enhance market stability and confidence.

Finally, we also identified topics for future research. First, beyond the factors analyzed in our study, we have identified a number of additional (non-fundamental) drivers that influence prices. They could be investigated with a view to how relevant their roles are compared to the influence of complementary policies. Second, it would be worthwhile to assess the impact of the newly adopted policies on EU ETS 2, notably the Energy

Performance of Buildings Directive, the Energy Efficiency Directive, the Renewable Energy Directive, and the strengthened Effort Sharing regulation targets, all of which are not reflected in our scenarios.

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