LIFE COASE

New Horizons for Emissions Trading Systems – Insights from Ex-ante and Ex-post Studies

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Research Project Report
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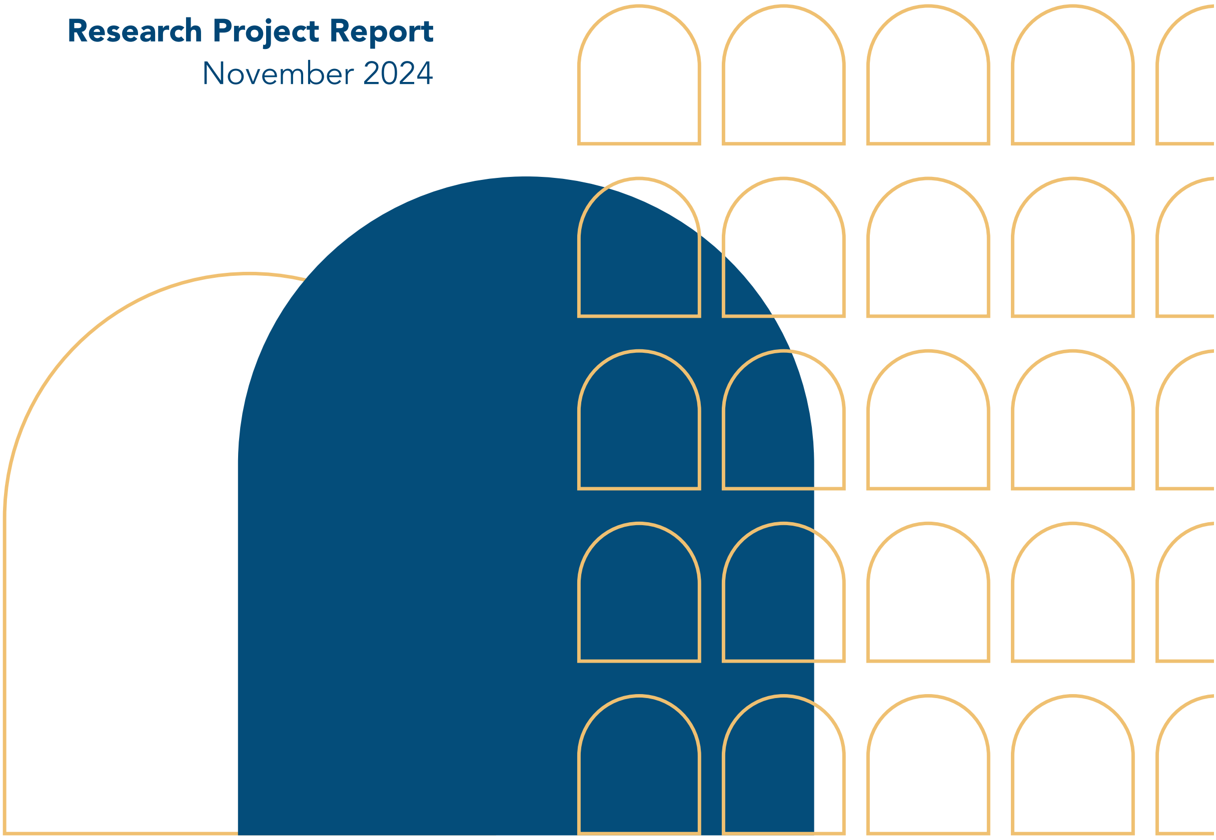

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Introduction

This report summarises the insights collected during the workshop on “The role of carbon markets in reaching carbon neutrality”, which took place in June 2024.[1] This workshop was part of the Joint Sessions of Workshops organised to celebrate the 30th anniversary of the Robert Schuman Centre. In line with the LIFE COASE project, the workshop consisted of two parts: presentations of papers that provided an ex-post evaluation of emissions trading systems (ETS) and presentations that focused on ex-ante modelling assessments of ETS.[2] The main topics addressed in the workshop were carbon leakage, scope expansion of emissions trading, negative emissions, voluntary carbon markets, policy overlap, compliance market oversight, trading behaviour, and future allowance prices. For the most part, the summaries below reflect the insights collected by Paul Ekins and Sebastian Osorio. All presenters are cited as main authors in the text, but the full information concerning the presented papers can be found in the references at the end of the summaries. This report served as a background paper to inform the discussion of the Net Zero Carbon Market Policy Dialogue that took place on 4 October 2024.

Summary of the Second International Conference on Ex-Post Evaluation of Emissions Trading

ETS and firm behaviour

The purpose of an ETS is to change the behaviour of the regulated firms. Anderson et al. (2024) described the results of an evaluation of the kinds of behaviours that had been displayed by the participants in the UK ETS since it was established in 2021. The evaluation used a realist approach to analysing behaviour, investigating UK ETS market participants, asking questions about ‘what happened, for whom, in what circumstances and why’ in response to the establishment and operation of the UK ETS in the search for emergent patterns of behaviour.

The research identified a wide range of market behaviours, from buying just to comply, to occasional selling, to hedging via intermediaries or through in-house staff, or, for the power sector, trading according to the spark spread (differential between the wholesale price of electricity and the purchase price of gas-plus-carbon), which drives the economics of gas-fired generation.

Carbon-emitting firms in the compliance market might buy their allowances at the fortnightly auctions, through the Intercontinental Exchange (ICE) for daily (spot) or quarterly futures contracts, or through over-the-counter (OTC) trading, depending on their size and emission characteristics. Other market participants include speculators, market makers, brokers and clearing houses.

The UK ETS had made at least 60% of all operators except micro-emitters (52%) more aware of carbon-reduction opportunities, and at least 90% of operators reported having a carbon abatement plan. The plans included a wide range of operational measures and investments and differed according to the three main sectors in the UK ETS: aviation operators, power operators and energy-intensive industry. However, the research also revealed considerable uncertainty about the best abatement options.

The research uncovered many points for consideration as the UK ETS evolves, including: how to in-

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[1] The workshop program can be found in Appendix I. More information about the Joint Sessions of Workshops event can be found online: https://www.eui.eu/en/projects/joint-sessions-workshops/about

[2] LIFE COASE – Collaborative Observatory for the ASsessment of the EU ETS – is a project co-funded by the EU Life Programme of the European Union. More information: https://lifecoase.eui.eu

crease market liquidity; possible alignment with the EU ETS; the need for policy certainty to encourage long-term investments; the design of complementary carbon reduction policies; how to increase access to and availability of the electricity grid, carbon capture, use and storage (CCUS), sustainable aviation fuels (SAF), biofuels, and hydrogen; the use of the revenues; and the inclusion of greenhouse gas removals.

The direct effects of an ETS will be felt by those firms who are covered by it. But there may also be indirect effects on both non-ETS and ETS firms in their production networks, arising from any changes in the prices of and demand for the ETS firms' products. Thus, firms downstream of an ETS firm may be affected by the ETS firm's participation in the ETS (depending on the pass-through of any ETS costs), but firms with ETS firms among their customers may also be affected (e.g. if the demand of the ETS firm for their product changes). Stoerk et al. (2023) described an investigation of these effects, using a particularly detailed dataset from Belgium, in which less than 400 firms are covered by the EU ETS out of more than 130,000 in the country as a whole.

In most Belgian industrial sectors, over 20% of firms are either suppliers to or customers of ETS firms, with the proportions for some sectors rising to more than 40%. In the great majority of Belgian industrial sectors more than 80% of firms have an upstream or downstream exposure to ETS firms. While some ETS sectors have revenue exposure of around 50% or more, most have a revenue exposure of around 30% or less. For non-ETS sectors, the revenue exposure is always less than 6%, and for most sectors, it is around or less than 3%.

A regression using the dataset and exploiting the doubling in the EU ETS price that occurred between 2012 and 2017/18/19 found a highly significant relationship between the price change and the revenue exposed in those firms with ETS firms upstream, i.e. from whom they bought products, with a revenue elasticity of around 0.2. This provides evidence of cost pass-through from the ETS firms down their production network. In contrast, the dataset yielded no clear results in respect of cleantech innovation.

Carbon pricing, carbon leakage and CBAM

An abiding concern about carbon pricing for policymakers has been that carbon pricing in one jurisdiction (e.g. in the EU) will have a negative impact on the competitiveness of carbon-intensive industries in that jurisdiction with respect to such industries elsewhere. This could result in foreign industries increasing both their production and greenhouse gas (GHG) emissions, thereby reducing the emission reduction brought about by the carbon price at home. This effect is known as carbon leakage. While the evidence in the academic literature is inconclusive as to the scale of carbon leakage from carbon pricing, some of that literature shows it to be substantial.

The study by Teusch et al. (2024) sheds new light on the possible scale of carbon leakage by exploiting the fact that one of the significant developments in carbon pricing between 2015 and 2021 is that there has been a substantial increase in many countries in the level of the price. Teusch et al. (2024) explore the effects of this increase on both emissions and trade on the basis of a new dataset of steel, cement and aluminium plants in 140 countries. The dataset covers 3,295 plants, most of which are in China, followed by India and the United States. There are 2,255 cement, 892 steel and 148 aluminium plants, accounting for around 80% of global production from these sectors and representing approximately 45% of industrial GHG emissions and almost 10% of global GHG emissions. Some of the plants have been subject to a carbon price, and some have not. For those plants with a carbon price, the average price increased from below USD 10 in 2015 to around USD 60 in 2021. This carbon price increase has occurred in both OECD and G20 countries, but the increase has been much greater in the former. Across the data set as a whole (i.e. including those plants with no carbon price), the carbon price in OECD countries went from an average of USD 4 in 2015 to over USD 40 in 2021. In non-OECD countries, the corresponding figures are around USD 1 in 2015 to USD 8 in 2021.

Moreover, from 2015 to 2021, GHG emissions from plants with a carbon price have not increased, while those from plants with no carbon price have increased by around 10%. The average differences in carbon prices between trading partners have also increased markedly over the period. Using a regression model for the effects of the carbon price increases on emissions and a gravity model to investigate the trade effects, the study explores how the emission and trade effects vary across the dataset both between steel and cement (aluminium plants were excluded from this part of the study because of data constraints) and with the difference in the carbon prices between different trading partners.

The results show the semi-price elasticities3 of emissions to be relatively large: 1.9% in the steel sector and 0.7% in the cement sector, leading to average reductions of emissions over 2015-2021, compared to a situation with no price increases, of 39% and 17% in the steel and cement sectors, respectively.

The reduction in emissions is substantially greater than the reduction in output from the steel and cement sectors, suggesting that the increased carbon prices significantly reduce the carbon intensity of the domestic sectors to which they apply. However, as carbon prices increase, so do imported emissions, leading to significant carbon leakage. For those plants in the dataset that have a carbon price, on average, an increase of USD1 reduces GHG emissions by 1.3%, but 13% of that reduction is offset by carbon leakage to countries where such plants do not face a carbon price. This average carbon leakage of 13% is composed of a much greater contribution from cement (23%) than from steel (3.43%).

To date, the EU has responded to the threat of carbon leakage by giving free emission allowances to energy- and trade-intensive (EITI) sectors, but the tightening targets in the Fit for 55 package and the need for emission reductions from these sectors make this practice increasingly unsustainable. At the same time, the tightening targets are expected to raise the price of allowances, perhaps substantially. Without a compensating measure, the end of free allowances and the increased allowance price could increase carbon leakage considerably above estimates of current levels.

To counter this enhanced threat of carbon leakage, the EU is bringing in a Carbon Border Adjustment Mechanism (CBAM) from 2026. CBAM will impose a carbon price on imports of some products from certain energy-intensive sectors (basic and fabricated metals [aluminium and iron and steel], chemicals [fertiliser], cement, electricity, hydrogen). CBAM-affected products amount to 3.6% of EU imports, of which 65% is accounted for by the metals. The covered emissions are 2.5% of EU energy and process-related emissions. The countries with the highest affected trade flows are China, Turkey and Russia. The carbon price at the border under CBAM would be the EU-ETS price, less any carbon price in the countries where imports come.

Haramboure et al., (2023) modelled the direct and indirect economic effects on a baseline (allowance price EUR 25, no policy changes) of three cumulating factors: scenario 1 – the increase in the EU-ETS allowance price to EUR 80 and the phasing out of free allowances to non-EITI; scenario 2 – this, plus the end of free allowances to the CBAM sectors; scenario 3 – this plus the CBAM itself, this last scenario amounting to the Fit-for-55 package. The effects were calculated for both the CBAM and non-CBAM sectors in the EU and other countries.

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[3] A semi-price elasticity gives the percentage reduction in demand for a unit (i.e. non-percentage) change in price.

While the results (compared to the baseline) are broadly in line with economic theory, the modelling gives an idea of their possible scale. In scenario 1, in the EU CBAM sectors, both value-added (VA) and emissions are reduced (around 0.4% and 10%, respectively), while in non-EU countries, these sectors exhibit a small VA and emissions increase (<0.1% in each case). The leakage rate is around 5%. In scenario 2, the VA loss in the EU CBAM sectors increases to around 0.8%. There is also a small further reduction in EU CBAM sector emissions. In non-EU countries, the VA and emissions increase more than double to more than 0.1%, and the leakage rate rises to around 14%. Implementing CBAM in scenario 3 reduces the VA loss in EU CBAM sectors to below 0.7% while very slightly increasing CBAM sector emissions above those in scenario 2 (but the emissions reductions stay around 10-11% in all three scenarios). The VA increase in non-EU country CBAM sectors falls from that in scenario 2 back to below 0.1%, but emissions in these sectors fall below the baseline in this case (by about 0.1%), so the leakage factor becomes negative, at around -13%. For the world as a whole, the Fit-for-55 package reduces CBAM sector emissions by 0.75% while having a very small negative effect on the global CBAM sector VA (<0.1%). For the whole EU economy, the Fit for 55 package reduces EU GDP by 0.26% (compared to 0.2% in the European Commission’s impact assessment).

Gérardin and Ferrière (2024) dig deeper for a possible extended role for CBAM in the steel sector. There are three main manufacturing routes for steel: blast/basic oxygen furnace (BF/BOF) production, which uses metallurgical coal and has high GHG emissions (the steel sector is responsible for about 10% of global emissions), direct reduction of iron using either fossil methane gas or hydrogen (the emissions of the former depending on whether carbon capture and storage (CCS) is used, the emissions of the latter depending on the carbon intensity of the electricity source that makes the hydrogen) and electric arc furnace (EAF) production using steel scrap. Typically, EAF steel is one-third of the cost and, again, depending on the carbon intensity of the electricity used, produces one-fifth of the emissions of BF/BOF.

The lower production cost of EAF steel, which sells at the same price as BF/BOF steel, means that scrap steel commands a high price (around 300 EUR/t), a value that is enhanced if CO2 emissions have a price because EAF emits about 1.6 tCO2 less per tonne of steel than BF/BOF. As a result, current steel recycling rates are already high: 100% of pre-consumer and 85% of post-consumer scrap.

Because of the past growth in the production of steel, the availability of end-of-life consumer scrap is increasing and is projected to rise to 900mt per year in 2050 from 390mt in 2018. Half of the current scrap generation comes from the USA, Europe and Japan, although these regions only produce about 16% of primary steel.

There are three possible routes to steel decarbonisation: increased scrap collection – because levels are already high, this would only result in a global emissions reduction of 3-5% of steel sector emissions; material efficiency (using less steel in products) – if the decarbonisation of primary steel had increased its cost by around 50% per tonne, incentivising greater material efficiency, this could at a rough estimate reduce global steel emissions by between 8 and 16%. Most of the remainder of global steel emissions would need to be removed through a shift to low-carbon primary production at a cost of around 150 EUR/tCO2 (equivalent to about a 1% price increase in the cost of a motor car).

CBAM is currently due to be applied to steel products only insofar as they are made of primary steel, with a view to decarbonising such production. However, especially with the projected increase in the availability of scrap, which can be converted back to steel with much lower emissions, there is a danger of ‘resource shuffling’, with countries choosing to export to the EU scrap or scrap-derived products facing a lower carbon import tariff, if any, while they divert their high-carbon primary steel to other markets. In such circumstances, global emissions would not fall, but existing primary steel production, which would face the full carbon price, and new low-carbon primary steel production, whether in the EU or outside it, would both face a significant competitive disadvantage compared to imports of scrap or scrap-derived steel.

To avoid such effects, Gérardin and Ferrière (2024) suggest that CBAM could be extended to scrap and steel produced from scrap, with different CBAM arrangements for each, citing the existing CBAM provisions for electricity as a model.

Extending ETSs

The initial coverage of many ETSs, including that of the European Union (EU), was energy-intensive industry, but there is increasing interest in extending this coverage to other sectors. The rationale for this is twofold: first, it is well established that equalising carbon prices across sectors can lead to efficiency gains, and bringing new sectors into the ETS, where their emissions are being constrained by other policies, can achieve this. Second, as carbon caps tighten towards a common objective of net zero emissions by 2050, bringing more sectors into the ETS can increase the liquidity of trading on the carbon market.

Peterson et al. (2023) explore several aspects of the implications of bringing additional sectors into the EU ETS. At present, the EU ETS in all Member States only covers installations with large combustion plants in energy-intensive industries (the ETS1), plus some emissions from aviation and shipping. In total, these sectors are responsible for about 40% of the EU's total GHG emissions. Other emissions from other sectors are covered by the Effort Sharing Regulation (ESR) and, at the Member State level, by a range of other policies. It is now proposed to introduce an EU ETS2 to bring emissions from transportation and buildings into the EU ETS by selling emission permits to the upstream sectors that supply the fossil fuels to transportation and buildings. ETS2 is expected to cover around an extra 36% of the EU's total GHG emissions.

Efficiency considerations would suggest that the ETS1 and ETS2 emission allowances should be tradable between each other, which would equalise the allowance price across the sectors. But there are a number of arguments why, initially at least, ETS2 should be allowed to develop independently of ETS1. These reasons include administrative considerations (it takes time to set up systems of monitoring, reporting and verification), considerations of competitiveness of ETS1 industries (given that it is likely that the inclusion of ETS2 sectors would raise the carbon price in ETS1), and the desirability of gaining experience with ETS2 (for example, in terms of revealing the carbon price in the ETS2 sectors) in order to guarantee its robustness.

Peterson et al. (2023) show that different models project a wide range of carbon prices in ETS2, between around 50 EUR/tCO2 and 500 EUR/tCO2. There are doubts about the political feasibility of the higher prices, reinforcing the desirability of keeping the ETS1 and ETS2 systems separate until there is a greater understanding of the implications of the latter.

A further challenge is the integration of negative emissions into carbon markets, which is likely to be necessary both to incentivise their delivery by providing payments to those who deliver negative emissions and to reduce the carbon price that would otherwise have to rise to very high levels to reduce emissions to zero and to maintain carbon market liquidity. However, integrating negative emissions into the EU ETS raises many practical issues, the resolution of which may require experimentation and institutional innovation. For example, Peterson floats the idea of a carbon central bank to manage the introduction of carbon reduction certificates (CRCs) and oversee the rules regarding their trading. However, any such arrangement would require care in the design of the institution itself and with respect to its articulation with the Market Stability Reserve (MSR) and, perhaps, the European Central Bank (ECB).

Von Bebenburg et al. (2022) also take up the theme of carbon (or greenhouse gas) removal (GGR). In its Balanced Net Zero Pathway, the UK Climate Change Committee envisages that for the UK to reach net zero by 2050, GGRs will need to ramp up quickly from 5 MtCO2/year in 2030 to 58 MtCO2/year in 2050. Incentives will be required for the generation of GGRs, either through carbon markets or through government policies such as Contracts for Difference or direct subsidies. The costs of GGR technologies per unit of GHG removed vary very greatly, from 0-100 EUR/tCO2 for nature-based solutions to 18-900 GBP/tCO2 for direct air carbon capture (DACC).

Von Bebenburg et al. (2022) articulate a number of core principles which should underpin incentives for GGR: long-term effectiveness in reducing overall emissions, efficiency of markets, fairness of cost allocation, practicality/ease of implementation, and integrability with EU ETS. On the basis of these principles a number of options through which GGRs could be integrated into carbon markets are explored. For ETS integration robust processes of monitoring, reporting and verification would need to be in place to ensure that the integrity of the ETS was not undermined; and the GGR units would need to be discounted according to their (lack of) permanence. Three of the four options described involve the integration of GGRs into ETS markets, with differing degrees of government involvement. The fourth option requires that ETS emitters purchase GGR units at the same time as they purchase emission allowances. These GGR units would need to be surrendered within a given period, such that their associated finance flowed to the GGR provider. For the first three options, in order to maintain the incentive to abate, the reduction cap should be unchanged so that the GGRs are additional to emission reduction. How the emission allowances are reduced as the cap declines will obviously have distributional implications, which may be counteracted by complementary policy.

Bearing in mind that carbon dioxide removal (CDR) and GGR, more generally, are vital to the achievement of the EU net zero target by 2050 and for the negative emissions thereafter that are likely to be required to meet the Paris temperature targets by 2100, Bonfiglio et al. (2024) explored various strategies for incorporating CDR into EU climate policy.

CDRs will be either technology- or nature-based, and the removals will be either temporary or permanent, characteristics that will have to be accounted for in any legislation. The inclusion of CDRs in EU climate is already envisaged in current EU legislation, most notably in the Carbon Removals Certification Framework (CRCF), and CDRs will also need to be considered in upcoming legislation, such as the revision of the EU ETS Directive. Their treatment in EU policy will need to be different pre-2050 when their role is to compensate for residual EU emissions, and post-2050, when they will be needed to make the EU net negative in emissions and, potentially, to extend CDR beyond the EU’s borders, for example through the Carbon Border Adjustment Mechanism (CBAM).

Bonfiglio et al. (2024) consider that there are powerful reasons to integrate CDRs into the ETS, including adding liquidity to the ETS as the cap declines towards 2050 rather than setting up a separate market or generating them through direct procurement. However, such integration requires decisions about a number of key issues, such as how to convert carbon removals into credits, the creation of a price discovery mechanism, what types and volumes of carbon removals to allow into the market and the control of the supply and demand of EUA allowances, and to account appropriately for non-permanent

CDRs. These decisions could be made and managed either by existing ETS institutions or through the creation of a new institution. Integration with the ETS is likely to be easier than alternatives, such as determining sectoral targets for CDRs, including them in Member States' National Energy and Climate Plans (NECPs) or relying on the voluntary carbon market (VCM).

Considered politically sensitive, an extension of the EU ETS to the agriculture sector (AgETS) is being explored by the European Commission to lower emissions in the field. Globally, agriculture is a sector whose emissions still need to be addressed. At the global level, agriculture and land use change (most of which relates to clearing forests for agriculture) are responsible for about a quarter of GHG emissions. In the EU agriculture emissions amounted to around 400 MtCO2eq in 2021, most of which comes from the digestive systems of livestock (especially cattle and sheep) and the use of fertilisers. At present, no ETS in the world includes GHGs from agriculture. Exploring how these might be integrated into the EU ETS is the subject of the paper by Görlach et al. (2024).

Reasons for such integration include their significant share of emissions, the existence of abatement options across the value chain, efficiency considerations in terms of equalising the carbon price across sectors, the slow current rate of emission reduction in agriculture (which means that its share of emissions will increase as other sectors reduce their share) and the potential of agriculture to remove emissions from the atmosphere. Against this, there are issues of data quality on emissions, abatement potential and costs of monitoring, reporting and verification (MRV) linked to this, the substantial subsidisation of EU agriculture, and industry and public acceptability.

Abatement options in agriculture exist across the value chain: upstream (agricultural inputs, mainly feed and fertiliser), on-farm (farming methods), food processing and food waste. An ETS obligation could be placed upstream, on-farm or on food processors. Upstream there are fewer covered entities, but the abatement incentive down the supply chain requires cost pass-through and does not cover all abatement options. An on-farm obligation (covering all GHGs, just meat and dairy, and/or peat) would give farmers a more visible incentive, and (arguably) they are aware of the abatement options, but the bureaucratic burden could be considerable; there are MRV issues and doubts about farmers' propensity to trade. Obligating food processors, like the upstream option, again would have fewer covered entities and be less problematic for imports (and leakage), but again would only give a partial incentive for abatement, only cover meat and dairy products and have higher political visibility. Görlach et al. (2024)'s qualitative assessment of the options against a range of criteria suggests that the downstream and upstream options would be preferable to an on-farm obligation.

Many of the issues relating to including agricultural GHG removals in an ETS have been discussed earlier in this section, and include deterrence of emission reduction, permanence, MRV robustness and cost, additionality and leakage. These issues would need to be addressed in whatever design of ETS were to be introduced. Görlach presents five possible options in which an agricultural ETS could relate (or not) to a broader ETS scheme, ranging from complete disconnection to interconnection through government to various levels of integration with an ETS market. The assessment of these options against criteria of effectiveness, efficiency, coherence and political and legal feasibility reveals, as with the ETS obligation options, different advantages and disadvantages for each option.

A stakeholder assessment of the different options of obligation and level of ETS connection revealed a strong preference for the obligation to be placed downstream on food processors in a scheme that was either completely disconnected from the wider ETS (governments would require food processors to purchase allowances and then use the revenues to purchase removals from food supply chains) or the deductions model in which food processors would deliver emissions reductions in their own supply chains and only have to purchase removals for their residual emissions.

Beyond the EU ETS

The EU ETS is the oldest ETS in force, but since its inception, more jurisdictions have adopted emissions trading systems to reduce GHG. With currently 36 systems in force globally and an additional 22 in various stages of consideration and development, this market-based approach to addressing the climate crisis has spread worldwide.

Di Pasquale (2024) treats the case of Brazil, where a carbon market is currently in the early stages of development. A regulated national carbon market was already created in the 2009 Climate Change National Policy in Brazil, but the system has yet to be designed and enforced. The challenges which have slowed enforcement and operationalisation include political uncertainty and the lack of infrastructure, capacity building, financial resources, and technology transfer. There seems to be an increased momentum for the operationalisation of an ETS in Brazil following the enactment of the legal framework for implementing an ETS in Brazil (Decree No. 11550/2023).

It is underlined that Brazil can benefit from the experience of subnational entities active in the voluntary carbon markets (VCMs). Through the Clean Development Mechanism (CDM) under the Kyoto Protocol, Brazil has gained extensive experience with carbon credits. Until its last year of implementation, the CDM was responsible for the creation of 340 projects in Brazil, mobilising US$32 billion in investments in the country, mainly in renewable energy generation projects – 97% of the total invested. Like many countries, it relies on the developments of the next COP regarding Article 6.4 of the Paris Agreement and, more specifically, on the details of the new international crediting mechanism.

Finally, Di Pasquale (2024) stresses the importance of ensuring a just and inclusive transition to support Brazil's socio-economic development whilst ensuring it reaches its GHG reduction objectives. On top of addressing distributional concerns regarding carbon pricing, a common issue also present in the European setting, Brazilian regulators also face specific challenges, such as curbing illegal deforestation. Indigenous and traditional communities are also a key local factor. Indigenous peoples should be included in the decision-making process due to their contribution to the conservation of native vegetation and the preservation of ecosystem services in Brazil.

In places such as Brazil where there is no system for compliance emissions trading, VCMs are important levers for decarbonisation investments. VCMs operate by an individual or business buying a 'carbon credit' from an organisation that claims that this credit represents the removal of 1 tCO2 from the atmosphere. L'Horty et al. (2024) estimates that between 2005 and 2023, 2.4 billion of these credits were bought and sold.

Aside from the international crediting mechanism, which continues to be discussed within Article 6 of the Paris Agreement, there are also regional and national crediting arrangements, as well as credit provision and accreditation by independent providers (two of the best known are Gold Standard and Verra). VCMs cover a wide range of differing projects, relating to renewable energy, nature-based solutions, waste, transport, and household or community energy use.

However, VCMs have been beset with issues of poor quality and lack of integrity relating to its credits. These issues include measurement discrepancies, emissions 'leakage', non-permanence of carbon removal, greenwashing, and non-observance of land and other human rights. Moreover, VCMs suffer from an almost complete lack of transparency relating to such issues as transactions, prices, and value distribution through the value chain. These issues have received extensive analysis and coverage in both the academic literature and mainstream media, and the problems revealed have resulted in a significant decline in the annual quantity of credits sold between 2021 and 2023. The ongoing work of L'Horty et al. (2024) seeks to disentangle which of these issues has the greatest influence on the willingness of credit buyers to lay claims on the underlying emission reduction. Key findings include the heightened appeal of projects certified by Gold Standard over other standards, the greater attractiveness of chemical and industrial projects, the preference for projects in regions with lower human development indices and higher Rule of law.

In jurisdictions with an implemented ETS system, climate and energy policies are also enacted to combat climate change - renewable energy support schemes and taxes to improve energy efficiency, for example. These policies often overlap, with one policy being implemented by a jurisdiction for a specific sector, which is applied alongside a multi-jurisdictional carbon pricing system like an ETS. These policy overlaps produce interactions that can lead to different economic outcomes than if they were applied as a standalone policy. Studying the interacting effects of these policies together is paramount to ensure the implemented policy package is efficient and leads to the desired decarbonisation targets.

Aside from the EU case, which relies on a cap-and-trade (CAT) system, emissions trading systems can be designed with an intensity-based cap. These rate-based systems are increasingly being implemented. Examples include China's national ETS and Canada's output-based pricing system (OBPS). In these tradable performance standards (TPS) systems, emissions quantities and prices are both flexible. The implications of overlapping policies have mainly been studied for CAT systems and the effects of policy interactions are less understood for TPS.

Fischer et al. (2024) extend the prior literature with their study on the economic effects of a policy overlap between ETS and subsidies to renewables and taxes on electricity for a range of ETS. The analytical model developed in the paper reveals that limitations in cost-effectiveness associated with the design of a given ETS can be partly or fully offset by some of the policies with which it overlaps. Applying a numerical model, Fischer et al. (2024) showed that overlapping policies improve the performance of differentiated benchmarks. Switching to Cap and Trade would eliminate the need for indirect emissions pricing and, in turn, reduce costs. Even with incomplete coverage, the cap-and-trade system without overlapping policies was found to be most effective. The question is whether transitioning from a TPS to a cap-and-trade system, aiming to improve the system's efficiency, could still address the competitiveness concerns for which a TPS was implemented in the first place. Overall, both the type of ETS and the type of overlap impact the nature of the interactions, highlighting the need to consider both aspects jointly when undertaking reforms.

Summary of the second Workshop on Ex-Ante Assessments of Emissions Trading

At a time when ETSs are increasing in number and face similar issues, only a few comparisons of ex-ante models exist. As part of the workshop different studies were presented, including the second annual ex-ante model comparison. The goal of the ex-ante assessment of ETSs was to step up the benefits of knowledge sharing and mutual learning by collecting scientific evidence from different ETSs worldwide.

Besides the model comparison, this section also includes the takeaways from the numerical applications of the ex-ante models presented during the workshop. Given the number of survey respondents and the workshop's broader focus, not all models were presented. Thus, the illustration of the model applications is limited to a few models.

Survey results and model comparison

One of the workshop sessions was devoted to the comparison of selected macroeconomic models simulating the development of different ETSs or, more generally, the effort to decarbonise different regions. The comparison comprises 17 carbon market models from 16 organisations[4]– academic institutions, consultants, public bodies and international organisations. The regions, organisations and models covered are shown in Figure 1 and the main model characteristics are summarised in Appendix II in Table 1.

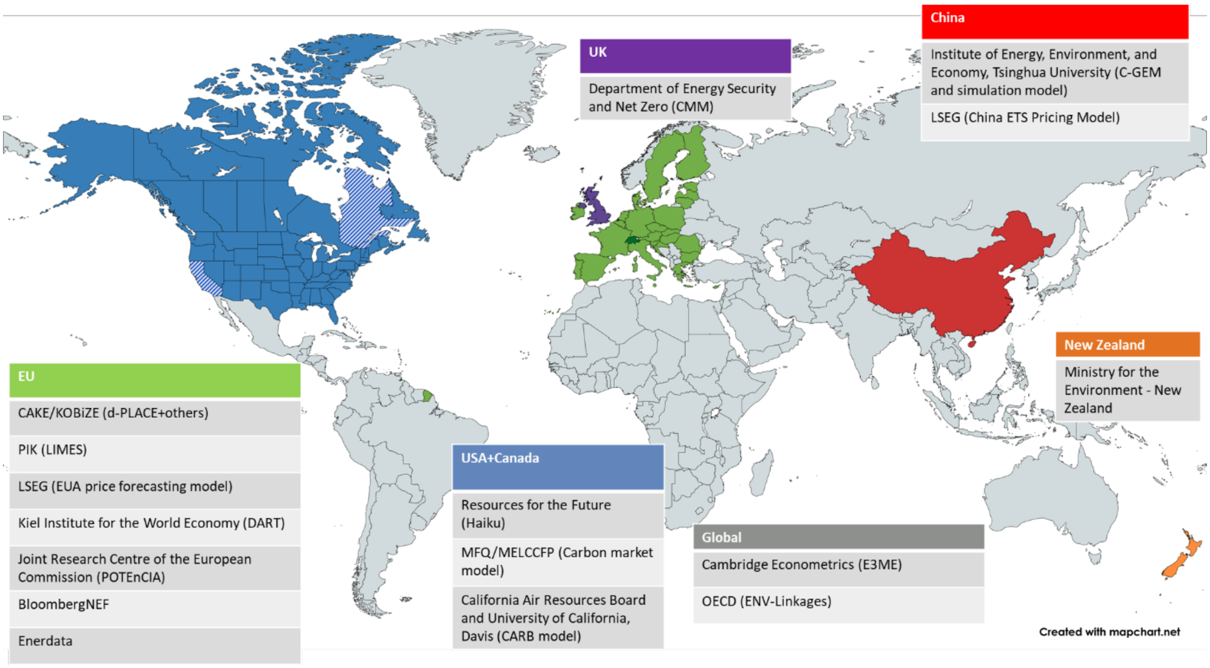

Figure 1. Models presented or reviewed at the workshop with their corresponding institutions and regions covered.

The workshop discussed the model types, implementation details, and core assumptions employed in analysing carbon prices and carbon removals from models worldwide. More specifically, it took stock of the diversity of approaches, provided insights on the operation and expected challenges of the respec-

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[4] The Institute of Energy, Environment, and Economy from Tsinghua University operates two models, C-GEM and a China ETS simulation model. In addition to 14 models for which a comprehensive survey was completed, two additional modeller teams provided input on how they model CDR. These were Enerdata and BloombergNEF with models for the EU ETS.

tive carbon markets, and identified the main drivers affecting the price dynamics of carbon prices and removals until the end of this decade and beyond. Like in 2023, several modellers who participated in the workshop also took part in a survey to prepare for the model comparison session. This survey was roughly composed of five sections: (i) a short model fact sheet, (ii) carbon removal modelling, (iii) main scenario assumptions, (iv) carbon prices, and (v) questions on their interaction with policymakers.

The approaches used in the models include top-down (6), bottom-up (3), and hybrid (6). Although optimisation models following a top-down approach constitute an efficient tool for long-term planning and provide high-level policy assessment, they generally struggle to capture market dynamics. This can be tackled by complementing such models with bottom-up approaches. In comparison to the 2023 model comparison, this year's exercise included more models of this type, also highlighting the need to capture the entire system dynamics in energy systems that are increasingly interconnected. Most hybrid approaches involve Computational General Equilibrium (CGE) solving iteratively with more detailed sectoral models, e.g., the d-PLACE model covers all sectors of the economy, following a top-down approach based on a CGE model coupled with a detailed energy sector model (MEESA). This allows the evaluation of the impact of the EU ETS on other sectors of the economy and associated differences in the impacts on them.

The time granularity used in the models is mostly yearly (10), while some models use other intervals (5), typically every 5 years. Forecast representation varies, with 9 models having limited forecasts based on actors reacting to current prices for 3-5 years, 3 models having perfect forecasts, and two models using a combination of both depending on model size and detail (e.g., perfect in MEESA and limited in d-PLACE (CAKE)). Among the models assuming perfect foresight, LIMES-EU and LSEG-China also have myopic setups. This highlights a trend among modellers to acknowledge the limitations posed by such an assumption in such markets facing increasing uncertainty.

Such as in 2023, linkage to other carbon markets does not appear to be a relevant feature of the models presented, reflecting the current state of policy worldwide. However, some models incorporate the possibility of linking, and two of them (C-GEM and DART) have been used to study the potential impact of linking the China and EU ETS, among others. Likewise, only 5 models include offset credits. For example, offset credits are included in models for China and the USA/Canada, with up to 100 MtCO2 in China by 2030 (LSEG).

The regions covered by the models are the USA/Canada, EU/UK, China and New Zealand. Additionally, two models (E3ME and ENV-Linkages) have global coverage, allowing them to provide average carbon prices and, in the case of ENV-Linkages, carbon prices for the USA and Canada. Not all models have a specific representation of existing ETSs in the region, and thus the computed carbon prices do not necessarily reflect the expected allowance prices. For instance, the global models provide global carbon prices and prices for different regions, such as the USA and Canada, even if no ETS covers such geographical scope. Although this makes the price comparison more difficult, this provides some insights into the differences across regional long-term costs of decarbonisation.

Carbon prices

Figure 2 shows the carbon prices computed by the survey models for different regions. In the case of the EU and UK, the models represent the EU ETS and UK ETS, respectively. In terms of predicted prices, the survey further revealed an overall increasing trend across jurisdictions, with predicted prices of non-EU ETSs remaining at a lower level than EU prices (see Figure 2). Carbon prices increase from 5-240 EUR/tCO2 in 2030 to 34-492 EUR/tCO2 by 2050. The price range increases as a result of the uncertainty regarding abatement costs, the coverage scope and overlapping policies. The price in non-EU jurisdictions follows an increasing trend, but at a substantially lower level: prices are substantially lower in China and in New Zealand than in the USA/Canada, which are also lower than in the EU/UK ETS. It remains unclear whether these prices reflect abatement costs or, rather, the higher influence of complementary policies. Given the model complexity, it is difficult to identify the reason for the price differences.

Regional prices appear to be around the estimated global carbon prices, which range between 122-140 EUR/tCO2 by 2030, and between 254-282 EUR/tCO2 by 2050 (see central panel Figure 2). These two estimations, from the models E3ME and ENV-Linkages, indeed display a very similar trend, and their differences remain almost unchanged over time. E3ME results reflect the outcome of less ambitious targets than ENV-Linkages. Indeed, the former represents a business-as-usual trajectory in which policies that have been implemented in the past continue to have an effect in future years, and the scenario is consistent with approximately 3-4°C average temperature increase by 2100, while ENV-Linkages estimations come from the last published NZE scenario. As a consequence, pressure on carbon prices is higher in the latter.

In the case of China, prices range between 5-69 EUR/tCO2 by 2030 and between 81-187 EUR/tCO2 by 2050 (see left panel of Figure 2). The models reflect a focus on expanding coverage to more sectors, tightening benchmarks over time, and maintaining specific allocation or performance-based approaches. Besides the lower ambition with respect to the EU ETS[5], the lower prices might also be explained by the fact that the Chinese ETS is a tradable performance standard (TPS) and not a cap-and-trade system.

Prices in the New Zealand ETS (NZ ETS) will decrease from 40 to 36 EUR/tCO2, with prices peaking at 46 EUR/tCO2 by 2030. In the period to 2030, the behaviour of allowances holders is a critical driver. From around 2030, forestry units will become the main source of supply. Because forestry units are relatively cheap and can enter into the ETS in unlimited volumes at present, they drive the ETS price towards the price that is sufficient to match the long-run marginal cost of afforestation, which is likely to be lower than emissions abatement costs.

Models covering the US and Canada estimate prices between 34-131 EUR/tCO2 by 2030 and between 103-292 EUR/tCO2 by 2050 (see central panel). These models comprise different jurisdictions, the only model covering an ETS (the WCI) being MFQ/MELCCFP. There is no clear pattern of whether prices are higher or lower in Canada than in the US.

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[5] For instance, C-GEM assumes climate neutrality by 2060.

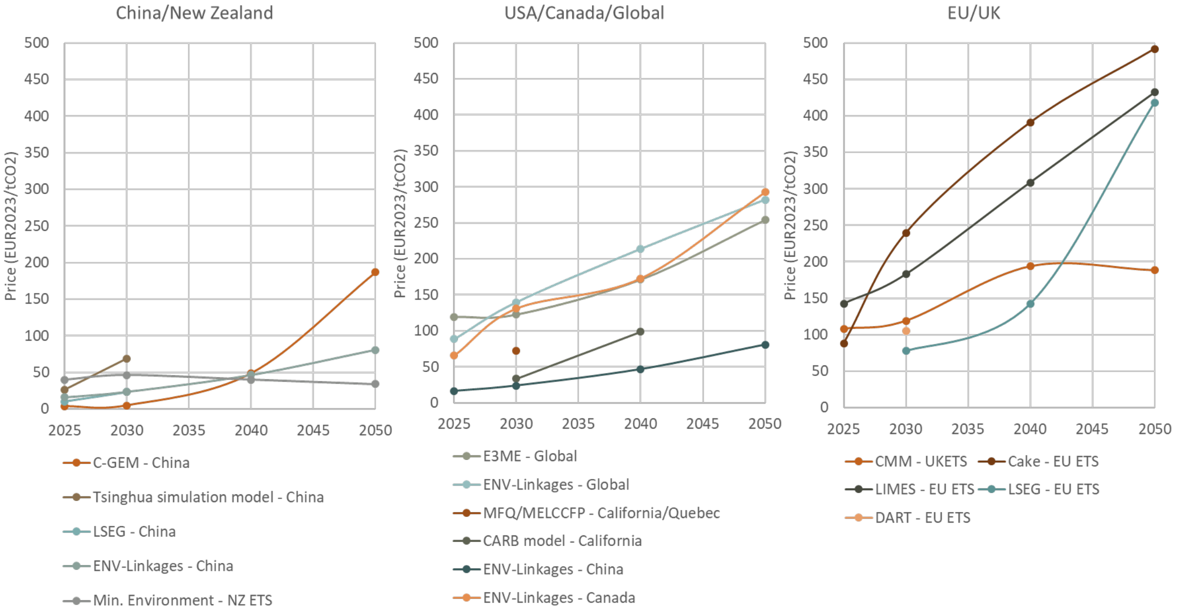


Figure 2. Carbon prices computed by the surveyed models for China, USA, Canada, California, the California/Quebec ETS, the EU ETS, the NZ ETS and the UK ETS. We also include global carbon prices computed by the models E3ME and ENV-Linkages in the central panel, dedicated to carbon prices in the USA and Canada.

Finally, prices estimated for the EU ETS range between 77-240 EUR/tCO2 by 2030 and between 418-492 EUR/tCO2 by 2050 (see right panel of Figure 2), while prices for the UK ETS are substantially lower, increasing from 120 EUR/tCO2 in 2030 to 190 EUR/tCO2 in 2050 (slightly lower than in 2040). The EU ETS models have in common ambitious reduction targets, aiming for significant reductions by 2030 and beyond, in line with recent reforms, e.g., the ‘Fit for 55’ package, and reflecting the 2040 presumable ambition. While some models explicitly incorporate REPowerEU and other additional policies, others assume a baseline scenario without new policy interventions, focusing instead on existing and reformed ETS frameworks. These might explain the difference between EUA and UKA prices. For instance, the CMM model assumes less ambitious regulation for the UK ETS (climate neutrality by 2050, while the cap reaches zero before that in EU ETS models) as well as more complementary decarbonisation policies. Likewise, lower prices computed by LSEG-EU are explained by a looser emissions cap post-2040 (e.g., 2.5% compared to 4.4% in LIMES-EU).

Carbon removals

In addition to the 15 models for which a comprehensive survey was completed, two additional modeller teams provided input on how they model CDR. These were Enerdata and BloombergNEF with models for the EU ETS. In the analysis of 17 models, 11 incorporate Carbon Dioxide Removal (CDR) technologies, with only three (E3ME, CAKE and the NZ Ministry for the Environment), including temporary removals. The CDR methods covered include afforestation (3 models), Bioenergy with Carbon Capture and Storage (BECCS) (8 models), Direct Air Carbon Capture and Storage (DACCS) (9 models), and other methods (6 models). The assumptions regarding the integration of CDR technologies generally indicate full fungibility, except for the CAKE model, where negative emissions from afforestation are priced at 50% of the carbon price in non-ETS sectors.

Regarding availability and constraints, the models do not impose lower bounds but present varying upper bounds for CDR availability, typically between 2025 and 2035. Additional constraints highlighted in the models include deployment rates, global deployment, biomass availability, the amount of land that can be converted and the capacity to plant (10 models), as well as transport and storage capacities, technical limitations, clusters, and geological formations (5 models). The primary drivers for investments in CDR identified are subsidies (5 models) and carbon prices (10 models).

Although most models surveyed consider CDR, only a few of them reported recent estimations on CDR deployment, more precisely C-GEM for China, CAKE and ENV-Linkages at EU-level, Enerdata, LIMES and LSEG specifically for the EU ETS, and the NZ Ministry for the Environment for the NZ ETS (see Figure 3). Although all models, including CDR, represent different types, mostly technology-based, the results reported in the surveys were mostly aggregated. Only the surveys from LIMES and Enerdata provided figures differentiating by type of removal.

As for the carbon prices, the differences in scope and assumptions make it difficult to identify the main drivers explaining the differences in carbon removal volumes. However, Figure 3 provides a picture of the removal range required to balance residual emissions in the long term. As expected, removals increase over time, and volumes achieved until 2030 are almost inexistent. It is noticeable that removals required in China are much larger than in the EU: they reach 970 MtCO2/yr in 2040 and 1970 MtCO2/yr in 2050, while estimations for the EU are 200 MtCO2/yr in 2040 and 330-420 MtCO2/yr in 2050. The differences between China and the EU highlight an extended dependency on fossils in China, while the difference in 2050 at the EU level potentially stems from upper bounds and the very expensive DACCS costs assumed in the CAKE model. As expected, the removals triggered solely by the EU ETS are lower than those at the EU level, as removals at the EU level could be used to balance residual emissions from the ETS2 or agriculture. Some removals are deployed already before 2030 (less than 14 MtCO2/yr). Figures increase to 8-50 MtCO2/yr in 2040 and 30-200 MtCO2/yr in 2050. LSEG provides the highest estimations, while Enerdata provides the lowest. BECCS appears to be the dominating technology, but the role of DACCS is expected to increase over time. Removals in the NZ ETS are substantially lower -as expected- due to the system size. They increase from 6 to 28 MtCO2/yr, with barely any increase between 2040 and 2050.

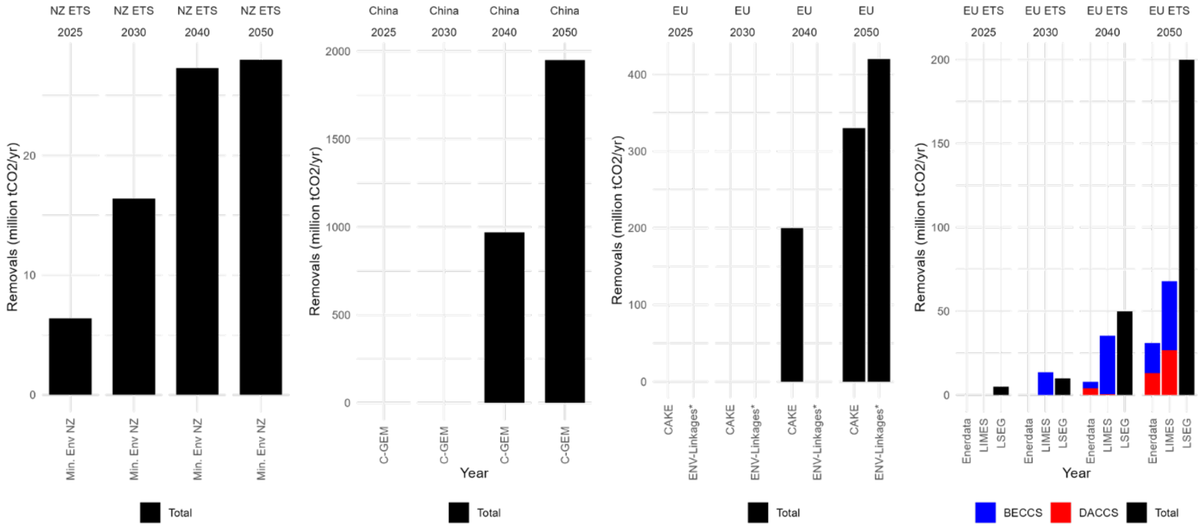


Figure 3. Carbon dioxide removals estimated by the surveyed models for China, the EU, the NZ ETS, and the EU ETS. Note: The results from ENV-Linkages in the central panel also include UK and the EFTA countries.

Bridging the gap with policymaking

The interaction between modelling teams and policymakers concerning ETS modelling involves a multi-faceted approach that includes workshops, direct engagement, and dissemination of analyses. Responses from LSEG-China, CAKE, CMM, and PIK emphasised the role of organised events, where policymakers and modellers come together to discuss the latest findings and their implications. These events, such as workshops and conferences, facilitate mutual understanding and ensure that model outcomes align with policy needs. For instance, CAKE highlighted its involvement in the LIFE VIIEW 2050 project, where it presented new analyses to government officials, fostering a collaborative environment. Similarly, the PIK team mentioned that project-funded meetings and events enable an exchange of ideas that can influence policy decisions.

In addition to organised events, ongoing collaboration through project meetings and advisory roles plays a crucial role in bridging the gap between modelling and policymaking. Teams like CAKE and the Institute of Energy, Environment, and Economy at Tsinghua University noted that continuous engagement with policymakers through project meetings, internal policy recommendation reports, and open dialogues ensures that model results are not only communicated but also integrated into policy development processes. For example, the Tsinghua team actively provides policy recommendations to the Ministry of Ecology and Environment in China, which has led to the adoption of several suggestions. This ongoing interaction ensures that the models remain relevant and that their outputs are utilised effectively in the policymaking process. Modellers from the NZ Ministry for the Environment emphasise the importance of modelling work carried out in-house alongside policy advisors and analysts to inform decisions that enable this close collaboration and upskill policymakers.

Furthermore, dissemination through the production of reports, policy briefs, and public testimonies serves as a critical mechanism for translating modelling insights into actionable policy recommendations. Teams such as RFF and CARB have highlighted the importance of direct testimonies before legislative committees and public workshops in influencing policy. These reports and briefings provide a structured way to present complex modelling outcomes in an accessible format, making it easier for policymakers to understand and act upon the information. E3ME, for example, has conducted various impact assessments for the EU and other international organisations, advising on the effects of policy packages and system expansions. This combination of formal reports and direct engagement ensures that policymakers have the necessary information to make informed decisions, ultimately leading to more effective and evidence-based climate policies.

To better bridge the gap between ETS modelling and policymaking, several common improvements have been suggested by various teams. A key recommendation is enhancing data transparency and sharing. LSEG-China and PIK emphasise better access to high-quality, granular data on emissions and abatement costs to ensure more accurate and relevant models. The Institute of Energy, Environment, and Economy at Tsinghua University also stresses the importance of robust and comprehensive data support from the public and private sectors. This increased transparency would help create reliable policy formulation tools, fostering trust and enabling more informed decision-making.

Improved communication and collaboration between modellers and policymakers are also frequently highlighted. CAKE, PIK, and LSEG-EU advocate for more structured and frequent communication channels, such as regular workshops, seminars, and meetings. These interactions would facilitate continuous dialogue and knowledge exchange, ensuring that models better represent real-world complexities and that the latest scientific insights inform policies. Moreover, engaging stakeholders from various disciplines and maintaining a shared understanding of modelling approaches, as suggested by PIK and E3ME, would help in aligning model outcomes with policy needs and in anticipating investor expectations. Finally, Enerdata suggests improving the visibility of organisations providing model-based expertise and strengthening links between ETS policymakers and modellers through contact directories, mailing lists, and annual workshops.

It was also mentioned that there was a need to develop capacity building and upskilling of policymakers to better understand the opportunities modelling work represents as well as its limitations.

Case studies

The collected responses above highlight the heterogeneity not only among the models but also among the different systems in terms of maturity, decarbonisation ambition, and scope. The results on CDR deployment are a good example of the extent to which these systems are already preparing for their climate neutrality commitments independently of their maturity level. However, the considerations dominating the debate and assessment needs in every system became more apparent in the presentations during the workshop.

In a recently implemented system (2021), such as the Chinese, the focus is on how to keep expanding its scope while improving its efficiency. Primarily covering the power generation sector (40% of China’s emissions), the system is about to expand to additional industries by 2025, with further expansions planned ahead of 2030. The primary instrument is the Chinese Emissions Allowances (CEA), although the market allows limited claims through China Certified Emissions Reduction (CCER) credits. The system has seen a significant price increase in 2023, and according to Jin and Song's (2024) modelling exercise, a tightening of available allowances relative to covered emissions is foreseen from 2026 onwards.

Finally, studies based on the EU ETS focus on how carbon pricing can deliver climate neutrality. Osorio et al. (2024) and Boratinsky et al. (2024) show to what extent integrating CDR into the climate policy, which appears inevitable to balance residual emissions, leads to a significant drop in EUA prices. Furthermore, Boratinsky et al. (2024) showed that CDR enhances GDP and consumption. However, the impact of different policies on carbon prices is not always straightforward amid increasingly interconnected energy systems and regulatory frameworks. For instance, hydrogen displaces fossil fuels, lowering carbon prices but increasing electricity demand, which in turn raises carbon prices. At the same time, policies integrating CDR, independently of the consensus on their high-level role and their positive impact on the system costs, need further substantiation. According to Osorio et al. (2024), the high uncertainty on CDR cost and fragmented regulation give rise to the risks of abatement deterrence and excessive biomass use. To ensure climate neutrality while avoiding such risks, the long-term regulatory framework needs Pigouvian efficiency, supply-side efficiency, and net-negative readiness. For this, Osorio et al. (2024) propose a three-stage path for removal integration into the EU ETS based on risk reduction contingencies that serve as preconditions for entering subsequent stages.

Conclusion

The third workshop of the Joint Workshops to mark the 30th anniversary of the Robert Schumann Centre was on ‘The role of carbon markets in reaching carbon neutrality’.

Climate change is, of course, a huge all-encompassing global issue that can be analysed from many different angles and perspectives. The theme on which this workshop focused was relatively narrow – namely, emissions trading.

One of the relatively rare points of agreement among economists is that the policy response to climate change should include carbon pricing – the putting of a price on the emissions of the gases that cause anthropogenic climate change, the most important of which is carbon dioxide (CO2). Despite this agreement, it is still the case that all too often these gases are emitted free of charge.

There are two main ways of pricing carbon emissions: imposing a tax on each unit of CO2 emitted (a carbon tax); or the granting of permits to emit carbon to organisations in an emissions trading system (ETS). These permits can be traded between the organisations that have acquired more than they need to cover their emissions and the organisations that are emitting more carbon than can be covered by their permits. This trade creates a carbon price. Overall emissions reduction is achieved by the number of permits being issued declining over time. The ETS set up by the EU was the first of its kind, and it still covers more emissions than any others.

The EU ETS has been globally influential in that many other countries have now set up, or are planning to set up, their own ETSs. For example, China, the world’s largest carbon emitter, is in the middle of establishing its own scheme. The Chinese researcher at the workshop, describing its evolution, was explicit about what China had learned from the EU system.

The EU ETS is undergoing its own evolution, as described in the keynote presentation by Prof. Sonja Peterson. In particular, it is undergoing a major expansion from just including emissions from heavy industry, some aviation and, from 2024, some shipping, to take in emissions from road transport and home heating as well. The workshop engaged in much discussion of the challenges to the EU ETS that this entails.

Two other major issues, which now always arise in connection with emissions trading, were explored at the workshop: carbon removals and industrial competitiveness.

It is now clear that limiting the rise in global average temperatures to the targets set out in the Paris Agreement (well below 2oC, aiming for 1.5oC) will require carbon to be removed from the atmosphere, as well as the reduction of emissions to close to zero. The question explored in the workshop is whether and how carbon removals could be included in an ETS. Conceptually this is clearly possible, but the inclusion is complex and, if it is not well planned, could have major unintended negative consequences. A number of the presentations and much of the discussion in the workshop explored these complexities with a view to making policy recommendations.

Industrial competitiveness has always been a concern in relation to carbon pricing, as a result of which those industrial sectors in the EU that are deemed both energy- and trade-intensive have had their emission permits given to them for free, while other sectors have had to buy them in auctions. The European Commission desires to phase out this practice, but concerns remain that, as climate policy becomes more stringent, and the reduction in emission permits causes their price to rise, the prospects of negative effects on the competitiveness of EU industry and increases in industrial output and carbon emissions elsewhere in the world (carbon leakage) need to be taken seriously.

The proposed EU policy response is the Carbon Border Adjustment Mechanism (CBAM), which will be fully implemented in 2026. CBAM involves imposing a carbon tariff on some products as they enter the EU when they come from a country which does not have a carbon price comparable to that in the EU.

A number of presentations at the workshop discussed the economic and trade implications of this mechanism, which is not uncontroversial with some of the EU's major trading partners, but there is already clear evidence that it is causing them to bring forward implementation of their own carbon pricing schemes in order not to be hit by the CBAM.

Overall, the workshop showed an ETS to be a technical and somewhat specialised policy instrument, the importance of which now spreads well beyond Europe as countries implement their own systems and respond to those implemented elsewhere. The EU has played a central role in developing this crucial instrument of climate policy and looks set to continue to do so in the future.

References

Anderson, M., Ramsay-Collins, C., Kirkup, B., & Morgan, D. (2024). Reaslit analysis of UK ETS trading and abatement behaviour.

Antosiewicz, M., Boratyński, J., Jeszke, R., Kobus, P., Lewarski, M., Lizak, S., . . . Witajewski-Baltvilks, J. (2024). Economic interaction between climate policy instruments.

Barbosa Sa Leitao Di Pasquale, A. (2024). Enhancing climate policies through the implementation of regulated carbon markets in Brazil: reflecting on strategies for closing the policy-science loop.

Dechezleprêtre, A., Haramboure, A., Kögel, C., Lalamne, G., & Yamano, N. (2023). Carbon Border Adjustments: An examination of the direct and indirect effects of the European Carbon Border Adjustment Mechanism (CBAM).

Fischer, C., Qu, C., & Goulder, L. (2024). Interactions Between Emissions Trading Systems and Other Policies: Insights from Theory and an Application to China.

Gérardin, M., & Ferrière, S. (2024). Steelmaking and decarbonization: don't set the wrong objectives!

Görlach, B., Mc Donald, H., & Bognar, J. (2024). Options to Expand Emissions Trading to Agriculture in Europe.

Jin, B., & Song, Y. (2024). China's National ETS Price Outlook: Long-Term Forecast and Policy Scenarios.

L'Horty, T., Delacote, P., & Elias, M. (2024). Willingness-to-claim voluntary carbon offsets: market evidence of revealed-preferences.

Marcu, A., Bonfiglio, E., & Lopez Hernandez, J. (2024). The integration of negative emissions in the EU legislation. ERCST.

Martin, R., Muuls, M., & Stoerk, T. (2023). The effects of carbon pricing along the production network.

Rickels, W., Rischer, C., Schenuit, F., & Peterson, S. (2023). Potential efficiency gains from the inroduction of an emissions trading system for the buildings and road transport sectors in the European Union.

Sultani, D., Osorio, S., Günther, C., Pahle, M., Sievert, K., Schmidt, T., . . . Edenhofer, O. (2024). Sequencing Carbon Dioxide Removal into the EU ETS.

Teusch, J., D'Arcangelo, F., Kruse, T., & Pisu, M. (2024). Carbon prices, emissions and international trade in sectors at risk of carbon leakage: Evidence from 140 countries. OECD Economics Department Working Papers.

von Bebenburg, C., & Shamsi, S. (2022). Market design options for integrating negative emissions into the ETS.

Appendix I – Workshop Program

“The role of carbon markets in reaching carbon neutrality”

18 June

10:00-10:45 Introduction, Tour de Table, Ice Breaker

11:15-12:05 **Keynote speech: The merits and shortcomings of the EU carbon markets**

Sonja Peterson | Kiel Institute for the World Economy

12:15-13:00 **Session 1: Chinese National ETS Model**

China’s national ETS price outlook: long-term forecast and policy scenarios [Introduction]

Boyang Jin | London Stock Exchange Group

14:00-15:30 **Session 2: EU ETS Models**

Economic interaction between climate policy instruments [Abstract]

Jakub Boratyński | KOBiZE

Sequencing CDR into the EU ETS [Abstract]

Sebastian Osorio | Potsdam-Institute for Climate Impact Research

16:00-17:10 ETS Model Comparison

Sebastian Osorio

19 June

10:00-11:30 **Session 3: Carbon leakage**

Carbon border adjustments: an examination of the direct and indirect effects of the European Carbon Border Adjustment Mechanism (CBAM)

Antton Haramboure |Organization for Economic Cooperation and Development

Carbon prices, emissions and international trade in sectors at risk of carbon leakage: evidence from 140 countries [Abstract]

Jonas Teusch | OECD

Session 4: Carbon pricing and firm behaviour

The effects of carbon pricing along the production network [Abstract]

Thomas Stoerk | National Bank of Belgium & LSE

Realist analysis of UK ETS trading and abatement behaviour [Introduction]

Mary Anderson | CAG Consultants

14:30-15:30 **Policy panel: ETS Endgame – Including new sectors and removals ETSs**

Edoardo Croci | Bocconi University

Sebastian Osorio | Potsdam-Institute for Climate Impact Research

Elena Marro | European University Institute

16:00-17:30 **Session 5: Beyond the EU ETS: Offsets & China ETS Policy Overlap**

Willingness-to-claim voluntary carbon offsets: market evidence of revealed-preferences [Abstract]

Tara L'Horty | Université de Lorraine

Interactions between emissions trading systems and other policies: insights from theory and an application to China [Abstract]

Carolyn Fischer | World Bank

20 June

09:15-11:30 **Session 6: Decarbonising industry and agriculture**

Steel in the EU CBAM: will scrap-resource shuffling delay the sector's global decarbonization? [Abstract]

Maxime Gérardin | France Stratégie

Market design options for integrating negative emissions into the ETS [Introduction]

Carlotta Von Bebenburg | Oxera

Options to expand emissions trading to emissions from agriculture in Europe [Abstract]

Benjamin Görlach | Ecologic Institute

12:00-13:30 **Session 7: Legislation for carbon pricing**

The integration of negative emissions in the EU legislation [Introduction]

Elena Bonfiglio | European Roundtable on Climate Change and Sustainable Transition

Enhancing climate policies through the implementation of regulated carbon markets in Brazil: reflecting on strategies for closing the policy-science loop [Introduction]

Adriana Isabelle Barbosa Sa Leitao Di Pasquale | University of Pisa

14:30-15:30 **Guest lecture: Stopping climate change**

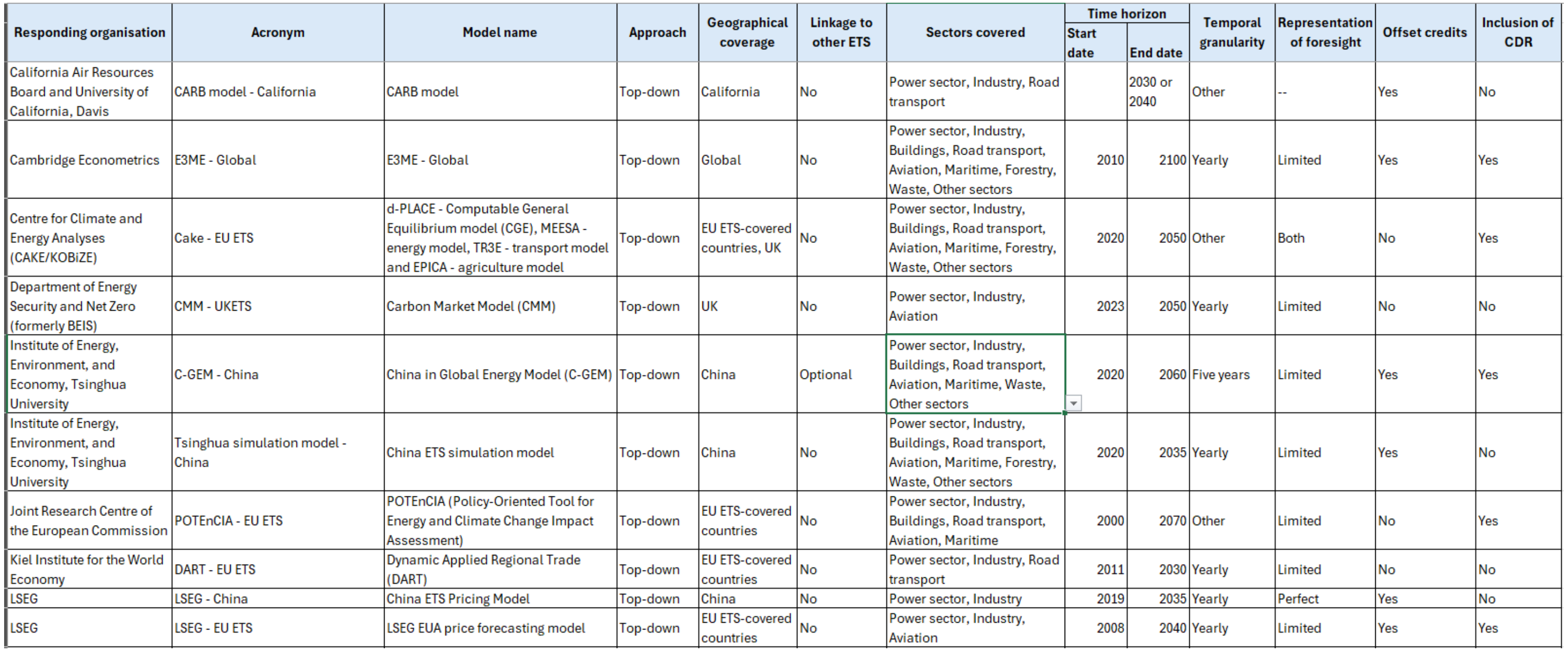
Paul Ekins | UCL

16:00-17:30 **General discussion & conclusions**

17.30 Close

Appendix II – Ex ante model features

Table 1. Categorisation of models along different features and methodological aspects.



Responding organisation	Acronym	Model name	Approach	Geographical coverage	Linkage to other ETS	Sectors covered	Time horizon		Temporal granularity	Representation of foresight	Offset credits	Inclusion of CDR
							Start date	End date				
California Air Resources Board and University of California, Davis	CARB model - California	CARB model	Top-down	California	No	Power sector, Industry, Road transport		2030 or 2040	Other	--	Yes	No
Cambridge Econometrics	E3ME - Global	E3ME - Global	Top-down	Global	No	Power sector, Industry, Buildings, Road transport, Aviation, Maritime, Forestry, Waste, Other sectors	2010	2100	Yearly	Limited	Yes	Yes
Centre for Climate and Energy Analyses (CAKE/KOBiZE)	Cake - EU ETS	d-PLACE - Computable General Equilibrium model (CGE), MEESA - energy model, TR3E - transport model and EPICA - agriculture model	Top-down	EU ETS-covered countries, UK	No	Power sector, Industry, Buildings, Road transport, Aviation, Maritime, Forestry, Waste, Other sectors	2020	2050	Other	Both	No	Yes
Department of Energy Security and Net Zero (formerly BEIS)	CMM - UKETS	Carbon Market Model (CMM)	Top-down	UK	No	Power sector, Industry, Aviation	2023	2050	Yearly	Limited	No	No
Institute of Energy, Environment, and Economy, Tsinghua University	C-GEM - China	China in Global Energy Model (C-GEM)	Top-down	China	Optional	Power sector, Industry, Buildings, Road transport, Aviation, Maritime, Waste, Other sectors	2020	2060	Five years	Limited	Yes	Yes
Institute of Energy, Environment, and Economy, Tsinghua University	Tsinghua simulation model - China	China ETS simulation model	Top-down	China	No	Power sector, Industry, Buildings, Road transport, Aviation, Maritime, Forestry, Waste, Other sectors	2020	2035	Yearly	Limited	Yes	No
Joint Research Centre of the European Commission	POTEnCIA - EU ETS	POTEnCIA (Policy-Oriented Tool for Energy and Climate Change Impact Assessment)	Top-down	EU ETS-covered countries	No	Power sector, Industry, Buildings, Road transport, Aviation, Maritime	2000	2070	Other	Limited	No	Yes
Kiel Institute for the World Economy	DART - EU ETS	Dynamic Applied Regional Trade (DART)	Top-down	EU ETS-covered countries	No	Power sector, Industry, Road transport	2011	2030	Yearly	Limited	No	No
LSEG	LSEG - China	China ETS Pricing Model	Top-down	China	No	Power sector, Industry	2019	2035	Yearly	Perfect	Yes	No
LSEG	LSEG - EU ETS	LSEG EUA price forecasting model	Top-down	EU ETS-covered countries	No	Power sector, Industry, Aviation	2008	2040	Yearly	Limited	Yes	Yes

Responding organisation	Acronym	Model name	Approach	Geographical coverage	Linkage to other ETS	Sectors covered	Time horizon		Temporal granularity	Representation of foresight	Offset credits	Inclusion of CDR
							Start date	End date				
New Zealand Ministry for the Environment	NZ ETS Market Model	New Zealand Emissions Trading Scheme Market Model	Hybrid	New Zealand	No	Power sector, Industry, Buildings, Road transport, Forestry, Waste	2020	2050	Yearly	Limited	No	Yes
OECD	ENV-Linkages - Global	ENV-Linkages - Global	Top-down	Global	No	Power sector, Industry, Buildings, Road transport, Aviation, Maritime, Forestry, Waste, Other sectors	2014 or 2017	2050 or 2060	Yearly	Limited	No	No
Potsdam Institute for Climate Impact Research (PIK)	LIMES - EU ETS	LIMES-EU	Top-down	EU ETS-covered countries, UK	No	Power sector, Industry, Aviation, Maritime	2010	2070	Other	Perfect	No	Yes
Resources for the Future	Haiku - USA	Haiku	Top-down	California, other US states	No	Power sector, Industry, Buildings, Road transport	2024	2045	Yearly	Perfect	Yes	Yes
The Ministère des Finances du Québec (MFQ) and the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)	MFQ/MELCCFP - California/Quebec	Carbon market model	Top-down	California, Quebec	No	Power sector, Industry, Buildings, Road transport, Aviation, Maritime	2024	2050	Yearly	Both	Yes	Yes
BloombergNEF	BloombergNEF	BloombergNEF	Top-down		No							Yes
Enerdata - EU ETS	Enerdata	Enerdata	Top-down		No							Yes

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