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Evaluation of the UK Emissions Trading Scheme

Phase 1 report

A report to the UK ETS Authority by CAG Consultants, Winning Moves and University College London

December 2023

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Executive Summary

Introduction

This report presents findings from phase 1 of the evaluation of the UK Emissions Trading Scheme (UK ETS), focusing on UK ETS processes (chapters 3 and 4) and market outcomes (chapters 5, 6 and 7). Phase 2 of the evaluation will examine UK ETS impacts on carbon abatement and economic activity in more detail.

The UK ETS is a 'cap and trade' scheme that aims to incentivise cost-effective Greenhouse Gas (GHG) emissions reductions at the pace and scale needed to deliver the UK and devolved governments' climate targets, while providing appropriate mitigations against carbon leakage. Carbon leakage is defined as the movement of production and associated emissions from one country to another due to different levels of decarbonisation effort through carbon pricing and climate regulation. Through this 'cap and trade' scheme, the UK and devolved governments impose a limit on GHG emissions from sectors covered by the scheme and firms can trade emission allowances within this limit.

The UK ETS was established in January 2021. The scheme was designed to follow on from UK participation in the EU Emissions Trading System (EU ETS) from 2005 until the UK's exit from the EU in December 2020. The first phase of the UK ETS runs from 2021 to 2030. The scheme is run by the UK ETS Authority, comprising representatives from the UK Government, Scottish Government, Welsh Government and the Department of Agriculture, Environment and Rural Affairs for Northern Ireland. Participants are regulated by the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA), Natural Resources Wales (NRW), the Northern Ireland Environment Agency (NIEA) and Office Petroleum Regulator for Environment and Decommissioning (OPRED). An earlier, voluntary UK ETS ran from 2002 to end 2004, and helped to inform the development of the EU ETS.

The UK ETS applies to power generation, energy intensive industry, offshore oil and gas, and aviation[1]. The UK ETS covers around a quarter of the UK's domestic emissions, so it is an important policy for achievement of the UK and devolved governments' net zero targets.

A person or organisation who operates an installation or performs an aviation activity regulated under the UK ETS (known as an 'operator' or 'aircraft operator' (AO) respectively) must monitor and report emissions of greenhouse gases to their UK ETS regulator on an annual basis, having these reports verified by an independent accredited verifier. By 30 April in the year following each scheme year, operators and AOs must comply with the UK ETS by surrendering UK Allowances (UKA), equal to their reportable emissions in the scheme year from their operator holding account in the UK ETS Registry. Operators of installations that receive free allocations of UKA must also report activity levels annually and have these reports verified.

[1] The types of flights covered by the UK ETS are outlined in chapter 1 of the main report.

Operators in energy intensive industry sectors are eligible to receive some free UKA each year, depending on the level of international competition in their sector and on their performance compared to an energy efficiency benchmark for their sector. Free allocations to installation operators are adjusted if the firm's level of activity changes up or down by 15% or more. Some AOs are also currently eligible for free allocation. However, the UK ETS Authority has decided to phase out free allocation for the aviation sector by 2026.

Operators/AOs can source UKA from free allocations (where eligible for this), by buying UKA at fortnightly auction or by trading physical UKA (meaning actual UKA, not derivatives) or UKA derivatives (for example futures contracts) on the secondary market. Trades can be made via the Intercontinental Exchange (ICE) or via bilateral trades with any other account holder in the UK ETS Registry (known as 'Over the Counter' (OTC) transactions). Physical UKA and UKA derivatives can be traded by organisations without compliance obligations (for example banks, brokers and other traders) provided that they have a trading account in the UK ETS Registry. In the secondary market, daily ('spot') and monthly futures contracts in UKA are traded via ICE, while physical UKA, forward contracts and swaps are traded via OTC transactions.

In 2022, there were a total of 1,051 installations in the UK ETS (including energy intensive industrial sites, power generation and offshore oil and gas sites) and 378 AOs[2]. The term 'main scheme' is used in this report to indicate operators/AOs obliged to comply with the UK ETS by surrendering UKA via the UK ETS Registry. Installations with lower emissions and those providing services to hospitals can apply for 'Hospital or Small Emitter' (HSE) status or 'Ultra Small Emitter' (USE) status to follow simpler procedures. Installations with HSE and USE status are exempted from the requirement to surrender UKA, though HSE installations have annual emissions targets that they are required to meet or pay a penalty.

Reported emissions in 2022 were 111 million tCO2e. Emissions were concentrated in the hands of a few large emitters, with 12 entities (in the power generation and heavier energy intensive industry sectors) accounting for 50% of total emissions. About 41 million tCO2e were covered by free allowances in 2022, representing 37% of total emissions.

In March 2022, the UK ETS Authority issued a consultation on the future development of the UK ETS: 'Developing the UK Emissions Trading Scheme'. This included consultation on the introduction of an emissions cap that was consistent with the UK and devolved governments' net zero targets. The UK ETS Authority's main response[3] to the consultation, including policy positions about adoption of a net zero consistent cap, was published in July 2023 during the research period for phase 1 of the evaluation.

Methodology

This is a theory-based evaluation that uses contribution analysis to test a theory of change against a set of competing hypotheses. A theory of change explains how the activities undertaken by an intervention (such as a policy) contribute to a chain of results that lead to

[2] https://www.gov.uk/government/publications/uk-emissions-trading-scheme-regulator-reports
[3] https://www.gov.uk/government/consultations/developing-the-uk-emissions-trading-scheme-uk-ets

intended outcomes and impacts. The evaluation has 2 phases, with phase 1 of the evaluation running from February 2023 to end March 2024, and phase 2 of the evaluation running from summer 2024 to early 2026. Phase 1 of the evaluation was designed to respond to evaluation questions A and B below, while gathering some early evidence on evaluation question C. Phase 2 of the evaluation will examine UK ETS impacts more fully, when further evidence is available. The final part of phase 1 of the evaluation will involve detailed scoping of impact evaluation work to be undertaken during phase 2 of the evaluation.

Table 1: Evaluation questions (EQs) for phase 1 of the evaluation

Evaluation questions on UK ETS process, outcomes and impacts
A. WAS THE UK ETS EFFICIENTLY AND EFFECTIVELY DELIVERED?
A1. Has the introduction of the UK ETS ensured a smooth continuation of emissions trading for UK emitters previously in the EU ETS scheme?
A2. How has the operation of the UK ETS influenced the delivery of a functioning carbon market?
A3. Has the UK ETS delivery ensured that the scheme is administered efficiently and effectively (for both compliance operators in the main scheme as well as participants in the two opt-out schemes; hospitals and small emitters, and ultra small emitters)?
B. WHAT WERE THE OUTCOMES OF THE UK ETS?
B1. What has been the behaviour of market participants and what have been the implications of observed behaviour (e.g. for ETS market functioning or for firms' decarbonisation prospects)? How has this varied across different types of firms and sectors?
B2. Has the UK ETS delivered a carbon market, which is sufficiently accessible to participants and sufficiently liquid to enable its policy objectives to be achieved?
B3. What are the risks to the effective functioning of the carbon market and how can these be mitigated?
C. WHAT HAVE BEEN THE IMPACTS OF THE UK ETS AND ON WHOM?
C1. What has been the impact of the UK ETS on emissions and emissions intensity in the traded sector and how has this varied across sites, firms, sectors and UK regions?

C2. What has been the impact of the UK ETS on carbon leakage, investment leakage or carbon leakage risk in the traded sector? To what extent and how has carbon leakage, investment leakage and carbon leakage risk in the traded sector been influenced by carbon leakage mitigation policies, such as free allocation?
C3. Have there been any unanticipated consequences of UK ETS in the traded or non-traded sectors, and how have they varied across different types of firm or sector or UK region?

Workstreams in phase 1 of the evaluation included a scoping stage, qualitative research (with operators, AOs, traders and other stakeholders), a quantitative survey with main scheme and HSE operators, network analysis of the UK Transactions Log (meaning transactions in physical UKA logged in the UK ETS Registry), a literature review on the quality of secondary markets for 'cap and trade' systems, analysis of the UK ETS secondary market (meaning trading in UKA futures contracts), and synthesis of findings across these workstreams.

The qualitative interviewees comprised 36 UK ETS operators/AOs, 26 UK ETS traders (meaning organisations with UK ETS trading accounts) and 9 wider stakeholders (including delivery bodies, verification/compliance consultants, industry bodies and climate change stakeholders). Seven of the traders interviewed represented the trading arms of UK ETS operators/AOs while others represented banks, clearing banks, brokers and other firms trading in UKA.

The sample for the operator and AO survey covered the main scheme (meaning operators/ AOs with UK ETS registry accounts and surrender obligations) as well as installations with HSE and USE status. Survey responses were received from 204 entities in the UK ETS main scheme plus 24 HSEs, with no response from USEs. USE installations represent a very small proportion of total emissions, so this is a minor limitation of this research.

Impact evidence from phase 1 of the evaluation is limited, being based only on subjective, reported views from UK ETS operators/AOs. Evidence on carbon leakage is particularly limited, being based only on qualitative research which focused primarily on high emitters (in this case, firms emitting more than 50,000 tCO2e in 2022). UK ETS impacts will be researched further in phase 2 of the evaluation.

EQ A1: Did the UK ETS transition go smoothly?

The transition from the EU ETS to the UK ETS in January 2021 generally worked smoothly, largely because the UK ETS was designed to be very similar to the EU ETS and used many of the same processes and administrative systems.

However, some wider stakeholders commented that the timing of the decision regarding whether to replace the EU ETS with a carbon tax or UK ETS, taken in late 2020 shortly before

the UK ETS start date, created significant challenges for those involved in the introduction of the scheme. Some operators/AOs also commented that this created high levels of business uncertainty.

Transition costs for operators/AOs were generally modest, except for some operators in the power sector, where electricity was commonly sold up to 2 years in advance. These operators typically hedge future carbon costs by buying UKAs to cover their forward sales. Trading in UK allowances (UKA) opened in May 2021, 5 months after the start of the UK ETS. This was problematic for these operators as they hedged with EUA during these initial months and then needed to dispose of large quantities of excess EUA in unfavourable market conditions, because of the scale of capital tied up in allowances.

EQ A2: Is the UK ETS delivered efficiently and effectively?

Levels of operator and AO satisfaction with UK ETS processes were generally high (for example 70% or more), as were levels of satisfaction with the services provided by UK ETS regulators. Operators were least satisfied with the approach to free allocation (44% satisfied, n=104) and, for installation operators, the process of submitting activity level reports (52% satisfied, n=77).

The UK ETS involves two administrative systems, the ‘UK ETS Registry’ (an online compliance and trading system for UKA) and the online permitting, monitoring, reporting and verification system, through which operators/AOs perform regulatory actions including the reporting of GHG emissions. Although the survey found high levels of satisfaction with the UK ETS Registry (72%, n=183), qualitative research interviewees reported that registering, or changing, authorised representatives on the system was time consuming. Transition from the old online permitting system (Emissions Trading Scheme Workflow Automation Project, ETSWAP) to a new system (Manage Your Emissions Trading System, METS) was underway at the time of the research. While it was too early to assess feedback on the new system, some installation operators were frustrated that there was no automatic transfer of their UK ETS documentation from the old to the new system.

There was also frustration about the length of time that the UK ETS Authority had taken to publish its full response to the March 2022 consultation on ‘Developing the UK Emissions Trading Scheme’. Although traders reported in interview that the UK ETS Authority’s engagement processes were good in the early UK ETS period, and the majority of operators/AOs were satisfied with information received from the UK ETS Authority (63%, n=183), traders commented in interview that the UK ETS Authority could have engaged more with industry and the market about emerging post-consultation ideas (for example through working groups), rather than delaying any announcement until it had made a decision. Operators, AOs and traders interviewed expressed concern about remaining uncertainties around future plans for the UK ETS.

EQs A1 and B1-3: How well has the UK ETS market been operating?

Most operators/AOs with high emissions (more than 50,000 tCO2e in 2022) reported that they bought allowances more than once a year, because compliance costs have become significant to their business. This was partly because of decreasing free allocations and partly because of increased UK ETS prices since 2021. Large power sector operators were found to be particularly frequent traders, being primarily concerned with the differential between electricity sale prices and the cost of gas and carbon inputs. About half of operators/AOs (generally those with lower emissions) reported that they bought allowances once a year to meet their compliance requirements.

Most operators/AOs reported that they bought physical UKA or UKA derivatives (for example futures and forward contracts, explained in the Glossary in Appendix 1) via banks or brokers because this was the easiest and simplest route, avoiding the need for them to develop trading expertise and register for the primary auction or ICE platform. A small proportion of operators/AOs with high emissions reported that they bought physical UKA at auction and traded directly in futures contracts on ICE. These were primarily operators/AOs with specialist trading arms or in-house expertise in trading.

The behaviour of in-house and financial sector traders was analysed to comprise clearing, market making, broking, compliance trading and speculating. Network analysis found that market making was important for market liquidity, while speculation was less widely observed and appeared to contribute less to market liquidity. Traders expressed concern about perceived lower liquidity and higher volatility in the UK ETS compared to the EU ETS. However secondary market data analysis found that key metrics of market quality for the UK ETS were similar to the EU ETS, albeit with more variation in these metrics over time than in the larger EU ETS market. Some elements of the market data analysis were based on limited time series and are subject to confirmation by further analysis over a longer timescale.

The research identified some risks to future market quality and stability, including uncertainties about government policy on the UK ETS, the risk of oversupply of allowances in the next three years and uncertainties around the EU's introduction of the Carbon Border Adjustment Mechanism (CBAM), a new initiative which adjusts the prices of imports if they have been produced under jurisdictions with lower carbon prices or regulation.

Use of algorithmic trading, a computer-led trading approach which uses mathematical rules to determine trading decisions (based on market patterns or differentials between markets), was cited as a risk to the UK ETS market. However, the research did not find evidence of algorithmic trading.

EQ C1: Early findings about whether the UK ETS is influencing abatement of GHG emissions

The term ‘abatement’ is used here to mean reductions in GHG emissions. The early findings on abatement impact are based on reported behaviour and views from the qualitative and quantitative workstreams of the evaluation. A more objective assessment of UK ETS impact on abatement, based on energy and carbon data, will be undertaken in phase 2 of the evaluation.

The operator/AO survey found that a majority of operators/AOs (90%) reported having a plan to reduce carbon emissions, though 9% said they did not have one (n=203). Qualitative research, primarily with high emitters, confirmed that most were actively pursuing current carbon abatement opportunities, with many researching or progressing more future abatement options, including potentially innovative solutions.

In the qualitative research, operators/AOs reported that there were multiple drivers influencing both current and future abatement strategies. Over 4 in 10 (44%) respondents to the survey reported that the UK ETS influenced their awareness of carbon reduction opportunities to a ‘great’ or ‘large’ extent (n=167). Around 6 in 10 (62%) installation operators reported that the cost of UKAs influenced decarbonisation investment in UK plants, equipment or machinery (n=97). However, only 1 in 5 (20%) AOs said that the cost of UKAs had influenced their organisation to increase decarbonisation investment in new aircraft or aircraft upgrades (n=84). Qualitative research found that AOs mainly focused on operational efficiencies and planned to increase use of Sustainable Aviation Fuel (SAF), with the latter being influenced more by EU ETS incentives than by the UK ETS.

A small number of large power generators were found to factor UK ETS costs into operating decisions as to whether they ran gas-fired power stations on a daily or hourly basis. Although numbers were small, this was important because of the large volume of emissions involved.

The most commonly cited barrier to abatement was uncertainty around future carbon reduction technologies (31%, n=183). Qualitative research with installation operators highlighted that the necessary technical solutions for large-scale abatement were still at the early stages of development (for example Carbon Capture Utilisation and Storage (CCUS), hydrogen) while grid capacity was reported to restrict electrification. Several respondents noted the importance of being part of (or risk of not being part of) the UK industrial clusters as key in addressing access to the necessary future abatement infrastructure. The CCUS Cluster Sequencing programme[4] involves government support for net zero infrastructure (including CCUS and hydrogen) in a number of geographical clusters of energy intensive industry (for example the HyNet cluster in North West England and the East Coast cluster). AOs consistently remarked on the lack of technical abatement solutions for the sector beyond use of SAF.

[4] https://www.gov.uk/government/publications/cluster-sequencing-for-carbon-capture-usage-and-storage-ccus-deployment-phase-2

EQ C2-3: Early findings about whether the UK ETS is influencing carbon leakage and any unanticipated consequences

Evidence on carbon leakage was drawn primarily from qualitative research, focusing on larger emitters. As noted above, carbon leakage is defined as the movement of production and associated emissions from one country to another due to different levels of decarbonisation effort through carbon pricing and climate regulation. The UK ETS is designed to mitigate carbon leakage risks through increased free allocations to operators/AOs in sectors identified as being at risk. Although installation operators reported differences in competitiveness between the UK and EU countries (for example differences in overall taxation and energy costs), these were not interpreted as carbon leakage because the carbon pricing and regulation regimes in the UK and EU are broadly similar (albeit with some variation in their relative stringency over time).

Based on early evidence, this evaluation has so far found carbon leakage risk to be low in the power sector and aviation sectors. Although some AOs raised concerns in interview about potential changes to routes and frequencies involving destinations outside the UK and EU, an independent study by Frontier Economics and Air Transportation Analytics[5], commissioned by the Department for Transport and Department for Business Energy and Industrial Strategy, found minimal risk of carbon leakage, based on the current scope of the UK ETS. The study's findings were based on detailed quantitative research on the impacts of carbon pricing on UK aviation using a global aviation model.

This evaluation found carbon leakage risks to be greatest for commodity producers (meaning energy intensive industries producing globally traded commodities) who had minimal ability to pass on UK ETS costs to their customers, but risks were also found for installation operators in other energy intensive industries. In qualitative interviews, energy intensive industry operators cited examples of carbon pricing playing a role in increased competition from cheaper imports of certain products, and in international firms deciding to invest in other countries (beyond the EU and UK) or deciding to fulfil production requirements from their existing plants in these other countries. A more objective assessment of UK ETS impact on carbon leakage, based on economic data, is required in phase 2 of the evaluation to confirm these findings.

In terms of unintended consequences, there was some limited evidence of installation operators downsizing equipment to avoid being part of the UK ETS. There was also evidence about the process for activity related adjustments of free allowances potentially having unanticipated consequences in terms of both emissions and production activity. For example, some installation operators reported that the two year time lag for Activity Level Changes (ALC) disincentivised the restart of production where a plant or production line had been closed for some time. One installation operator also cited a risk (not actually observed) that –

[5] Frontier Economics and Air Transportation Analytics, (2022) Economic research on the impacts of carbon pricing on the UK aviation sector, Final report. https://www.frontier-economics.com/media/s1enxvsn/economic-research-on-the-impacts-of-carbon-pricing-on-the-uk-aviation-sector.pdf

close to the 15% ALC threshold – there could be a perverse incentive for an operator to carry out an activity to avoid losing free allowances, even if this would lead to greater emissions.

Preliminary assessment of whether the UK ETS is functioning as intended

An assessment of the UK ETS against evaluation questions A to C is presented above, based on evidence available to phase 1 of the evaluation. It is too early to assess the overall functioning of the ToC, as set out in chapter 2 of the main report. However, preliminary assessment of the ToC identified 3 important assumptions underlying the theory of the UK ETS design that were only partially supported by evidence from phase 1 of the evaluation.

- **"Regulated firms are aware of technical abatement options and costs"** (only partially supported because around a quarter (25%) of operators/AOs reported having limited capacity or capability to consider abatement options, while 31% reported considerable uncertainties associated with carbon reduction technologies (n=183)).
- **"Firms pursue a mix of responses (hold, abate, buy, sell) and they aim to respond in the most cost-effective manner through active trading as opposed to 'compliance behaviour"** (only partially supported because around 4 in 10 (44%) of survey respondents reported that they only buy UKA once a year, which appears to be simple 'compliance behaviour' (n=169)).
- **"Sufficient liquidity is achieved despite the limited number of market actors"** (only partially supported because, while the qualitative research found widespread concern about liquidity, the secondary market data analysis showed sufficient liquidity for the UK ETS to be considered a functioning carbon market, for the time periods analysed).

One important assumption was found to be unsupported by the evidence: **"Firms are confident in the long-term direction of travel – in relation to decarbonisation policy – and are therefore prepared to make long-term capital investments to deliver decarbonisation".** The qualitative research suggested that, at the time of the research, there was a lack of confidence in the long-term direction of travel for the UK and devolved government's net zero policy. This was reported to undermine businesses' ability to plan and deliver major capital projects.

For certain sectors, there was some support for competing hypotheses that challenge the ToC:

- Evidence that non-UK ETS factors were driving emissions reductions for some organisations, particularly in the aviation sector where EU ETS and, in future, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) were also named as drivers of abatement. CORSIA is a global market-based measure that applies to international aviation emissions. Offsetting under the scheme is expected to begin from 2024, but many AOs were already considering future CORSIA requirements because they sell flights a year or more in advance.

- Evidence of reductions in activity levels and apparent carbon leakage for some energy intensive industry operators.
- Mixed evidence on market quality, with secondary market data analysis indicating relatively good market quality for a market of UK ETS size, but traders still reporting some concerns about liquidity and volatility.
- Announcement of the transition to a net zero cap was made towards the end of the research period for Phase 1 of the evaluation. Until this point, the trajectory of the UK ETS cap was not consistent with the UK's net zero ambitions, although actual emission levels were below the cap.
- There were limited findings about unanticipated outcomes. There was some evidence of free allocations being made to sectors that were not in fact at risk (for example aviation), but the UK ETS Authority has announced the phasing out of aviation free allocations in 2026.

The assumptions underlying the ToC, and the overall strength of evidence for the ToC and competing hypotheses, will be assessed further during phase 2 of the evaluation.

Wider findings on the UK ETS

Wider comments about fundamental aspects of UK ETS design were as follows:

- Many operators/AOs would like to see closer alignment between the UK ETS and EU ETS, with some operators/AOs and traders calling for some form of linkage between the UK ETS and the EU ETS, both to increase the size of the UK ETS market and to formalise future alignment of the two systems.
- Both operators, AOs and traders commented that the UK ETS Authority needed to clarify how the UK ETS will operate beyond 2030, to help industry plan major capital projects. They commented that the EU ETS had provided firmer long-term plans.
- A number of operators/AOs made comments about potential use of UK ETS revenues to support decarbonisation. At the simplest level, they suggested that there was a need for more transparency about how UK ETS revenues were used.
- Many stakeholders commented that there was a need for government policy to include incentives for decarbonisation ('carrots') as well as the disincentive for carbon emissions ('sticks') provided by the UK ETS.
- There was considerable interest amongst installation operators and traders about the potential inclusion of Greenhouse Gas Removals (GGR) in the UK ETS and some interest from AOs and wider stakeholders in potential extension of the scheme to additional sectors (for example transport and agriculture/nature-based solutions respectively).
- Some installation operators would prefer to pay a carbon tax instead of being part of the UK ETS. They saw the carbon market as a distraction from their main business and from the task of decarbonisation.

- Finally, there was some suggestion that the UK ETS could be linked to developing country systems in Africa, Latin America or Asia which offered more cost-effective abatement opportunities.

Chapter 1. Introduction

This chapter provides an introduction to the UK ETS and to the purpose of this evaluation. A glossary is presented in Appendix 1.

In early 2023, the Department for Energy Security and Net Zero ('the Department') commissioned CAG Consultants (CAG) to undertake an evaluation of the UK Emissions Trading Scheme (UK ETS). For this evaluation, CAG leads a consortium with University College London (UCL), Winning Moves (WM) and Cambridge Econometrics (CE).

This report presents findings from phase 1 of the UK ETS evaluation, focusing primarily on the scheme's implementation process and on outcomes since the start of the scheme. The final phase, phase 2 of the evaluation, to be undertaken from 2024 to 2026, will focus on the impacts of the UK ETS.

About the UK ETS

The UK ETS is a 'cap and trade' scheme that aims to incentivise cost-effective Greenhouse Gas (GHG) emissions reductions at the pace and scale needed to deliver the UK and devolved governments' climate targets, while providing appropriate mitigations against carbon leakage. Carbon leakage is defined as the movement of production and associated emissions from one country to another due to different levels of decarbonisation effort through carbon pricing and climate regulation. Through this 'cap and trade' scheme, the UK and devolved governments impose a limit on GHG emissions from sectors covered by the scheme and firms can trade emission allowances within this limit.

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The UK ETS applies to GHG emissions from power generation, energy intensive industry, offshore oil and gas, and CO2 emissions from aviation. For aviation, the UK ETS covers flights within the UK, flights from the UK to the European Economic Area (EEA), flights from Great Britain to Switzerland, as well as flights between UK and Gibraltar. Return flights from the EEA and Switzerland are covered by the EU ETS and Swiss ETS respectively. The UK ETS covers around a quarter of the UK's domestic emissions so it is an important policy for achievement of the UK and devolved governments' net zero targets.

A person or organisation who operates an installation or performs an aviation activity regulated under the UK ETS (known as an 'operator' or 'aircraft operator' (AO) respectively) must monitor and report emissions of greenhouse gases to their UK ETS regulator on an annual basis, having these reports verified by an independent accredited verifier. By 30 April in the year following each scheme year, operators and AOs must comply with the UK ETS by surrendering UK Allowances (UKA) equal to their reportable emissions in the scheme year, from their operator holding account in the UK ETS Registry. Operators of installations that receive free allocations of UKA must also report activity levels annually and have these reports verified.

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In March 2022, the UK ETS Authority issued a consultation on the future development of the UK ETS: 'Developing the UK Emissions Trading Scheme'. This included consultation on the introduction of an emissions cap that was consistent with the UK and devolved governments' net zero targets. The UK ETS Authority's main response[6] to the consultation, including policy positions about adoption of a net zero consistent cap, was published in July 2023 during the research period for phase 1 of the evaluation.

The intended operation of the scheme is summarised in Figure 1 within chapter 2. Full details of the UK ETS can be found on gov.uk[7]. A summary of the scheme is also available in the factsheet published by the International Carbon Action Partnership[8].

[6] https://www.gov.uk/government/consultations/developing-the-uk-emissions-trading-scheme-uk-ets
[7] https://www.gov.uk/environment/climate-change-energy-emissions
[8] https://icapcarbonaction.com/en/ets/united-kingdom

Characterisation of UK ETS installation and aircraft operators

In 2022, there were a total of 1051 installations in the UK ETS (including energy intensive industrial sites, power generation and offshore oil and gas sites) and 378 AOs[9]. The term 'main scheme' is used in this report to indicate operators/AOs obliged to comply with the UK ETS by surrendering UKA via the UK ETS Registry. Some installation operators had multiple sites: there were over 400 installation operators in the main scheme.

Installations with lower emissions and those providing services to hospitals can apply for 'Hospital or Small Emitter' (HSE) status or for 'Ultra Small Emitter' (USE) status to follow simpler procedures. Unlike those in the main scheme, installations with HSE and USE status are exempted from the requirement to surrender UKA, though HSE installations have annual emissions targets they are required to meet or pay a penalty. HSE status is available to installations that supply hospitals or have a rated thermal output below 35 MW and emissions less than 25,000 tCO2e (meaning tonnes of CO2 and other GHGs converted into 'CO2 equivalents') over the qualifying period. Similarly, USE status is available to installations with reportable emissions were 2,500 tCO2e or less in the three scheme years 2021, 2022 and 2023. In 2022, there were 703 installations in the main UK ETS scheme, 249 HSE installations and 99 USE installations.

Over 70% of the main scheme and HSE installations were regulated by the EA, with 11% regulated by SEPA, 8% by OPRED, 7% by NRW and 2% by DAERA. Nearly all the 378 AOs were regulated by the EA.

AOs with low emissions are permitted to use a simplified reporting procedure but are still included in the main scheme: 247 of the 378 AOs made use of this in 2022. Some organisations operate multiple installations: an estimated 652 entities were involved in the 'main scheme' (meaning the full UK ETS excluding HSE and USE installations), across installation and aircraft operators.

Reported emissions in 2022 were 111 million tCO2e. Emissions were concentrated in the hands of a few large emitters, with 12 entities (in the power generation and heavier energy intensive industry sectors) accounting for 50% of total emissions. About 41 million tCO2e were covered by free allowances in 2022, representing 37% of total emissions.

This report analyses findings across a number of high level sectors that are characterised as follows. The first 4 categories in the table below are mutually exclusive (aviation, power, heavy industry, other industry) while the fourth category is a variant of the heavy industry category that was used to analyse carbon leakage impacts.

[9] https://www.gov.uk/government/publications/uk-emissions-trading-scheme-regulator-reports

Table 2: Overview of high-level sectors within the UK ETS main scheme

Type of operator	Sector group	High level sector	Characterisation of UK ETS operators and AOs in this sector
Aircraft operators	Aviation	Aviation	The majority of aviation emissions were from AOs with emissions above 2,500 tCO2e per annum, with a few large companies having total emissions exceeding 500,000 tCO2e per annum. AOs included a large number of 'micro-emitters' (less than 1,000 tCO2e per annum covered by the UK ETS) for which total emissions were small. Aviation micro-emitters were primarily private jets but may include some large airlines with low numbers of UK flights. AOs are excluded from the scheme if their total emissions within the UK ETS and EU ETS are below 1,000 tCO2e in a given year.
Installation operators	Power generation	Power	Power sector emissions were dominated by a few large companies with gas-fired generation. While most individual installations within the power sector of the UK ETS had emissions in the range 2,500 to 25,000 tCO2e per annum, some firms owned multiple installations.
Installation operators	Energy intensive industry	Heavy industry	The heavy industry sector included firms producing cement, chemicals, distribution of gas, iron and steel, oil and gas, refining and processing of nuclear fuel. The chemicals and oil and gas sectors had the most installations in the scheme, but iron and steel and refining had the highest levels of emissions. Most installations had emissions exceeding 50,000 tCO2e per annum, with some exceeding 500,000 tCO2e per annum.
Installation operators	Energy intensive industry	Other industry	The 'other industry sector' included operators from the food and drink, non-metallic minerals, non-ferrous metals, paper and pulp and other sectors (including combined heat and power plants). Installations showed a range of emission levels but mostly had emissions between 2,500 and 50,000 tCO2e per annum.

Type of operator	Sector group	High level sector	Characterisation of UK ETS operators and AOs in this sector
Installation operators	Energy intensive industry	Commodity producer (variant of 'heavy industry')	A slightly different grouping of energy intensive industry was used to analyse carbon leakage risks, because of the competitive pressures on sectors producing commodities that are widely traded internationally. The commodity production sectors were defined as a variant of 'heavy industry', comprising cement, chemicals, iron and steel, oil and gas but also including lime, ceramics and food-based commodities from the 'other industry' sector.

Source: Evaluation team analysis, based on published data for UK ETS installation and aircraft operators.

Purpose of evaluation

The purpose of the overall evaluation is:

- To evaluate the implementation of the scheme and possible impacts that it might have on delivery (process evaluation).
- To assess the operation of the UK ETS allowance market, and the extent to which it is effective in facilitating the scheme's ultimate goal of enabling firms to cost-effectively abate their emissions (outcomes evaluation).
- To evaluate the impact of the scheme on Greenhouse Gas (GHG) abatement and carbon leakage; to provide insight on how and why targeted impacts were (or were not) achieved; and to assess the role of scheme design in achieving (or not) those impacts (impact evaluation).

This report presents findings on phase 1 of the evaluation, focusing primarily on UK ETS processes and outcomes. Where available, some early impact evidence is presented, but a fuller assessment of UK ETS impact will be made in phase 2 of the evaluation (to be conducted from 2024 to 2026), when more evidence of impact is available.

Chapter 2. Methodology

This chapter outlines the overall approach to this evaluation and summarises the methodologies used for phase 1 workstreams and synthesis.

Overview of theory-based approach

This is a theory-based evaluation which uses a Theory of Change (ToC) to set out how the UK ETS is intended to contribute to desired outcomes and impacts. A ToC explains how the activities undertaken by an intervention (such as a policy) contribute to a chain of results that lead to intended outcomes and impacts. Contribution analysis[10] has been used as an overarching methodology to test the 'contribution story' set out in the ToC against alternative explanations for observed outcomes/impacts. The alternative explanations are set out in the form of 'competing hypotheses', as explained below.

The main reason for using a theory-based approach is the complexity of the UK ETS and of the other policies and influences with which it interacts. These influences include other government policies that aim to support progress to net zero, past (and ongoing) influence from the EU ETS and external factors such as changes in energy prices, economic climate, world events, technology and awareness of/attitudes towards climate change issues. A theory-based approach can explore the reasons why the UK ETS has or has not influenced different stakeholders in different ways, relative to these other influences. Contribution analysis provides a structured framework for synthesising evidence from a range of sources (including both subjective and objective evidence) and weighing the support for the 'contribution story' (as set out in the ToC) relative to competing hypotheses that could explain observed outcomes and impacts.

Phase 1 of the evaluation focused on evaluation of UK ETS processes and outcomes, including whether the UK ETS market is operating in ways that are sufficiently efficient and liquid for the scheme to achieve its objectives (as set out in the ToC). Phase 1 of the evaluation also collected some early insights on UK ETS impact, to inform the UK ETS Authority's 2023 review of the scheme, but full assessment of impact will be undertaken during phase 2 when more robust evidence is available.

Theory of Change and competing hypotheses

The ToC presents a high level summary of how the main UK ETS is intended to work. It was developed during a 2021 scoping study[11], through in-depth consultation with policy staff in the Department for Business, Energy and Industrial Strategy (BEIS, now superseded by DESNZ) and with stakeholders involved with the UK ETS (including operators, AOs and traders). The

[10] Mayne, J. (2008), Contribution analysis: An approach to exploring cause and effect, May 2016, ILAC Brief 16.
[11] UCL and CAG Consultants delivered a separate scoping study for the UK ETS evaluation during 2021.

full ToC comprises 6 components, with the causal logic flowing from the bottom of the diagram up to the top:

- Rationale: a summary description of the problem that the UK ETS is seeking to address.
- Inputs: the resources which the UK ETS Authority are investing to enable the operation of the scheme.
- Causal pathway: a logic chain showing the sequence of scheme activities, and participant / market responses, that the scheme is intended to trigger.
- Assumptions: implicit and explicit assumptions that underpin the operation of the causal pathway.
- Outcomes: the target outcomes from the scheme (as defined by the UK ETS Authority).
- External factors: a list of the factors, external to the scheme, which might impact on the working of the UK ETS and thereby affect the delivery of the target outcomes. External factors can be both positive and negative.

A summary of the ToC is shown in Figure 1 below. Detailed assumptions are not shown in this summary version, to aid legibility, but are shown in the full ToC in Appendix 3.

A set of competing hypotheses has been formulated to reduce the risk of 'confirmation bias' in this evaluation (meaning the risk that the evaluation research largely looks for evidence that would confirm rather than refute the ToC). The competing hypotheses offer alternative explanations for observed outcomes and impacts, challenging parts of the ToC. The contribution analysis considers the validity of the different competing hypotheses and ToC for different sectors and groupings within the UK ETS traded sectors.

The competing hypotheses shown in Table 3 were initially proposed in the 2021 scoping work and then refined in consultation with Departmental staff, UK ETS stakeholders and a peer reviewer during phase 1 scoping work. The hypotheses set out below summarise possible risks to the ToC, namely ways in which stakeholders think the UK ETS might not work as intended.

Figure 1: Theory of Change (summary diagram)

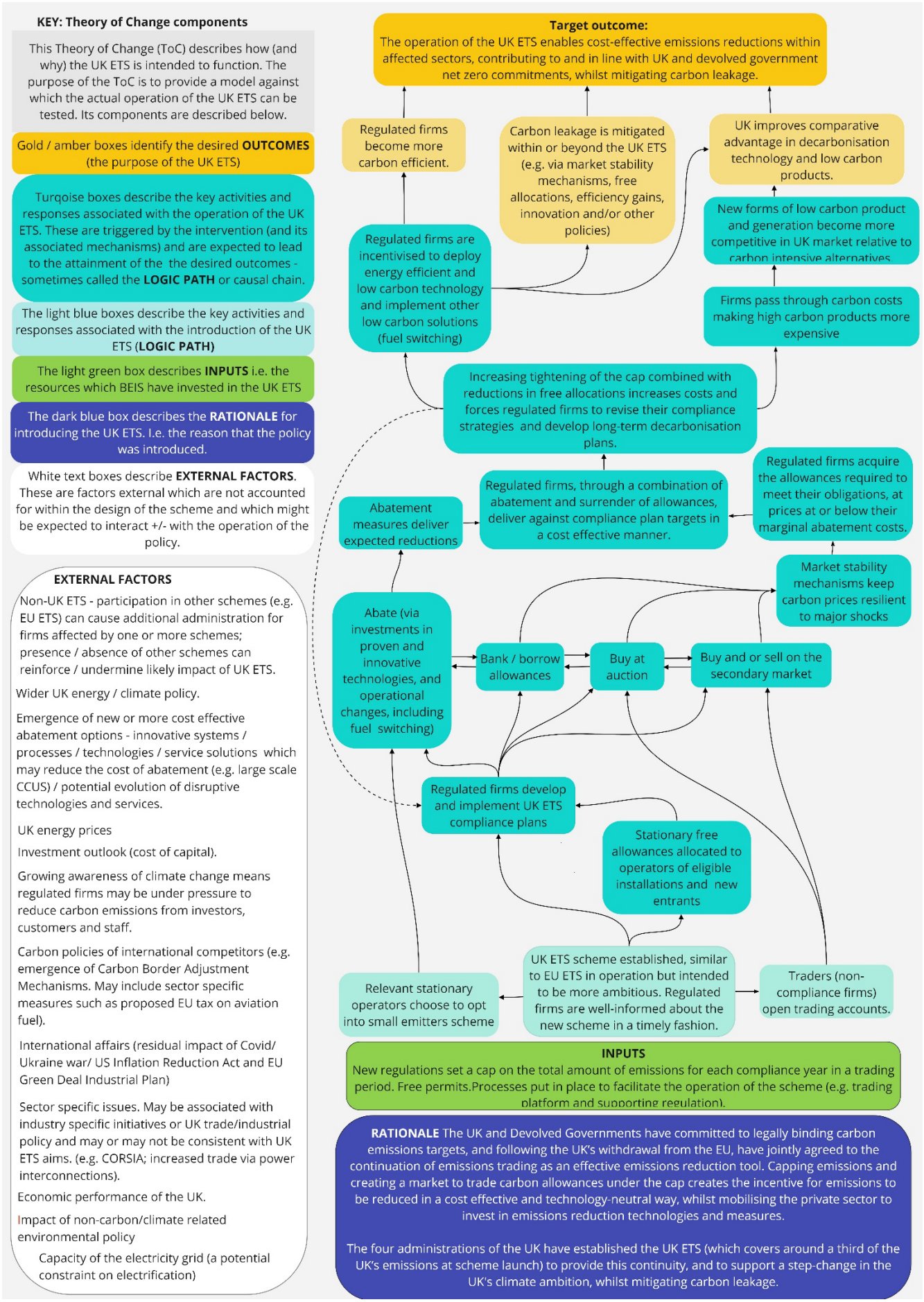


Table 3: Primary and competing hypotheses for the UK ETS

Primary ToC hypothesis: The operation of the UK ETS brought about cost-effective emissions reductions within affected sectors, contributing to and in line with UK and devolved government net zero commitments whilst mitigating carbon leakage.
Competing hypotheses: 1. Emissions were reduced, and carbon leakage was limited, but this was largely driven by other factors, not the UK ETS 2. Emissions were reduced but this was largely because of changes in activity levels, some of which was due to UK ETS contribution to carbon leakage 3. The UK ETS has limited liquidity or exhibits other aspects of poor market quality, so met its carbon abatement and carbon-leakage mitigation objectives in a sub-optimal way 4. The UK ETS made some contribution to carbon abatement but this was not consistent with the UK's net zero ambitions 5. The UK ETS caused unforeseen outcomes and impacts **6.** The UK ETS provided carbon-leakage mitigation to sectors that were not in fact at risk

Evaluation questions

Phase 1 of the evaluation focused primarily on process and outcomes and also provided some early insights into impact. The high and mid level evaluation questions for process, outcomes and overall impacts, as agreed with the Department, are shown in Table 3. Phase 1 of the evaluation was designed to respond to evaluation questions A and B below, while gathering some early evidence on evaluation question C. The full set of evaluation questions for phases 1 and 2 of the evaluation, including detailed questions on process, outcome and impact of the UK ETS, are set out in Appendix 2.

Table 4: High and mid level evaluation questions on UK ETS process, outcomes and impacts

High and mid level evaluation questions on UK ETS process, outcomes and impacts
A. WAS THE UK ETS EFFICIENTLY AND EFFECTIVELY DELIVERED?
A1. Has the introduction of the UK ETS ensured a smooth continuation of emissions trading for UK emitters previously in the EU ETS scheme?

A2. How has the operation of the UK ETS influenced the delivery of a functioning carbon market?
A3. Has the UK ETS delivery ensured that the scheme is administered efficiently and effectively (for both compliance operators in the main scheme as well as participants in the two opt-out schemes; hospitals and small emitters, and ultra small emitters)?
B. WHAT WERE THE OUTCOMES OF THE UK ETS?
B1. What has been the behaviour of market participants and what have been the implications of observed behaviour (e.g. for ETS market functioning or for firms' decarbonisation prospects)? How has this varied across different types of firms and sectors?
B2. Has the UK ETS delivered a carbon market, which is sufficiently accessible to participants and sufficiently liquid to enable its policy objectives to be achieved?
B3. What are the risks to the effective functioning of the carbon market and how can these be mitigated?
C. WHAT HAVE BEEN THE IMPACTS OF THE UK ETS AND ON WHOM?
C1. What has been the impact of the UK ETS on emissions and emissions intensity in the traded sector and how has this varied across sites, firms, sectors and UK regions?
C2. What has been the impact of the UK ETS on carbon leakage, investment leakage or carbon leakage risk in the traded sector? To what extent and how has carbon leakage, investment leakage and carbon leakage risk in the traded sector been influenced by carbon leakage mitigation policies, such as free allocation?
C3. Have there been any unanticipated consequences of UK ETS in the traded or non-traded sectors, and how have they varied across different types of firm or sector or UK region?

Evaluation workstreams

Phase 1 of the evaluation had 7 workstreams, involving the collection and analysis of evaluation evidence to inform the contribution analysis. These workstreams are outlined in the table below. The report also builds on scoping work undertaken by UCL and CAG Consultants

during 2021 which included a wider literature and evidence review. The methodology used in each workstream is described in more detail in Appendix 4.

Table 5: Overview of phase 1 workstreams

Workstream	Summary
Phase 1 scoping	Updating of scoping work undertaken during 2021 and finalisation of phase 1 methodology.
Qualitative research with UK ETS operators, AOs, traders and wider stakeholders	Collection and analysis of qualitative insights and evidence about the UK ETS main scheme processes and outcomes, focusing on sectors and firms that represent a significant proportion of GHG emissions. This included exploration of process and carbon leakage issues, as well as realist analysis to identify typologies of behaviour on carbon abatement and trading. The interviewees comprised 36 UK ETS operators/AOs, 26 UK ETS traders (namely organisations with UK ETS trading accounts) and 9 wider stakeholders (including delivery bodies, verification/compliance consultants, industry bodies and climate change stakeholders). For operators/AOs with high emissions (referring here to firms with emissions exceeding 100,000 tCO2e per annum in 2022), the in-depth interviews were used not only to generate qualitative findings but also to generate quantitative responses for a small subset of the quantitative survey questions. This was done to ensure that high emitters were adequately represented in quantitative survey findings. Findings from this workstream are presented in chapters 3 to 9 of the report and in Annex 2.
Quantitative survey of UK ETS operators/AOs	Collection and analysis of quantified statistics about attitudes and behaviour in the UK ETS, focusing on UK ETS processes, carbon abatement and trading behaviour, covering both main scheme operators/AOs and HSE/USE operators. From a database of 759 organisations with compliance obligations in the UK ETS, a sample frame of 463 main scheme operators/AOs was identified for the quantitative survey. The sample frame excluded records where the operator/AO was no longer active or was new in 2023; where compliance was managed by a consultant; or where the sample had already been used for the pilot survey or for qualitative interviews. Telephone interviews lasting around 25 minutes were undertaken with 166 operators/AOs in the main survey (a response rate of 36%). Further interviews were included from the pilot survey (17) and from quantitative

Workstream	Summary
	responses generated by qualitative research with high emitters (21), bringing the total main scheme sample to 204. A separate telephone survey (with a self-administered online response option) was undertaken with HSE/USE operators, receiving 24 HSE responses. Quantitative findings from qualitative research with high emitters were obtained for selected survey questions on abatement and trading. Charts shown in this report indicate whether quantitative findings from qualitative research with high emitters were included for the survey question under consideration. The full main scheme sample included 108 installation operators and 41 AOs with emissions above 1,000 tCO2e per annum, and 55 'micro-emitters' (primarily from the aviation sector) with emissions of 1,000 tCO2e per annum or less. Due to the small sample size, the statistical significance threshold for survey analysis was set at 90%. The error margins around survey statistics are explained in the limitations section at the end of this chapter. Findings from this workstream are presented in chapters 3 to 8 of the report and in Annex 1.
Network analysis of UK ETS Transaction data	Preliminary network and cluster analysis was undertaken of physical UKA transactions in the UK Registry, via the UK Transactions Log. This provided evidence about network patterns and UKA transactions, including the frequency and volume of transactions by different types of UK ETS operators, AOs and traders. Alongside qualitative research, this supported the development of typologies of UK ETS trading behaviour. Findings from this workstream are presented in chapter 5. The UK ETS transaction data did not include information about UKA prices nor UKA derivatives (for example futures contracts) – see secondary market data analysis.
Literature review on the quality of secondary markets for cap-and-trade systems	The literature review undertaken during phase 1 was solely focused on secondary market data quality. It informed the choice of variables used to analyse the secondary market data, drawing on the literature about the efficiency and operation of cap-and-trade markets and (where relevant) other types of financial markets. Findings from this workstream informed the secondary market data analysis, which are presented in chapter 5 and Annex 3.

Workstream	Summary
Secondary market data analysis	This workstream assessed the liquidity, volatility and efficiency of the UK ETS secondary market operated by the ICE trading platform, contributing to the outcomes evaluation. The analytical method can be used to monitor the quality of the UK ETS secondary market in future. Findings from this workstream are presented in chapter 5 and Annex 4.
Phase 1 synthesis and reporting	Evidence from all workstreams was synthesised to respond to the high and mid level evaluation questions for UK ETS processes, outcomes and (where possible) early impacts. An initial assessment was made of the ToC and competing hypotheses, using contribution analysis. This report presents the findings from this synthesis which will feed into the UK Authority's 2023 review of the UK ETS. Findings from the initial assessment are presented in chapter 8.

Limitations

The main limitations of this phase of the evaluation were as follows:

- Phase 1 of the evaluation was not focused on impact and only collected subjective, reported information from UK ETS operators/AOs on carbon leakage and abatement. Information on carbon leakage is particularly limited, being based only on qualitative research which focused primarily on high emitters (referring here to firms emitting more than 50,000 tCO2e in 2022). Given the potential bias in these subjective views, the findings presented here need to be treated with caution. Preliminary findings on impact will be reconciled with more objective analysis of UK ETS impacts on energy use, GHG emissions and economic performance during phase 2 of the evaluation, when further impact data is available.
- The limited nature of impact evidence available to phase 1 of the evaluation means that assessments of the ToC, the competing hypotheses and 'impact' evaluation questions are tentative. These preliminary assessments will be revisited during phase 2 of the evaluation.
- The sample size for the quantitative survey with main scheme operators/AOs was fairly small (maximum sample 204), so the survey analysis used a confidence level of 90% rather than the 95% confidence level often used in policy evaluation research. The maximum margin of error at 90% confidence for the whole sample of 204 operators/AOs is 5.8%. Margins of error are wider for sub-samples: for example for the sub-samples of 108 installation operators and 41 aircraft operators and 55 micro-emitters, the maximum margins of error are 7.9%, 12.8% and 11.1% respectively. Further details are set out in the quantitative survey report in Annex 1.

- There were no responses to the HSE/USE survey from USE operators. Their views are therefore not represented in this report. This is a minor limitation because of the very low volume of emissions from USE operators.
- The secondary market data analysis of liquidity covered a limited time-period for market quality metrics that involved use of bid-ask spread data. The findings from these elements of the analysis need to be confirmed by further analysis over a longer timescale.
- The analysis of comparative EU ETS data in the secondary market data analysis was focused on December futures in EU Allowances traded on ICE and did not include December futures contracts traded on other Exchanges (for example EEX, Nasdaq Oslo). However, trading on ICE represents 85% of trade in EU ETS[12].
- The identification of transaction behaviour in the network analysis was preliminary and subject to further cross-checking and confirmation.
- While the number of operators/AOs and traders interviewed in the qualitative research was substantial, the qualitative research only included one interview with a verifier and one with a verifier/compliance consultant. The views of these groups should be treated with caution as they are based on a small sample.

[12] ESMA (2022), Final report – emissions allowances and associated derivatives

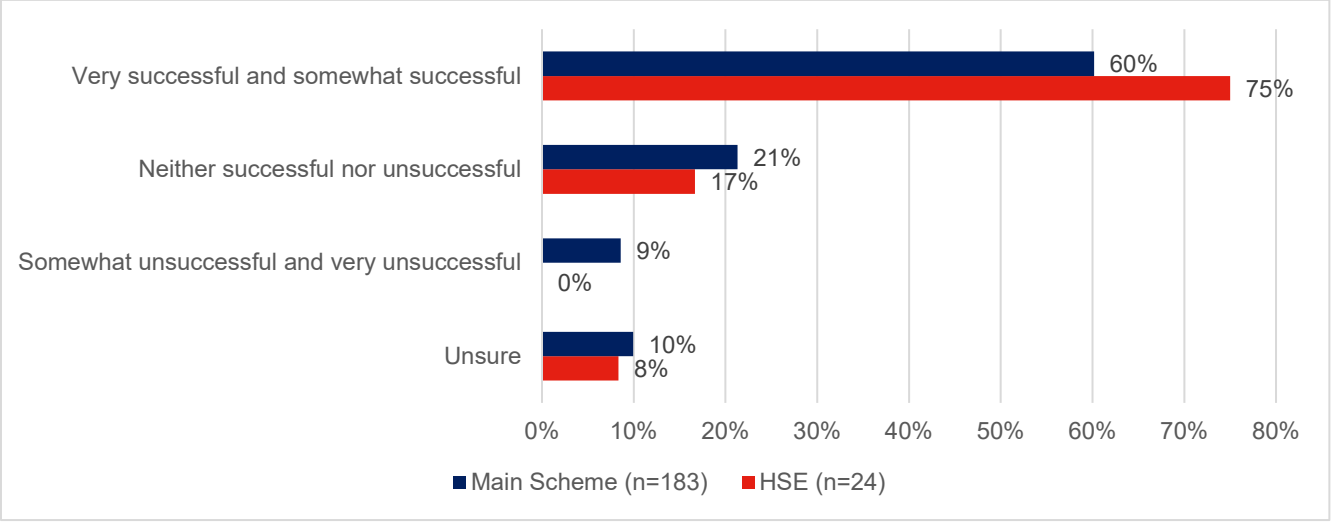
Chapter 3. Did the UK ETS transition go smoothly?

This chapter presents findings about how well the process of transition from the EU ETS to the UK ETS worked, in early 2021, responding to evaluation question A1. These findings are based on the quantitative survey and qualitative research. The transition was generally found to have worked smoothly, although the lateness of the decision regarding whether to replace the EU ETS with a carbon tax or the UK ETS created significant challenges for some stakeholders. Power sector operators reported issues arising from being unable to buy UKA during the first 5 months of the scheme.

What worked well?

A majority of operators/AOs that participated in the quantitative survey, 60% of main scheme operators/AOs (n=183) and 75% of Hospital or Small Emitter (HSE) operators (n=24), considered the government's handling of the transition from EU ETS to UK ETS to have been successful.

Figure 2: How would you rate the government's role in the transition from the EU ETS to the UK ETS? (all main scheme & HSE participants)



Source: quantitative survey with UK ETS operators/AOs.
(This question was not included in quantitative responses from the qualitative sample.)

The qualitative research is consistent with the survey, with interviewees suggesting that, overall, the transition had worked well. One of the key reasons for this was reported to be the similarities between the two schemes, in terms of their operation and the associated administrative systems.

> *I think choosing to basically clone the EU scheme and duplicate it in the UK, I think that was probably the best thing that could've happened to ease the transition. (Heavy industry operator)*

Interviewees also praised the efforts of the regulators and others involved in the transition, commonly suggesting that they had found them to be responsive and helpful. The qualitative research suggests the guidance issued in support of the transition was valued and found to be useful. The majority of survey respondents (70%, n=183) thought that information about the new scheme was clear and transparent.

Some qualitative interviewees reported that they had attended stakeholder engagement sessions and found these to be helpful, particularly as a mechanism for disseminating information.

> *I remember participating in a number of stakeholder engagement meetings with BEIS. And they were decently well managed, the information was passed through the associative bodies – Energy UK, IETA, EFET – through the industry. That was good. (Trader)*

What worked less well?

When asked to explain their rating of the transition process, many operators/AOs reported no problems (45%) but a third (35%) indicated that they had found the transition process to be complicated, while a fifth (21%) reported problems related to a reported lack of compatibility between the UK ETS and the EU ETS (n=163). The quantitative evidence suggested that firms with high emissions (meaning more than 50,000 tCO2e emissions) tended to find the process complicated, although the observed variation fell below levels of statistical significance[13].

The qualitative research identified several problems with the transition and supports the survey's suggestion that the transition posed substantive challenges for at least some high emitter operators/AOs. The main reported problem was the lateness of the decision regarding whether to replace the EU ETS with a carbon tax or the UK ETS. This created significant challenges for those involved in the introduction of the UK ETS, and for some operators/AOs who noted that this created high levels of business uncertainty. The qualitative research found that such uncertainty was a particular problem for the power sector operators (as discussed in the following section). Other reported concerns included:

- Some types of operators/AOs, one interviewee referred to small emitters, were felt to have received clarification on details of the UK ETS too late to make informed decisions regarding their participation in the scheme.

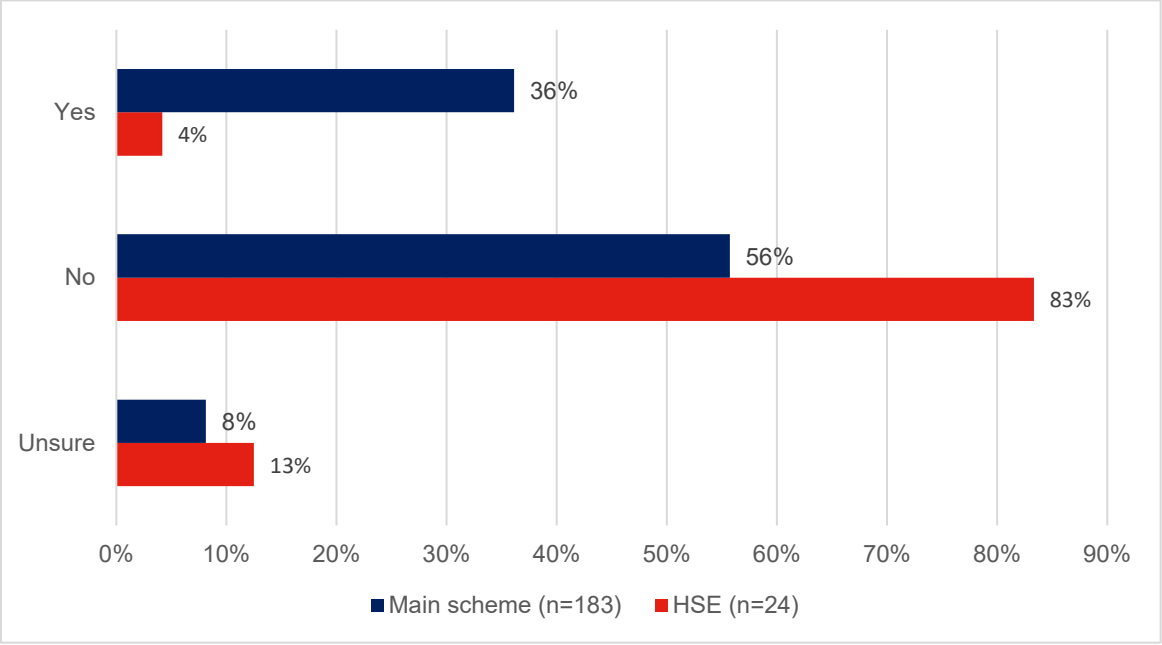
[13] Due to the small sample size of this survey, the statistical significance threshold for survey analysis was set at 90%. The error margins around survey statistics are explained in the limitations section at the end of chapter 2.

- Delay in the establishment of auctions and trading on ICE meant that operators/AOs could not buy physical UKA or UKA derivatives until May 2021, although the scheme opened in January 2021.
- When trading started, slow development of the secondary market was reported to mean that some firms chose to buy physical UKA rather than UKA derivatives, which had negative impacts on their cash flow.
- The volume of work that the transition generated, and the ongoing need (for some) to manage two schemes (namely involvement in both the UK ETS and EU ETS). In particular, AOs undertaking flights between the UK and EEA had to comply with the UK ETS for flights leaving the UK and with the EU ETS for flights leaving the EEA. Other firms with ETS regulated sites in the EU as well as the UK also had to comply with the relevant scheme for each of their sites.

Cost and disruption

About half (56%) of survey participants reported having incurred no one-off costs because of the transition from the EU ETS to the UK ETS (n=183). Among main scheme operators/AO, 36% stated that they incurred costs (n=183), whereas only 4% of HSE operators said they had done so (n=24).

Figure 3: Were there any one-off costs incurred by the organisation related to the transition from the EU ETS to the UK ETS? (all main scheme & HSE participants)



Source: quantitative survey with UK ETS operators/AOs.
(This question was not included in quantitative responses from the qualitative sample.)

Those main scheme participants reporting one-off costs incurred because of the transition from EU ETS to UK ETS suggested that these costs were primarily administrative fees (51%) and

internal resource costs (35%) (n=66). For the participants reporting one-off costs, the median reported cost was £1,000, with 40% of these participants incurring costs under £1,000, whereas 7% reported costs over £10,000 (n=66).

The qualitative research did not investigate administrative costs but did generate some insights on other transition-related costs, the most significant of which was associated with the power sector. Power sector interviewees noted that it is common to sell electricity up to 2 years in advance and that this generates a need to be able to 'lock in' their future costs. The price of carbon forms part of such future costs and therefore these operators buy futures or forward contracts to hedge their risk. Trading in UK allowances (UKA) opened in May 2021, 5 months after the start of the UK ETS, which was problematic for these operators. While unable to trade UKA, some power sector interviewees reported that they had bought EU ETS allowances only to then need to sell these under sub-optimal market conditions because of the scale of capital tied up in allowances.

> *…to move from one system to the other, meant that you had to quickly try and cover off your UK ETS exposure. So, you had to go in the market, and try and buy a price which then covers all the EUAs. But remember, you've already bought. So, you're trying to sell the EUAs, and if you- and so the component parts of the market were, the rest of the market knew that UK generators would be offloading EUAs because they couldn't use them anymore. Whereas they also knew they had to then cover very, very large liabilities, where they didn't have the UK ETS instead. So, spec traders obviously came in (Power sector operator)*

Another reported financial cost was associated with the need to dispose of previously acquired EU ETS allowances. It was noted that several operator types, not just in the power sector, had deliberately accumulated EU ETS but had needed to dispose of these as part of their adjustment to the new scheme. Aside from potentially selling at a loss, some interviewees suggested that they had lost money as they had been required to sell an asset that they anticipated was going to increase in value.

Qualitative research found that AOs also tended to sell flights up to 2 years in advance and sought to hedge their compliance obligations using futures or forwards. However, AOs did not mention costs associated with the lack of trading in the early months of the UK ETS scheme, possibly because they were able to hedge with EUA and then use excess EUA for compliance in their EU ETS operations.

Chapter 4. Is the UK ETS delivered efficiently and effectively?

This chapter presents findings on how effectively UK ETS processes work, responding to evaluation question A3. The chapter does not present findings on cost efficiency because of the lack of cost data at this stage of the evaluation. Findings are based on the quantitative survey and qualitative research. Feedback on the UK ETS auction and trading processes is presented in chapter 5. Generally, UK ETS processes were found to be complex but work well, with some concerns (such as free allocation, Activity Level Change processes, small emission sources, SAF and telephone support). While communication was generally good, operators/AOs and traders expressed frustration at the delay between the UK ETS Authority's consultation on development of the UK ETS (March 2022) and publication of the full consultation response (July 2023).

How operators/AOs organised UK ETS compliance

There were considerable variations in how operators/AOs organised UK ETS compliance, depending on the scale and sector of the organisation.

The quantitative survey found that 41% of main scheme operators/AOs managed UK ETS compliance through their operations department, while 37% used their environmental management department (n=176). There were variations between types of main scheme operators/AOs: AOs were more likely to manage compliance via their finance department (59%, n=37), while micro-emitters (with UK ETS emissions below 1,000 tCO2e per annum) were more likely to use their operations department (61%, n=51). About half of installation operators (52%, n=88) used their environmental management department. However, more main scheme operators/AOs with high emissions (above 50,000 tCO2e per annum, n=36) used their commercial department (20%) or Health and Safety department (13%). For HSE operators, 71% reported using their environmental management department (n=24).

About half of operators/AOs (53%, n=183) reported to the survey that they spent up to 15 days a year on UK ETS compliance, involving action approximately once a month. On the other hand, about 1 in 7 (13%, n=183) reported spending more than 50 days a year (approximately one day per week). Operators/AOs with high emissions (above 50,000 tCO2e per annum, n=38) tended to report more than 50 days a year dedicated to UK/EU ETS related activities, but this variation was not statistically significant.

UK ETS operators/AOs responding to the survey were almost evenly split on whether their organisation had a staff member or team with the sole responsibility of looking after compliance with ETS (which might include the EU ETS as well as the UK ETS). Over half of main scheme operators/AOs (57%, n=166) confirmed having at least one staff member whose sole responsibility was compliance with ETS, but 63% of HSE operators (n=24) said they did not have such a staff member. Within aviation, where most AOs were in multiple ETS (for

example UK ETS, EU ETS, Swiss ETS), 67% (n=35) had at least one staff member whose sole responsibility was ETS compliance, compared to 45% (n=82) of main scheme installation operators.

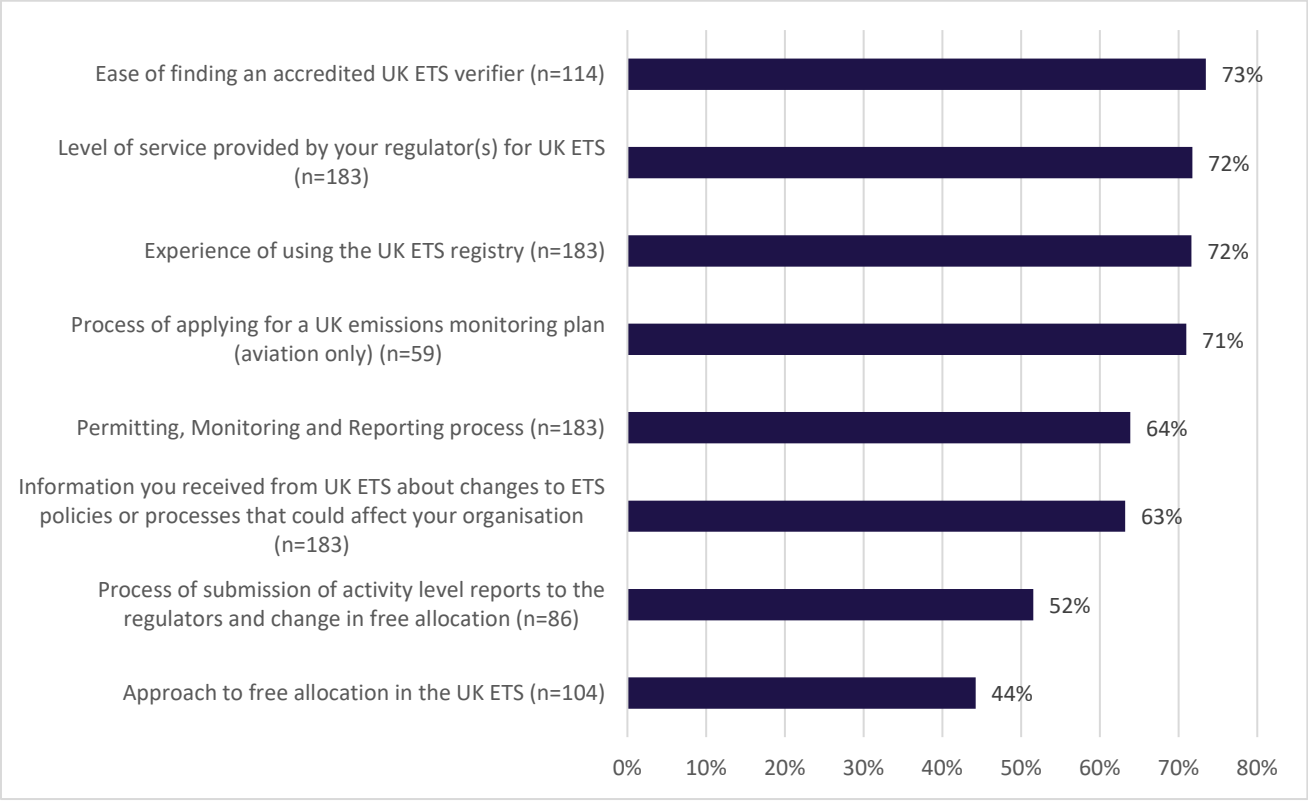
Qualitative research found that many high emitters had multiple different departments involved with UK ETS compliance, allowance procurement and trading. These typically included operations, energy or environmental management and finance departments, plus – for a few companies already procuring energy and/or trading in other commodities – specialist procurement or trading desks.

An overview of UK ETS processes for the main scheme is shown in Appendix 5.

Overall levels of satisfaction with UK ETS processes

Operators/AOs were generally satisfied with the day to day running of UK ETS processes, once the scheme was established. As shown in Figure 4, over 70% of operators/AOs were satisfied or very satisfied with most UK ETS processes, with the ease of finding an accredited verifier receiving the highest rating (73%, n=114). In contrast, operators/AOs were least satisfied with the approach to free allocation (44%, n=104) and (only relevant to installation operators) with the process of submitting activity level reports (52%, n=86).

Figure 4: Proportion of participants satisfied and very satisfied with various UK ETS processes (all main scheme participants)



Source: quantitative survey with UK ETS main scheme operators/AOs.
(This question was not included in quantitative responses from the qualitative sample.)

With regards to the four processes that were applicable to all respondents, about 4 in 10 operators/AOs (44%, n=183) were satisfied with all of these processes (namely the UK ETS Registry; permitting, monitoring and reporting; the level of service provided by regulator(s) and information received from UK ETS). There was a tendency for those with zero free allocation to be satisfied with all 4 of these processes, but their difference from the rest of the sample was not statistically significant.

There were very few respondents (8%, n=183) who did not express satisfaction with any of the processes that were applicable to all operators/AOs. This figure includes those that were unsure and neither satisfied nor dissatisfied.

Feedback on specific elements of UK ETS administration is presented below. Feedback on market mechanisms, such as the auction and ICE, is presented in chapter 5.

UK ETS Registry

The regulators advised that the UK ETS Registry portal was designed to be similar to the EU ETS Union Registry but simplified where possible. This is consistent from feedback from users in the qualitative research, who commented that some features of the UK ETS Registry were easier to use than the EU ETS Union Registry. For example, users could export statements from the UK ETS Registry more easily and could more easily transfer and surrender allowances.

Although the survey found high levels of satisfaction with the UK ETS Registry (72% as shown in Figure 4 above, n=183), qualitative research identified some issues with the current system. In particular, interviewees reported that registering, or changing, authorised representatives on the system was time-consuming. AOs and traders based outside the UK had particular difficulty complying with UK ETS Registry requirements for authorisation. Of the 83 survey respondents suggesting improvements for the UK ETS Registry, the majority (68%) focused on simplifying registry processes. A regulator commented that UK ETS Registry requirements could not be simplified further without compromising registry security and financial regulatory requirements.

The qualitative research found a range of views about UK ETS Registry guidance provided by the regulator. On the one hand, many operators/AOs reported that the process was smooth, and that the regulator provided helpful support on the UK ETS Registry. However, there were reports of operators/AOs finding it difficult to locate the right guidance online and having to rely on emails when communicating with the UK ETS Registry. Some operators/AOs reported continued reliance on EU ETS Union Registry documentation, although regulators questioned this finding.

There was some wider comment from traders and wider stakeholders in the qualitative research that there might be scope for developing more streamlined, digital registry systems in future, along the lines of foreign exchange trading systems.

Permitting, monitoring, reporting and verification (PMRV) systems

Overall views on PMRV processes

As shown in Figure 4 above, the survey found that operator levels of satisfaction with PMRV processes were fairly high (64%, n=183). Satisfaction with permitting, monitoring and reporting processes was lower among operators/AOs with high emissions (above 50,000 tCO2e per annum, n=39) with 45% expressing satisfaction and 14% expressing dissatisfaction with the process.

The main issue flagged in qualitative interviews with UK ETS installation operators and installation verifiers was around the time and hassle involved in applying for GHG permit variations. There was some suggestion that regulatory staff did not have sufficient resources to handle permit condition and variation requirements, which meant that approvals could take a long time.

Qualitative research found evidence of additional administrative burden for those AOs operating in Europe as well as the UK, as they had to participate in both the UK ETS and EU ETS (and, for some, also the Swiss ETS). However, the survey found that more AOs were satisfied with UK ETS monitoring and reporting processes (81%, n=37) compared to 51% of main scheme installation operators (n=91). There were very high levels of satisfaction (88%) from AOs using simplified reporting procedures (n=58). Qualitative interviews suggested that this was because AOs had access to central flight data from EUROCONTROL, which aided monitoring, reporting and verification. Further, AOs did not need to obtain a Greenhouse Gas (GHG) permit but were required to provide an emissions monitoring plan. There were high levels of satisfaction amongst AO respondents that had applied for an emissions monitoring plan under the UK ETS (71%) with only 8% expressing dissatisfaction (n=59).

Regarding the ways that the permitting, monitoring and reporting process could be improved, about half (56%) of the 85 operators/AOs making suggestions in the quantitative survey asked for simplified administrative processes, whereas one in four (25%) asked for better guidance. Micro-emitters (with UK ETS emissions below 1,000 tCO2e per annum), which were primarily AOs with accounts in both the UK ETS and EU ETS, were more likely (35%, n=23) to ask for more compatibility between the UK ETS and EU ETS.

Specific areas for improvement flagged by operators/AOs and verifiers in the qualitative research included further development of reporting and verification requirements for Sustainable Aviation Fuels (SAF), biomass fuels and methane flaring, and introduction of a ‘de minimis’ rule that would allow lighter-touch reporting and verification for small sources of emissions.

Transition from ETSWAP to METS

The permitting, monitoring, reporting and verification (PMRV) system used in the first two years of the UK ETS was called the ‘Emissions Trading Scheme Workflow Automation Project’ (ETSWAP). The ETSWAP system was developed for UK participation in the EU ETS and was reported by regulators to be nearing the end of its useful life. Regulators and operators/AOs were transitioning to a new system called ‘Manage your Emissions Trading System’ (METS).

Introduction of the new system was originally planned for the 2022 compliance year, but at the time of the research this had been pushed back into 2023.

The ETSWAP system was reported to have worked well, with operators/AOs generally complying with monitoring and reporting processes that were established under the EU ETS. Organisations that regularly used ETSWAP, such as verification and compliance consultants, said that they had learnt how to use the system. But organisations that only interacted with the reporting system once a year tended to find it complicated to use. Some brought in compliance consultants to reduce their need to interact with the system.

The regulator's intention was that METS should retain good aspects of ETSWAP but have a simpler user interface, with stronger security and GDPR compliant processes. The new system had been trialled with some operators/AOs during 2023 and improvements were still being made at the time of the research. It was too early to assess operators/AOs' and verifiers' experience of the new system in a meaningful way.

The survey found that about half of main scheme operators/AOs (57%, n=183) were aware of the transition from the ETSWAP to METS. Qualitative research found that the delay in introducing METS had caused some uncertainty, and some extra work in preparing for a transition that did not happen in 2022, but there was generally acceptance that the delay was sensible.

The main complaint about the transition, from operators/AOs interviewed for the qualitative research, was that operators/AOs were required to save historic documents and transfer details of all permits from ETSWAP to METS, rather than this being done automatically. This was reported to be particularly burdensome for installation operators with large numbers of small sites and contributed to some operators having a negative view of the transfer to METS. A regulator commented that it was a legal requirement for UK ETS operators/AOs to keep all records for 10 years but pointed out that ETSWAP had previously acted as a document store for operators/AOs. METS does not fulfil this role so the transition effectively created a new requirement for operators/AOs to keep a separate record of their UK ETS documents.

Verification

Among operators/AOs having to go through the verification process – which excluded those AOs using the simplified reporting procedure – 73% were satisfied with the ease of finding an accredited verifier, whereas 3% were dissatisfied (n=114). The vast majority of those expressing satisfaction in the survey with the ease of finding an accredited verifier said that they were using the same verifier as for the EU ETS, although some commented in the qualitative research that it was unhelpful that their EU ETS verifiers had to be re-accredited under the UK ETS.

Qualitative research with both operators/AOs and verifiers found that communication with verifiers generally worked well, with verifiers identifying compliance issues that need to be addressed. Verification was particularly straightforward for many AOs because EUROCONTROL provided a comprehensive and reliable source of flight data.

Qualitative research with both installation operators and verifiers found that the process of reporting activity levels for the purposes of 'Activity Level Changes' added another element to verification (see next section). In both the survey and qualitative research, operators suggested that verification processes should be simplified, particularly for 'de minimis' sources of emissions and for HSE installations with lower levels of emissions.

Operators/AOs in the qualitative research also mentioned the need for more consistency between verifiers and regulators on interpretation of some UK ETS rules, as well as more consistency between regulators on the timing of changes being introduced. Verifiers flagged that UK ETS rules were unclear around verification of SAF and biomass fuel use (see PMRV above), some aspects of the new Activity Level Change procedures, eligibility criteria for virtual site visits and the provision of energy efficiency information by installation operators.

Some operators/AOs perceived that an apparent 'extra step' had been introduced into the reporting of verified emissions figures and questioned the reason for this. In the UK ETS, operators/AOs submit their verified report to the regulator and the regulator then instructs the Registry Administrator to enter the verified emissions figures into the appropriate account in the UK ETS Registry. In contrast, in the EU ETS, operators/AOs submitted their verified report to the regulator and also entered their emissions figure into the EU ETS Union Registry, where it was confirmed by the verifier. The UK ETS process has been designed so that verifiers do not need to interact with the UK ETS Registry, but involvement of the regulator and Registry Administrator was perceived as an 'extra step' by some operators/AOs. Some operators/AOs reported in qualitative research that the UK ETS approach caused delays in confirmation of their free allocation.

Free allocations and Activity Level Changes

Overall comments on free allocations

Of those operators/AOs receiving some free allowances (meaning all main scheme operators/AOs except for power generators), around 4 in 10 (44%) of survey participants said they were satisfied with the process of allocating free allowances, whereas 23% said they were dissatisfied with the process (n=104). Operators/AOs with high emissions (above 50,000 tCO2e per annum, n=31) were more likely to be dissatisfied than satisfied with the free allocation process (39% dissatisfied and 35% satisfied).

In the survey, the 59 operators/AOs suggesting improvements for the free allocation process mainly asked for more information about free allocations sooner, as well as for clearer guidelines (49%). About one in five (19%) asked for more free allowances, and 14% asked for more clarity on the government's future plans regarding free allocation.

Free allocation comments from AOs

Qualitative research found dissatisfaction amongst AOs that free allocations were based on a dated benchmarking process, based on 2010 or 2014 data. They were also concerned that there was no potential for activity-related adjustments to free allocations for AOs, as there was for installation operators in the main scheme. However, the government announced in July

2023 that free allowances for AOs would be phased out by 2026[14]. While some AOs commented that this would impact negatively on their profitability, others reported that this would create a more level playing field for AOs, removing the perceived unfairness associated with the 2010/2014 benchmark.

Free allocation comments from installation operators

Qualitative research found considerable comment about delays in approving Activity Level Changes which delayed finalisation of free allocations. Initial free allocations were made available in the year in which emissions were made, but the final allocation could take several months (even up to 12 months) to be finalised. Delays in finalising free allocations were reported to be problematic because operators did not know how many allowances they needed to buy. This was particularly important for high emitters because of potentially large purchase requirements.

In qualitative research, some installation operators commented that the UK ETS Authority will have to consider carefully how to develop benchmarks for the free allocation process in the future, particularly for those sectors and processes that have few representatives in the UK.

Comments on Activity Level Changes from installation operators

Activity level reporting was introduced for installation operators in 2021, at the start of the UK ETS, but would have applied even if the UK had remained part of Phase IV of the EU ETS. It was introduced to support a new rule about Activity Level Changes: free allocations are now adjusted up or down if an installation's recent activity level (averaged over the past two years) increases or decreases by more than 15%. There is no adjustment process for AOs. In earlier phases of the EU ETS, free allocations for installations were only adjusted if production levels increased or decreased by more than 50%.

Operators and regulators commented in qualitative research that ALC created additional requirements and made reporting processes more burdensome for installation operators. Overall, around half (48%, n=86) of the operators for which this process was applicable said they were satisfied with the process, whereas 9% said they were dissatisfied with the process.

Qualitative research found that the main issues with the ALC process were partly that it was new (so installation operators, verifiers and regulators were still going up a learning curve) and partly that the ALC review and approval process was time-consuming for regulators and for the UK ETS Authority. ALC changes were processed by the regulators and UK ETS Authority in quarterly batches, to keep workloads manageable, but this contributed to the delays experienced by operators in having their free allocation finalised.

Of the 39 survey participants suggesting improvements to the process of submitting activity level reports, about half asked for streamlined reporting and tools (54%) while others asked for the process to be more transparent (40%) and quicker (15%). A regulator interviewed in the qualitative research commented that the ALC process involved use of templates and tools that

[14] https://www.gov.uk/government/consultations/developing-the-uk-emissions-trading-scheme-uk-ets

were developed by the EU Commission. They were concerned that the UK needed ongoing access to the latest version of these tools or needed to develop its own version of these tools.

There was also some indication from the qualitative research that ALCs might provide perverse incentives for operators to run certain processes unnecessarily, to avoid reaching the 15% threshold at which they would begin to lose free allowances. And, while the fact that free allocations varied in response to production levels was generally welcomed by installation operators, there was qualitative evidence from two operators that the two year timeframe for ALC adjustments adversely affected the profitability of restarting or increasing production for plants that had been through a period of lower production.

Enforcement

Insights on enforcement were gathered from qualitative interviews with regulators and verifiers/compliance consultants. Operators/AOs were not asked about enforcement in the survey or qualitative interviews, because this would have made interviews too long.

The regulators reported good compliance rates for installations, with most operators holding permits and surrendering the correct number of allowances. Good levels of engagement and compliance with the scheme had been established during the EU ETS scheme and carried over into the UK ETS. It was reported that only small numbers of installations failed to surrender any allowances, or surrendered insufficient allowances, with the former mainly involving companies that were in administration.

Regulators reported that engagement with AOs based outside the UK was problematic, because they had not previously been regulated by UK regulators. Some had not registered for UK ETS despite being covered by the scheme. The number of AOs covered by UK ETS was reported to be around 400, significantly higher than the 150 administered by the UK under the EU ETS. The increase resulted from having to regulate AOs registered or resident outside the UK that had previously been administered by other EEA States for the purposes of EU ETS. UK ETS regulators reported that they were working to reduce non-compliance by AOs based outside the UK.

Historically, under the EU ETS, penalties were reported to relate mainly to high level issues such as operating without a permit or failing to monitor and report correct emissions. Enforcement of lower-level issues under the EU ETS, such as compliance with permit conditions or monitoring plans, was reported to have been discretionary and more variable, possibly depending on regulator workloads. At the time of this research, few mandatory penalties had been issued within the UK ETS and the regulator had not yet published its Enforcement and Sanctions policy with regard to discretionary sanctions.

A compliance consultant noted that delayed enforcement action could cause unexpected shocks for any operators/AOs involved.

Aircraft operators

The research identified two process issues specific to AOs: the use of SAF and the interactions between the UK ETS and CORSIA.

Use of Sustainable Aviation Fuels

Qualitative research found that many AOs were planning to use SAF and, in some cases, invest in SAF production. The majority (82%, n=39) of AOs responding to the quantitative survey (excluding micro-emitters) reported that they planned to reduce carbon emissions through use of 'fuel switching as part of operational management'. While use of SAF might not technically be described as full 'fuel switching', because SAF is typically blended with conventional fuel, it is very likely that these AOs were referring to planned use of SAF.

Use of SAF was relatively new within the EU ETS and UK ETS, so systems for monitoring, reporting and verification were still being refined. The Environment Agency set up a pilot on how to monitor, report and verify use of SAF: some AOs and a verifier interviewed for qualitative research reported that this was well received. However, a verifier reported that, at the time of the research, more guidance was needed on the proof of sustainability required for SAF fuel, so that AOs could request the correct evidence from SAF suppliers.

Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

Around 4 in 10 (44%, n=81) of AOs responding to the survey reported that CORSIA, a global market-based measure covering international aviation emissions, had influenced their awareness of (and/or decisions about) carbon reduction opportunities. Offsetting under CORSIA is expected to begin from 2024 but many AOs were already considering future CORSIA requirements. Evidence from qualitative interviews suggests that AOs were primarily planning for CORSIA compliance rather than already buying CORSIA credits. Interviewees in the qualitative research mentioned that the credits eligible for use in CORSIA were trading at much lower prices than allowances in the UK and EU ETS. AOs suggested that a comprehensive international system would be preferable as it would avoid distortion of flight activity and routing. However, they advised that CORSIA would need to be ramped up, and better implemented, to provide a robust equivalent to the EU ETS or UK ETS.

AOs reported in interview that, in the short term, they would like to see greater clarity about the interaction between CORSIA and UK ETS. While the EU Commission had made announcements about how the EU ETS would interact with CORSIA going forward, there was less clarity for the UK ETS. AOs emphasised that they sold flights more than a year in advance and hence wanted a long period of advance notice of changes to carbon pricing for specific routes, so that they could price carbon costs into future flight sales.

HSE installations

The UK ETS process for HSE installations was simpler than for the main scheme. HSE operators still had to apply for GHG permits and had to monitor and report emissions, and either verify emissions or self-verify, but they did not need to buy or surrender allowances or submit activity level reports. They only paid for emissions in excess of emissions targets for

each year. These targets, specified in their GHG permit, were defined in absolute terms, with no adjustment for activity levels, and were set to decline over time. Emissions payments were collected via a civil penalty process, involving payment of a carbon price on the balance of emissions above the target for the relevant year.

Regulators reported that a number of HSE operators had exceeded their targets in recent years, either because of tightening targets or because of increased levels of operator activity. This is consistent with findings from the online survey which found that 4 in 10 HSE respondents thought targets were somewhat or to a great extent achievable, but 25% said they were only a little or not at all achievable, with another 38% taking a neutral position on this (n=24).

Regulators commented that the term ‘civil penalty’ could be misleading for instances where HSE operators had exceeded their emissions targets. For example, a hospital that built a new energy efficient building might exceed their target because their absolute level of emissions had increased and hence be liable for a civil penalty. To reduce the risk of reputational damage, the UK ETS regulators do not publish lists of organisations incurring these civil penalties.

Views on the process of applying to be a HSE operator were overwhelmingly positive with 50% of HSE survey respondents saying they were satisfied with it, and none expressing dissatisfaction (n=24). Though a high percentage (38%) were unsure, it is likely that many of these were unable to comment having not been involved in the application process. Likewise, 74% of HSE operators agreed that information about HSE was clear and transparent, whereas only 9% disagreed. Of the 24 HSE respondents, only one suggested improvements to the process.

Overall, satisfaction of HSE operators with the HSE processes was high. Satisfaction with the level of the service provided by the regulator(s) as well as the information received from the UK ETS Authority was very high, exceeding 80% (n=24).

No evidence was gathered from USE operators, because no USE operators responded to the online survey. For USE installations, operators do not need to report emissions provided they remain below the USE threshold (2,500 tCO2e in specified scheme years). In qualitative research, regulators suggested that there was a risk of USE operator contacts becoming out of date because there was no annual reporting process. There was a related risk that some USE operators might forget to inform the regulator if they exceeded the USE threshold. Regulators suggested that USE operators should be required to submit some form of annual return, to ensure that contact details for USE operators remained up to date.

Feedback on service provided by regulators

Overall, UK ETS operators/AOs showed good levels of satisfaction with the services provided by regulators. As shown in Figure 4, 72% of survey respondents (n=183) reported satisfaction with the level of service provided by the regulators was approved by respondents, while only 4% said they were dissatisfied.

The regulators reported that they provided extensive 'handholding' support to operators/AOs, especially AOs based outside the UK, who were difficult to engage.

Many of the operators/AOs interviewed in the qualitative research reported that their UK ETS regulator was helpful and responsive, and that they had developed a good relationship with a direct contact within the regulator organisation. There was a general view that telephone support was helpful in working out the solution to complex issues. Some operators/AOs and traders reported difficulty accessing telephone support for the UK ETS Registry portal. The regulator confirmed that telephone support is only available if arranged through helpdesk email.

Seventy survey respondents suggested ways to improve the services provided by regulators. About a third (34%) of these respondents (n=70) asked for a nominated person in the regulator to be directly contactable.

While the regulators were generally reported to be prompt in responding to queries, qualitative research found reports that some more complex requests took a long time to be processed. In one example, a permit variation was reported to have taken more than a year to be resolved. There was some suggestion that processing times had become longer in the past two years, possibly linked to regulator resources being stretched by the transition to UK ETS and the introduction of Activity Level Changes. And there was recognition that resourcing was particularly an issue for the devolved government regulators, where there were fewer individuals covering UK ETS. Among the 70 survey respondents suggesting improvements for the service provided by regulators, about 1 in 4 (26%) said that the regulator was understaffed, suggesting that more personnel to be hired. Other suggestions included reducing delays (21%), streamlining processes (19%) and improving communications (19%).

Consistency across regulators was important for firms that had multiple sites in different parts of the UK. In the qualitative research, there were mixed views on the extent to which the regulators coordinated their approach to UK ETS regulation. An example of inconsistency was the recent introduction of change of permit format by the regulator in England, where implementation of this change was delayed by the regulator in Wales.

Feedback on UK ETS guidance and communications

Guidance

In the qualitative research, there were mixed views on the quality and availability of UK ETS guidance. Some AOs reported that the UK ETS support and guidance were better than those provided by other EU ETS regulators. But there was also criticism from operators/AOs that had difficulty locating written guidance or that were critical of EU ETS guidance still being used within UK ETS. The regulators commented that they were particularly dependent on EU guidance for Activity Level Change reporting. At the time of this research, AOs expressed frustration that they were still waiting for official guidance on SAF.

More generally, operator or trader staff who were new to the UK ETS, and who only interacted with the system once a year, expressed a need for simple step by step guidance. Some

traders mentioned that the EU ETS Union Registry had videos showing step by step how to undertake simple tasks (for example adding a new authorised representative, initiating a transfer, check balances and so on) with screenshots of a mock registry account. At the time of this research, these interviewees were not aware of similar materials being available for the UK ETS.

Communications

In the qualitative research, operators/AOs were generally positive about regulator communications, finding the newsletter helpful. Both the regulators and other industry groups, including the UK Emissions Trading Group and (in some sectors) industry bodies, were reported to play a role in raising awareness and signposting operators/AOs to relevant communications and guidance.

While there was generally support for the decision to defer the move to METS (see PMRV section above), there was some comment that the move should not have been announced until the timing of the transition was more certain.

Feedback on UK ETS Authority communications

In general, UK ETS operators/AOs were broadly satisfied with their interaction with the UK ETS Authority. Regarding the information received from the UK ETS authority about changes to ETS policies or processes, approximately two-thirds of survey respondents (63%) said they were satisfied (n=183), whereas 10% said they were dissatisfied. Seventy one of the 183 operators/AOs surveyed suggested improvements to the information provided by the UK ETS about changes to ETS policies or processes. Of these 71 operators/AOs, 64% asked to be more promptly notified about any scheme changes, while 21% asked for rules and regulations to be explained in layman's terms, 13% asked for more targeted communications rather than generic emails and 11% asked for workshops to be organised to explain changes. Finally, 5% would like to see an increase in the maximum number of contacts allowed in the UK ETS authority email list for their organisation.

There was considerable comment in the qualitative research about the timing of the UK ETS Authority's consultation response, as discussed in the next sub-section.

Level of cap and UK Authority response to consultation on 3 July 2023

At the beginning of the research period, the UK ETS Authority had yet to publish its full response to the March 2022 consultation on 'Developing the UK Emissions Trading Scheme'[15]. An interim response was published in August 2022 but this did not cover important issues such as the introduction of a net zero consistent cap on emissions.

In qualitative research, both operators/AOs and traders expressed disappointment and frustration at the delay in publication of the response. Some commented that uncertainty about the future direction of the scheme had contributed to market weakness and to uncertainty about industry investments. The lack of industry and market engagement since the

[15] https://www.gov.uk/government/consultations/developing-the-uk-emissions-trading-scheme-uk-ets

consultation was contrasted with the EU ETS approach to consultation on changes, and with the UK ETS Authority's good level of engagement during the period of transition to the UK ETS. Market traders commented that the UK ETS Authority could have engaged with industry and the market about emerging ideas (for example through working groups), rather than delaying any announcement until it had made a decision.

In response to the UK ETS authority's response on 3 July 2023, the price of UKA December futures rose initially from £54/tonne to £58/tonne but subsequently declined, reaching £34/tonne by 21 September 2023. Interviews with traders suggested that the initial rise was fuelled by the fact that the consultation response had finally been published, before readers had time to review the details.

Interviews suggested that the market had expected that the UK ETS Authority would commit to a net zero consistent cap, and that there was some disappointment from traders when they realised that the weakest version of the net zero consistent cap was proposed and that some of the proposals were still open to further consultation. The net zero consistent cap was welcomed but some analysts reportedly thought that the market would still be in over supply, partly because of proposed release of allowances from the Reserve Pot to smooth transition to a lower cap. Traders commented that, under the proposals, 'key industries' would get free allowances so the lower cap would not yet bite. Wider stakeholders commented that there was still considerable uncertainty about the future of the UK ETS beyond 2026, despite the consultation response. In contrast, market commentators reported that there was more certainty around the 'Fit for 55' proposals for the EU ETS[16].

There was concern amongst operators/AOs, both before and after the announcement, that progressive tightening of the cap would not necessarily be matched by operators/AOs' opportunities to decarbonise. Those operators/AOs that perceived there to be a lack of viable decarbonisation options for their sector were concerned that they would be hit hard as the cap tightened and free allowances were reduced. Those operators/AOs able to pass UKA prices on to their customers were less concerned about the future level of the cap. A few operators/AOs that were strongly committed to decarbonisation reported that they would like to see a tighter market and higher carbon prices to support investment in Carbon Capture Utilisation and Storage (CCUS), hydrogen or other low-carbon fuels. They commented that these investments need to start now if the UK is to meet its carbon targets in 2030 and beyond.

[16] https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/

Chapter 5. How well has the UK ETS market been operating?

This chapter presents evaluation findings on UK ETS market functioning and outcomes, responding to evaluation questions A2 (about market processes) and B1-3 (about market participant behaviour, market accessibility/liquidity, and risks to effective functioning of the UK ETS carbon market). All the evaluation workstreams contributed findings to this chapter. Most operators/AOs were found to trade relatively infrequently 'Over the Counter' via intermediaries such as brokers and 'market makers' (explained below). A small number of operators/AOs with high emissions bought more frequently via the UKA auction and/or traded directly on ICE. There were mixed findings on price discovery and liquidity of the UK ETS secondary market, with data analysis finding that the market functions fairly well but traders reporting issues with liquidity and volatility.

This chapter reviews how the UK ETS market operates and how effectively it functions as a carbon market. The evaluation focused considerable attention on these issues because of potential concerns about price discovery and liquidity in a relatively small carbon market. The concepts of price discovery and liquidity are explained in the literature review, presented in Annex 3. Understanding trading activity was important because more active trading would potentially improve market efficiency and liquidity. The aspects of the UK ETS market considered in this chapter are:

- **Who trades in the UK ETS market, how and why?** characterisation of compliance-related and non-compliance trading activity, followed by consideration of how traders access the market and why (such as via auction, ICE, Over the Counter), and what products are traded and why (such as physical UKA and derivatives).
- **How is the UK ETS market performing?** assessment of trading volumes, price volatility, price efficiency and liquidity (benchmarked against the EU ETS where possible).
- **Feedback on UK ETS market design:** including the auction process, Auction Reserve Price, Cost Containment Mechanism, ICE platform and OTC trading.
- **Risks to UK ETS market quality:** and suggested ways in which the UK ETS market could be improved.

Who trades in the UK ETS market, how and why?

A key focus of phase 1 evaluation research was to deepen understanding of trading behaviours within the UK ETS (in response to evaluation question B1). Two main types of trading behaviour were observed in this research: trading linked to compliance and other 'non-compliance' trading. These are discussed in turn below.

Compliance trading behaviour

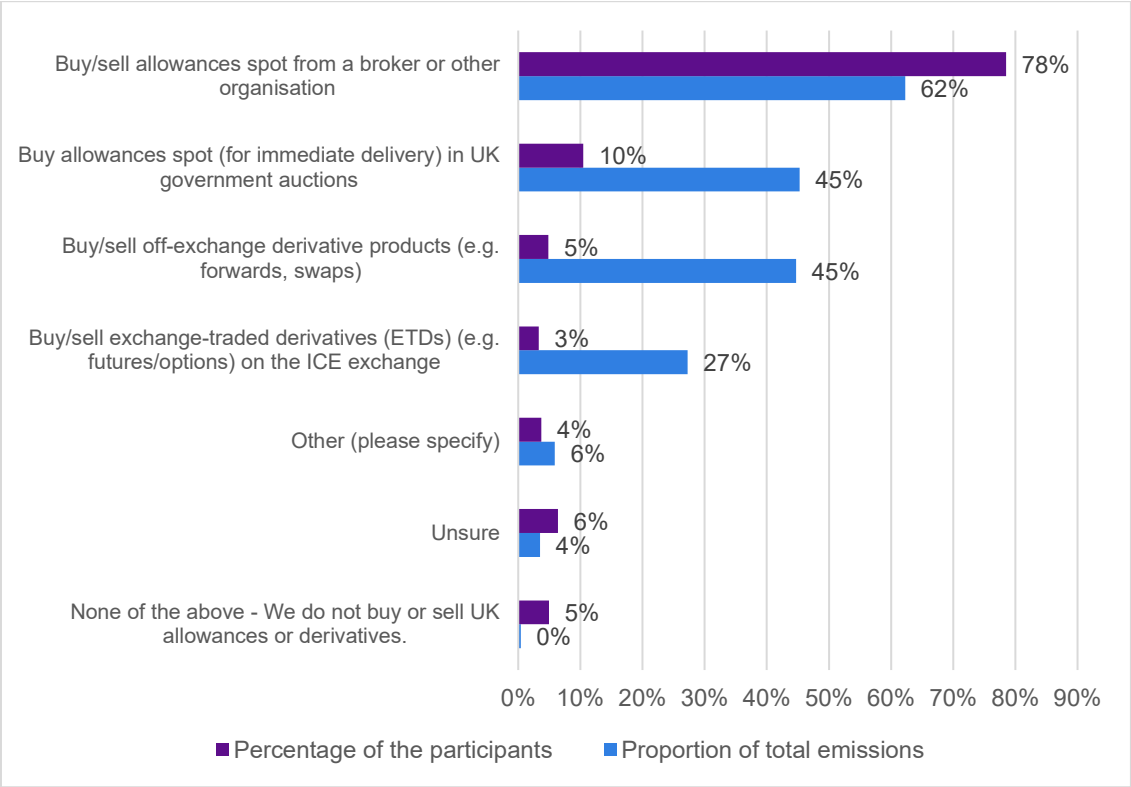
Operators/AOs are required to surrender UK allowances (UKA) by 30 April in the year following the scheme year to cover their reportable emissions in a given scheme year. They can obtain physical UKA from their free allocation (if eligible) and by buying them at auction (the primary market), or from ICE, intermediaries (such as brokers, banks) and other UK ETS operators/AOs (the secondary market). They can also trade UKA derivatives on the secondary market: futures and options contracts traded can be traded via ICE while forward and swaps can be traded 'off exchange' (or 'Over the Counter') via intermediaries and other UK ETS operators/AOs.

The quantitative survey found that the vast majority of operators/AOs receiving free allocations used at least some of this allocation for UK ETS compliance in the year of issue. In the survey, this was reported by operators/AOs receiving 98% of all free allocations (n=121). Some recipients of free allocations also held these allocations for future years (reported by operators/AOs receiving 23% of total free allocations) while others used free allocations to meet the previous year's compliance obligations (reported by operators/AOs receiving 15% of total free allocations). Less commonly, operators/AOs reported selling free allocations to another operator or trader (reported by organisations receiving 14% of total free allocations) or trading them on the derivative product market (less than 1% of total free allocations).

UK ETS data indicated that 50 of the 759 organisations in the scheme (7%) had free allocations fully covering or exceeding their reported emissions in 2022. The surplus free allowances received by these organisations represented just over 2% of total emissions. The remaining 93% of operators/AOs needed to obtain some UKA from other sources (for example carrying them forward from previous years, transferring them from other companies in their group, or purchasing physical UKA and/or UKA derivatives).

The quantitative survey found that nearly 90% of operators/AOs reported that they engaged in some trading in physical UKA and/or UKA derivatives (n=204). Generally, larger emitters were more likely to trade actively in UKA than small emitters and were more likely to trade directly in the auction or ICE rather than via intermediaries. As shown in Figure 5, 78% of survey respondents (representing 62% of emissions) reported that they bought at least some UKA 'spot' (meaning for immediate delivery) from a broker or other intermediary. Only 10% of survey respondents reported using the auction, but these organisations accounted for 45% of emissions. Similarly, 5% of survey respondents reported trading in off-exchange derivatives (for example forward contracts and swaps) and 3% reported trading in ICE-traded derivatives (namely futures and options), accounting for 45% and 27% of emissions respectively.

Figure 5: Does your organisation buy and/or sell allowances and/or derivative products in any of the following ways? (multiple response allowed; all main scheme participants, including quantitative data from qualitative interviews; n=204)

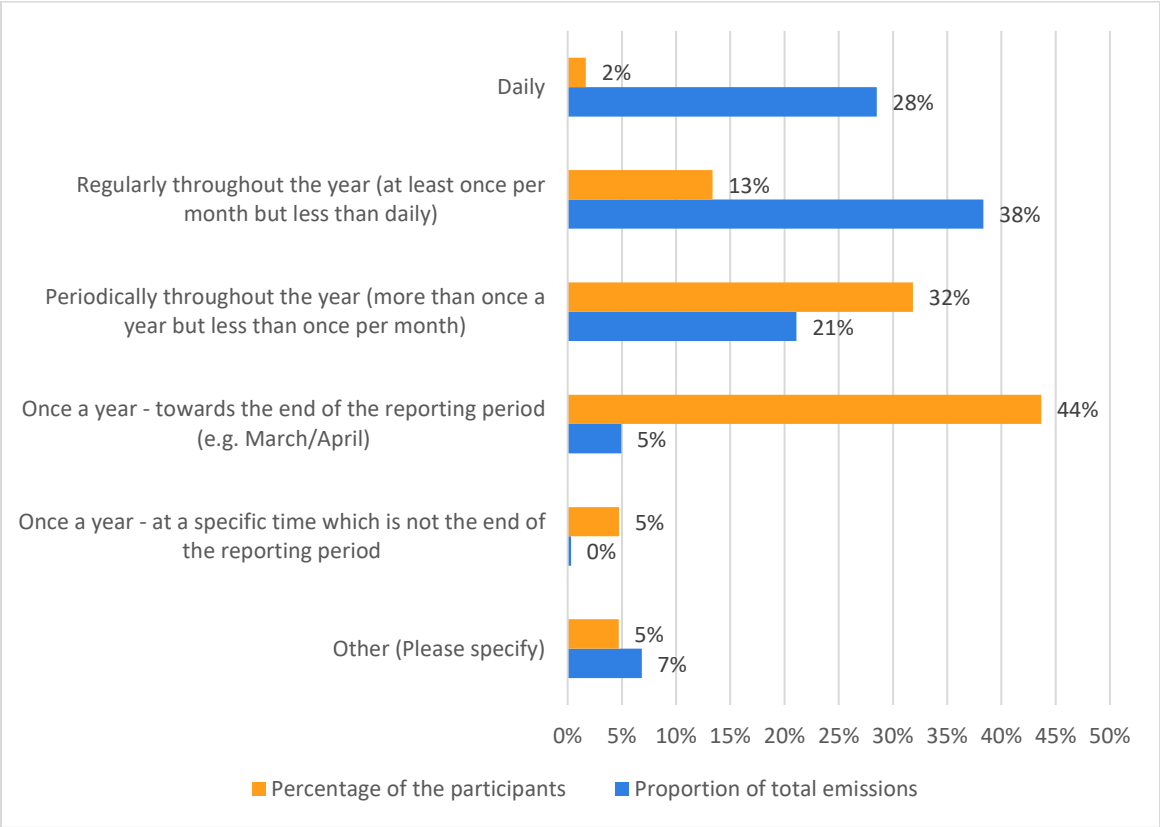


Source: quantitative survey with UK ETS main scheme operators/AOs (including quantitative responses from qualitative sample).

The survey also found that the majority (88%) of operators/AOs engaging in trading only bought physical UKAs and/or UKA derivative products, while 2% only sold physical UKAs and/or UKA derivatives (n=182). In contrast, 9% of operators/AOs (representing 29% of total emissions) engaged in both buying and selling.

Both the quantitative survey and qualitative research found that operators/AOs with larger UK ETS liabilities (meaning larger shortfalls in UKA after free allocation) bought more often to reduce their compliance risk. This is evidenced by the finding that more frequent purchasing patterns were associated with higher proportions of emissions, as shown in Figure 6.

Figure 6: How often do you buy allowances spot? (all main scheme participants buying allowances spot, including quantitative data from qualitative interviews; n=169)



Source: quantitative survey with UK ETS main scheme operators/AOs (including quantitative responses from qualitative sample)

Operators/AOs with trading accounts were generally focused on meeting their organisation's compliance obligations. Qualitative research indicated that some firms were constrained from speculation by regulation or by company policy.

> *…first and foremost we are compliance players in the market. We are not there to speculate. We are not there to make money out of a commodity. (Heavy industry operator)*

There were exceptions to this rule where operators/AOs had specialist trading arms. Some of these trading arms engaged in 'other types of trading behaviour' (for example speculation), in addition to meeting compliance requirements. These other types of trading are discussed in the next section.

The main patterns of operator trading behaviour identified by the quantitative survey and by realist analysis of qualitative research findings are set out below. These patterns were consistent with the preliminary findings of network analysis of the UK Transaction Log (UKTL), as set out in the sub-section below on 'Overview of UK ETS secondary market performance'.

Buy to comply

As shown in Figure 6, the survey found that 49% of operators/AOs bought UKA once a year: these tended to be smaller emitters, representing only 6% of emissions (n=169). Qualitative research found that these 'buy to comply' operators/AOs had lower emissions, saw UK ETS compliance costs as less significant to their business and wanted to keep compliance simple, and therefore bought physical UKA once a year. They used an intermediary (for example a broker or market maker) to buy 'Over the Counter' because they did not have the time or expertise to access the market directly.

> *Our only concern is that we should have sufficient allowances to cover whatever is used in the UK market. (Aircraft operator)*

Periodic/frequent hedging

As shown in Figure 6, the survey found that about a third (32%) of operators/AOs bought UKA periodically throughout the year (meaning more than once a year but less than once a month), with a further 13% buying at least once a month but less than daily (n=169). Together, these categories represented 59% of emissions in the UK ETS. Qualitative research found that these were UK ETS operators/AOs with medium to high emissions, that saw UK ETS compliance costs as significant to their business, and that bought physical UKA (and/or futures/forwards) at multiple points through the year, to provide certainty about the cost of UK ETS compliance associated with current production or forward sales, and to avoid the risk of higher prices if they left buying to the end of the compliance year. Qualitative research found that the more risk averse operators/AOs tended to buy regularly to 'lock in' the average price across the year, while others tried to buy when the price was favourable. Others, including most aviation and power operators, aimed to hedge the compliance costs associated with future sales, more than one year ahead. They bought futures or forward contracts in order to fix their future carbon costs, often passing carbon costs on to customers.

> *…we sell our flights [..] about a year and a bit out in advance, and therefore we have a good understanding of what the fuel requirement is going to be and therefore we have an understanding of what the carbon requirement is going to be. So we tend to hedge out into the future, knowing roughly what our flight programme is going to look like. (Aircraft operator)*

Qualitative research identified two sub-categories of operators/AOs undertaking 'periodic/frequent hedging':

- Operators/AOs that used an intermediary (for example a broker or market maker) to buy physical UKA or forward contracts 'Over the Counter' because they did not have the time or expertise to access the market directly. Figure 5 indicated that 78% of operators/AOs (representing 62% of emissions) bought at least some UKA 'spot' from a broker or other intermediary (n=204).
- Operators/AOs that accessed the market directly because they had in-house trading capacity and expertise (for example via a trading arm within their corporate group) and were registered with ICE. Figure 5 indicated that 10% of operators/AOs bought

allowances at auction and 3% traded futures or options on ICE, although these tended to be higher emitters representing a sizeable proportion of scheme emissions (n=204).

Daily trading in 'clean sparks'

As shown in Figure 6**,** 2% of operators/AOs reported buying 'spot' UKA daily, but these operators/AOs were very large emitters representing 28% of total emissions (n=169). Qualitative research confirmed that daily trading was primarily undertaken by very large power sector operators or their trading arms. These operators had ICE membership and used a variety of trading channels, including the auction and 'daily futures' (also known as 'spot' UKA), but primarily traded in December futures on ICE. Their daily trade in carbon was driven by the need to hedge the compliance costs of their future electricity sales and by changes in the market for 'clean sparks' (meaning the differential between the electricity sale price and the purchase price of gas and carbon).

The 'clean sparks' market was reported to be very active, reflecting daily shifts in the profitability of gas-fired power generation in the UK and Europe. Power generators reported in interview that it was profitable to run gas-fired power plants when there was a sufficiently positive differential between the electricity sale price and the cost of gas plus carbon. If the electricity sale price was below the combined cost of gas and carbon (for example because of cheap wind power being available on a given day), then power generators reported that it was more profitable for them to buy electricity on the market to sell to their customers rather than to run their gas-fired power plant. This could result in them selling carbon that they had previously bought as a 'hedge' to cover forward sales of electricity. Carbon trading was therefore driven by what was happening in the electricity and gas markets, rather than by compliance alone.

> *So if we can buy power cheaper than we can produce it, we'll buy back power that we've previously sold. [And] we've then got carbon that we don't need, and we'll sell that carbon back. But ahead of delivery in the futures markets, that might happen several times. [..] So that's why we're active on both sides all of the time. (Power sector operator)*

Occasional sales of UKA

The survey found that 2% of operators/AOs only sold physical UKA (n=182). Qualitative research found that these operators had excess free allowances (for example because of temporary/permanent closure or reduced production) and sold UKA assets to benefit their business in the short term. They used an intermediary to sell 'Over the Counter' because they did not have the time or expertise to access the market directly.

> *…allowances are a tradable commodity in [the parent company's] mind, and we are holding a commodity that we don't need at the moment, and therefore we should sell it. (Heavy industry operator)*

Other operator/AO trading behaviours

Operators with multiple installations in the UK ETS commonly reported that they used one of their operator accounts or their trading account as a holding account for allowances,

distributing them to the installations prior to compliance. Other trading behaviours were observed for a few operators in the qualitative research. These included:

- An operator receiving physical UKA from their customer, as part of their supply contract.
- An operator receiving physical UKA from a parent company that had sold excess EUA and then bought an equivalent value back in UKA. These transactions were undertaken via the same bank but it was not clear whether this was technically a financial swap contract.
- An operator, with low levels of emissions, having a surplus of physical UKA because of previous abatement action, and carrying forward this surplus to cover potential future contingencies.

The separation of the UK ETS from the EU ETS also meant that organisations could not simply transfer surplus allowances between subsidiary companies in the UK and EU, as they had previously done under the EU ETS.

Other types of UK ETS trading behaviour, not linked to compliance

The main types of non-compliance trading behaviour were characterised through realist analysis of findings from qualitative research with UK ETS traders, together with preliminary network analysis of the UK Transaction Log (UKTL). The main behaviours characterised here, and explained below, are ‘clearing’, ‘market making’, ‘broking’ and ‘speculating’.

A limitation of this analysis is that the UKTL documents transactions in physical UKA and does not capture trading in derivatives (for example futures and forwards contracts). Trading on the ICE is anonymous so futures trading cannot be analysed by trader type, while ‘Over the Counter’ (OTC) trades in forwards involve bilateral contracts for which data is not available. Nevertheless, the UKTL network analysis provided some preliminary confirmation of the trading patterns observed in the qualitative research, insofar as trading involved physical UKA transactions.

Clearing

Clearing firms were global businesses providing banking and financial services, with considerable financial standing. Only ICE Clearing Members could participate directly in the UK ETS auction and ICE platform. Other traders and operators/AOs were required to complete their transactions via an ICE Clearing Member, to reduce the risk of default on trades.

As ICE Clearing Members, clearers offered clearing services for UKA products to low-risk clients in return for a fee. There was some degree of risk involved in being a clearer (namely the risk that a client could not pay for a product that they had purchased on ICE via the clearer) so clearers vetted their clients (including UK ETS operators/AOs) on the basis of their financial health and strength.

> *…we've got a very, very strict onboarding and compliance and credit and risk process about bringing clients on board. [..] there are quite big hurdles just to get across the line to be a client. So most of our clients in this would be big banks or big asset managers or*

> *the larger hedge funds. But there are some corporates in there as well who would be doing this to hedge. (Clearer)*

Clearers sat in the middle of the market and facilitated the exchange of payments and UKA products on the ICE platform (for example where ICE sold futures or the auction sold physical UKA to an operator). Their function was process oriented and the clearing teams had no commercial interest in the trade itself. Clearers were found to act as clearers for both the EU ETS and UK ETS.

Preliminary analysis of trader accounts identified 17 financial institutions that were both Clearing Members of ICE Futures Europe and had active UK ETS trading accounts in early 2023. This was an increase from 11 clearers in 2021 and 16 in 2022. Network analysis showed that 5 of these 17 organisations solely undertook clearing services within the UK ETS market during 2023. The remaining 12 clearing members appeared to undertake market making activities as well as providing clearing services. The network analysis showed that accounts solely providing clearing services played a vital function but were less important than market makers in terms of their contribution to trading.

Market making

Market making (i.e. traders providing services while taking low-risk positions) was observed by firms providing a range of financial, risk and asset management services to an existing client base. They were usually registered on the ICE and primarily undertook trading in UKA products to meet the needs of clients that had obligations under the UK ETS. This enabled the market maker's clients to access the market and hedge their compliance risks (mainly using December futures), while the market maker generated a profit by charging a margin on sales, hedging their own positions and undertaking some relatively low risk speculation.

> *…a lot of our involvement originates from our lending base with a number of corporate clients that have these compliance obligations and we have strong banking relationships with [them]. (Market maker)*

Many, but not all, market makers traded frequently (for example daily), generating income by taking a margin on trades via the 'bid-ask spread'. The bid-ask spread measures the difference between prevailing best buy and best sell prices in the ICE order book and is indicative of the cost of trading in the market. Some market makers also engaged in ancillary speculative trading, while others provided clearing services as well.

Some market maker interviewees reported that they bought allowances from clients and then traded these (for profit) before selling them back to their clients. This practice provided the client with the opportunity to access cheap capital (through the sale of the allowances and through the market maker's cheap borrowing costs) and the market maker with the opportunity to generate additional profit.

Preliminary network analysis tentatively identified around 18 market makers in the UK ETS market during 2023, 12 of which also provided clearing services. This was an increase from 12 market makers identified by network analysis in 2021, and 17 market makers in 2022. A further 10 traders showed mixed behaviour incorporating elements of market maker, broker and

speculator patterns in 2023: these were tentatively classified in the network analysis as 'mixed market makers'. Preliminary network analysis suggested that market makers played a highly significant role in the market because of their level of activity, trading with multiple trader and operator accounts and providing liquidity to the market.

Broking

Broking firms are defined here as businesses delivering a range of services (including energy services), with carbon trading usually being an ancillary activity and forming part of a wider offer. They were usually registered on ICE and traded physical UKA and UKA derivatives on behalf of clients rather than in their own right. They did not take speculative positions and offered services to clients in return for a fee. Many of their clients were operators/AOs with compliance obligations.

> *…we only trade on behalf of clients, so we have zero position on our own. (Broker)*

Brokers appeared to be the one of the most widely observed type of trader. Preliminary network analysis suggested that there were around 17 firms exhibiting broker behaviour in the UK ETS market during 2023, but it was difficult to distinguish fully between firms undertaking broking and market making in the network analysis. This estimate for 2023 represented an increase from 10 firms exhibiting broking behaviour in 2021 and 13 firms exhibiting broking behaviour during 2022. Network analysis suggested that some firms had changed their trading patterns over time (for example between broking, which did not involve taking trading positions, and market making, which involved traders taking some low-risk positions). The reasons for these changes in trading patterns are not yet fully understood. Overall, network analysis suggested that brokers (as defined here) played an important role in linking operators/AOs with sources of UKAs in the UK ETS market. This confirmed the finding, from the quantitative survey, that the majority of UK ETS operators/AOs purchased physical UKA (and in some cases UKA derivatives) via intermediaries (for example brokers and market makers) rather than trading directly in the auction and ICE.

Speculation

Speculation behaviour involved firms registered on ICE taking potentially risky positions in the UK ETS market (mainly in December futures) because their commodity trading expertise and energy market insight meant that they were well placed to identify and realise opportunities to generate profit through speculative trading in UKA products. This suggests that they may be playing the role of 'informed traders', as set out in the literature review on carbon markets (see Annex 3). The literature review found that 'informed traders' are critical for price discovery and informational efficiency in a market, because they are the traders who possess the information needed to ensure that the instrument they trade is fairly priced.

> *…the bulk of what we do is we do a lot of analysis, then we build balances and selectively we kind of look at the system. So if we build balances on our side, we look at supply which tends to be formulaic, as they are set by government, we look at the demand which is the real kind of uncertainty in these markets and then look at whether we think price is a fair reflection of the equilibrium position, and off the back of that we*

> *may deploy strategies and capturing, you know, whatever discrepancy, whatever difference we see in the market. (Speculator)*

Network analysis tentatively identified around 9 speculators trading in physical UKA in the market during 2023, but this analysis did not capture trading in UKA derivatives (for example December futures). This was an increase from the estimate of 8 speculators identified by the network analysis for 2021 but slightly down from the estimated 11 speculators in 2022. The preliminary network analysis found that speculators did not appear to contribute significantly to market liquidity because their trades, although potentially large, were relatively infrequent and – unlike market makers - they did not facilitate the transfer of allowances to operators/AOs.

There was some suggestion from qualitative research with traders that interest from speculators was declining because of current weakness in the UK ETS market, linked to anticipated oversupply of allowances in the next few years during the transition to a net zero consistent cap.

Other types of trader

The network analysis also identified trading accounts belonging to operators/AOs that primarily exhibited compliance trader behaviour, involving transactions between small numbers of accounts. Compliance trading patterns are described in detail in the previous section.

Who buys allowances at auction, on the Intercontinental Exchange (ICE) or over the counter (OTC)? How and why?

Auction use

UKA auctions started in May 2021 and are held every fortnight. As noted above, the survey found that 10% of operator/AOs (representing 45% of emissions) participated in the auction (n=204). Network analysis suggested that these clearing houses handled auction transactions on behalf of market makers and operators/AOs with very high requirements for UKA (meaning very large emitters with low or zero free allowances). Reasons for using the auction, as reported by qualitative research interviewees, included:

- Being able to secure large volumes (for example 50,000 or more) of UKA without moving the market price, which some interviewees commented was more challenging in the secondary market.
- UKA prices at auction being, in general, slightly lower than futures prices (in part, because they did not need to take account of the time value of money or 'cost of carry')[17].
- Purchases not being time-sensitive, so fortnightly purchasing was acceptable.

Reasons given for not using the auction, as reported in qualitative research, were:

- Auction participation being perceived as a 'hassle', particularly for those not requiring large volumes of UKA.

[17] See Glossary in Appendix 1 for explanation of 'cost of carry'.

- Auction registration being restricted to operators/AOs and organisations authorised by the Financial Conduct Authority (FCA) under Part 4a of the Financial Services and Markets Act (2000). Non-operators participating in the auction were primarily banks, with some brokers and market makers being ineligible to participate, even via clearing houses, because they did not have a UK registered office or did not meet other FCA requirements for auction participation.
- Some operators/AOs lacking the cashflow required to buy UKAs at scale in auctions, since payment was required immediately, or at least within 3 days of the auction.
- Some companies perceiving auction participation as problematic within their corporate governance structures.

Some interviewees (for example market makers) noted that they might attempt to register for UKA auctions in future if there was sufficient demand from their clients.

ICE trading

ICE offers a range of futures contracts in ‘lots’ of one thousand allowances, ranging from ‘daily futures’ which mature into ‘spot’ UKA at the end of each day, to monthly futures contracts that mature into UKA at the end of each month. Secondary market data analysis found that December futures for the current year were the most actively traded contract, with December futures for the following year being the second most actively traded contract. Over the time period 22 May to 15 September 2023, on average 1,272 lots were traded per day in December 2023 futures. The next most frequent trades were 54 lots traded per day in December 2024 futures, 23 lots traded per day in ‘daily futures’ and 9 lots traded per day in March 2024 futures. The reasons for the ongoing dominance of December futures are unclear, given that the UKA surrender deadline in April of each year might suggest that March futures would be preferred. One hypothesis put forward by interviewees was that December deadlines fitted well with accounting requirements for emissions in a given calendar year. December futures were also reported to dominate secondary trading in EUA.

Qualitative research found that ICE tended to be used by compliance and non-compliance traders that wanted to hedge their risks on a regular basis. This included large operators/AOs, particularly from the aviation and power sector, who wanted to ‘lock in’ or hedge the carbon compliance costs of forward sales. Similarly, some market makers and brokers reported that they bought futures to hedge their own exposure while making OTC trades.

The main reasons for trading on ICE, as reported by qualitative research interviewees were:

- The flexibility of being able to trade on a daily basis**,** in between the fortnightly auctions. Flexible timing suited operators/AOs who were regular buyers (for example those regularly hedging forward sales) and operators/AOs or traders that wanted to respond quickly to market price signals.
- Cashflow considerations: while futures contracts usually require a small ‘initial margin’ or deposit to be paid upfront to the trader, operators/AOs only need to find the full value of the UKAs if and when the contract matures. Interviewees reported that futures tended to be bought and sold multiple times, with only a few being held to maturity.

- Price discovery and transparency: some traders mentioned that they checked prices on the ICE when making OTC trades.

Barriers to direct use of ICE, other than the need to develop a relationship with a clearer, were reported to include:

- Difficulties fulfilling large transactions in one block (for example buying 25,000 futures contracts at a given price) without some coordination between brokers outside ICE.
- And possibly also the hassle of paying a 'maintenance margin' on the value of a future contract, if there is a fall in the value of UKAs.
- Corporate governance rules precluding trading in derivatives.

Over the Counter (OTC) trading

The majority of operators/AOs reported buying some or all of their UKA requirements 'Over the Counter' (OTC): this means that they purchased UKA from an intermediary organisation such as a broker or market maker. The survey found that 78% of operator/AOs made some use of OTC transactions for physical UKA (or 'spot') purchases (n=204). OTC trades may involve 'spot' UKA, forwards contracts (namely commitments to buy a certain quantity of UKA at a given date and price) and – in some cases – swaps between UKAs and other assets (for example EUA). Given the private nature of these transactions, data on contract price and type are not available, while some information on volumes can be inferred from network analysis of the UKTL.

The preliminary network analysis showed that the UKA transaction network has become larger and more complex since 2021, the first year of the scheme. It also indicated that, other than transfers of UKA between operator accounts owned by the same firm, most operators/AOs only transacted with one, or possibly a few, intermediaries. Qualitative research found evidence of some operators/AOs getting quotes from several banks or brokers to ensure that they got the best deal on each trade.

Reasons given by operators/AOs for trading 'OTC' via market makers and brokers, from the qualitative research were:

- Simplicity – operators/AOs often had existing relationships with intermediaries (for example dating back to the EU ETS) and preferred to buy from them rather than set up their own trading accounts. One operator commented that, since they could only trade on ICE and buy at auction via a clearing house anyway, they might as well go through a market maker or broker that provided a fuller service (for example advice as well as clearing).
- Access to expertise – some operators/AOs noted that they dealt OTC with brokers who had more expertise in the market than they had, freeing them to concentrate on their own business.
- Cashflow – settlement terms in the OTC were reported to be more relaxed than in the auction or on the ICE platform (in that buyers were given a bit more time to pay than on

the auction or ICE). This was reported to be an advantage for operators/AOs but potentially a disadvantage for brokers' cashflow.

- Inertia – other operators/AOs noted that they continued buying from their usual intermediary because they did not feel that they had the expertise to determine which approach to UKA procurement was best.

There was limited comment about disadvantages of the OTC market (for example lack of transparency about trading volumes and prices).

Who trades in physical UKA and UKA derivatives?

As noted above, the survey found that most (at least 78%) of operators/AOs traded in 'spot' UKA (for immediate delivery), while 3% trade in ICE-traded derivatives (for example futures, options) and 5% trade in OTC derivatives (for example forwards, swaps) (n=204).

Trading in 'spot' UKA

Qualitative research found that most operators/AOs, particularly smaller emitters, preferred the simplicity of trading in 'spot' or 'physical' UKA, for immediate delivery.

> *…predominantly your industrial compliance buyers will trade spot. It's straightforward, simple contracts, no credit checks, done and dusted. The futures, and particularly the exchange trading, will be the realm of the power generators. (Market maker)*

However, market makers reported that some of their clients preferred not to tie money up by buying and holding UKA before they needed them. They reported that some clients sold UKA to a market maker, who then sold the UKA back at the end of the year, having made money by trading UKA in the meantime.

Trading in derivatives

Qualitative research found that only larger emitters (above 50,000 tCO2e per annum) tended to buy futures, with power generators and AOs making particular use of futures to cover future product sales and (for power) sparks trades. December futures were actively traded.

> *…so the volume is primarily in the futures. In general, a very small amount of the trades that our clients or affiliates enter into actually end up going into a delivery activity (Clearer)*

Both futures and forward contracts allowed operators/AOs to fix the price of compliance in advance, without having to pay the full cost of physical UKA upfront.

Some traders (for example in the power and aviation sectors) were interested in trading beyond the current calendar year because they wanted to hedge product sales in future years. They tended not to buy December futures for upcoming years, because liquidity in these products was low. Instead, they bought December futures for the current year and sold them towards the end of the year, buying December futures for the next year instead.

Interviewees were sometimes unclear whether they bought futures (via an intermediary) or forward contracts OTC. There was some suggestion that forward contracts were simple for

operators/AOs to administer in accounting terms, while futures contracts required ‘maintenance margins’ to be paid when the market price for UKA futures fell.

The qualitative research found some examples of swaps being made in OTC trading (for example excess EUA being sold and used to buy UKA, or vice versa). Lack of trading in options contracts was attributed to the small size and relatively limited liquidity of the UK ETS market. The next section considers market performance and liquidity in detail.

How is the UK ETS market performing?

Overview of UK ETS secondary market performance

Trading in UKA products started on 19 May 2021, after the first auction of UKA on 19 May 2021. Under financial regulations, futures contracts in UKA could not be traded on ICE until physical UKA were available in the market. There was therefore no trading in UKA products between the start of the UK ETS on 1 January 2021 and the start of trading in May 2021.

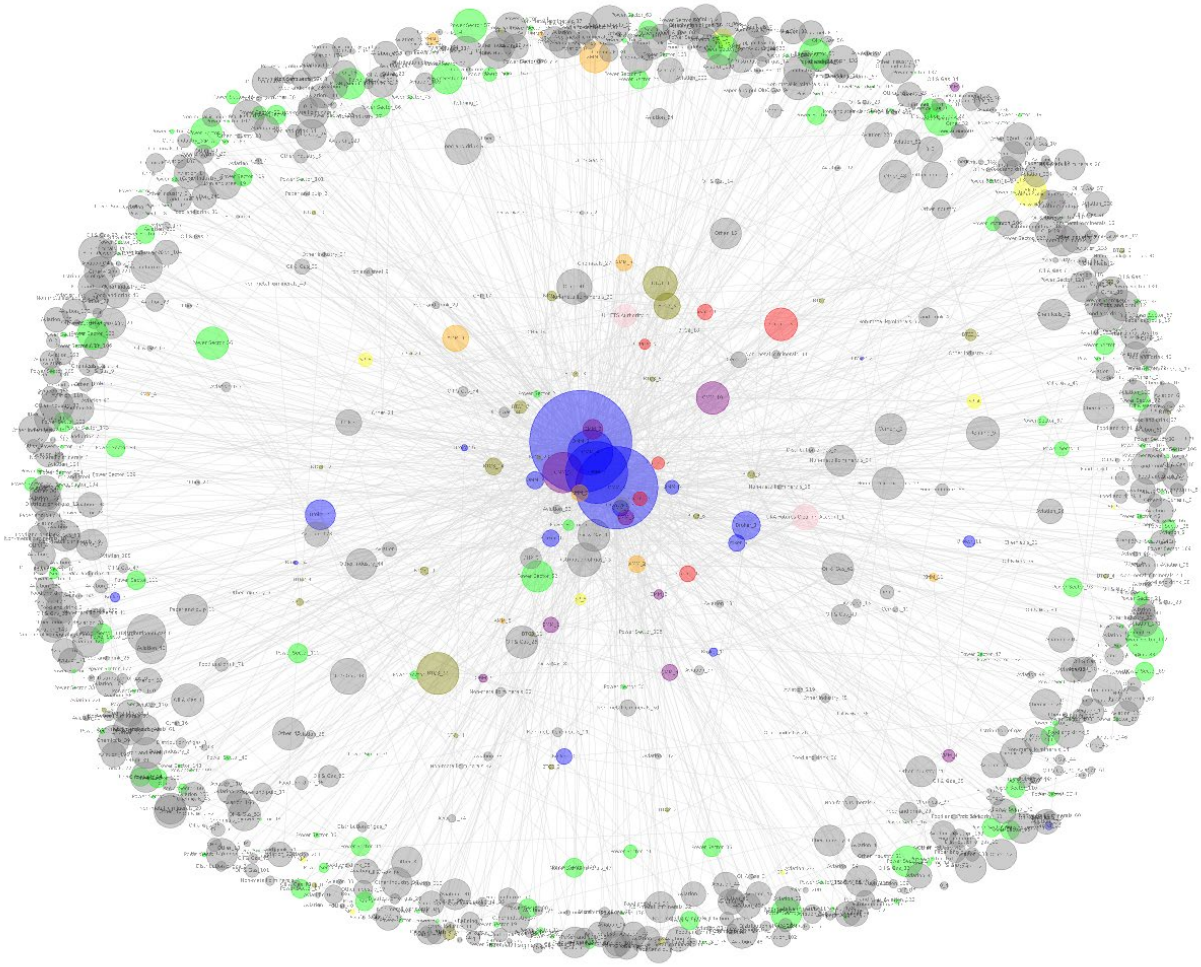
Preliminary network analysis of the UKTL found that the volume and complexity of transactions in physical UKAs had progressively increased from May 2021 to June 2023. In 2021, there were an average of 15 transactions per business day, rising to 33 transactions per day during 2022 and 50 transactions per day during the first half of 2023. The average volume of these transactions also increased, from 4.7 million UKA per day in 2021 and 2022 to 7.3 million UKA per day in the first half of 2023. However, the higher levels of activity for 2023 may partly reflect the fact that the first half of 2023 included the compliance period in March/April 2023.

At the time of this research, it was not possible to compare the trading network for 2022 with the network for a full year’s trading during 2023. Inclusion of a full year’s trading activity is important because of the high level of trading in physical UKAs in the run-up to the compliance period in March/April of each year.

The complexity of connections within the trading network in 2022 are shown in Figure 7 below. The accounts are colour coded to show the tentative typology of accounts developed in the network analysis. The size of the circles shows the importance of each account in terms of its connections to other accounts in the network, as measured by ‘eigenvector centrality’. ‘Eigenvector centrality’ is a measure of the importance of a node in a network that considers the importance of its neighbours. In other words, a node's eigenvector centrality is higher if it is connected to other nodes that are themselves highly connected (see Glossary in Appendix 1).

This figure shows the important role played by a relatively small number of non-clearing market makers and brokers (shown as large blue circles) in supplying physical UKA to a large number of operators/AOs (shown as small green circles for the power sector and small grey circles for other sectors).

Figure 7: Preliminary analysis of UKA trading network (2022)



Source: preliminary network analysis of UK Transaction Log, with size of accounts showing 'eigenvector centrality'. This chart shows only transactions involving physical UKA.

Key	**Tentative classification of accounts in UKTL**
Grey nodes	Operator/AO accounts (excluding power sector) - primarily receiving UKA from other types of account, for compliance purposes
Lime nodes	power sector operator accounts – a type of operator account more actively trading UKA
Olive green nodes	industry trader accounts – trading accounts linked to specific operators/AOs, buying and/or selling on their behalf
Blue nodes	brokers and non-clearing market makers – accounts that buy UKA and sell to many operator accounts (with 'market makers' taking some low-risk trading positions of their own)
Red nodes	'clearer only' accounts – organisations that only 'clear' transactions on behalf of others
Purple nodes	accounts combining market making with clearing activity – clearers who also buy UKA and sell to operator accounts, while taking some low-risk trading positions of their own
Yellow nodes	speculator accounts – organisations that take higher risk trading positions
Orange nodes	accounts exhibiting a mixture of broking, market making and speculation activity – accounts that buy UKA and sell to operator accounts, while also taking some trading positions of their own (not necessarily low risk)
Pink nodes	UKA Futures Clearing and Auction Account – central accounts run by ICE

ICE data shows that trading in December futures on the secondary market also increased since the start of the scheme in 2021, reaching 493 lots traded per day in December 2023 futures up to mid-September 2023.

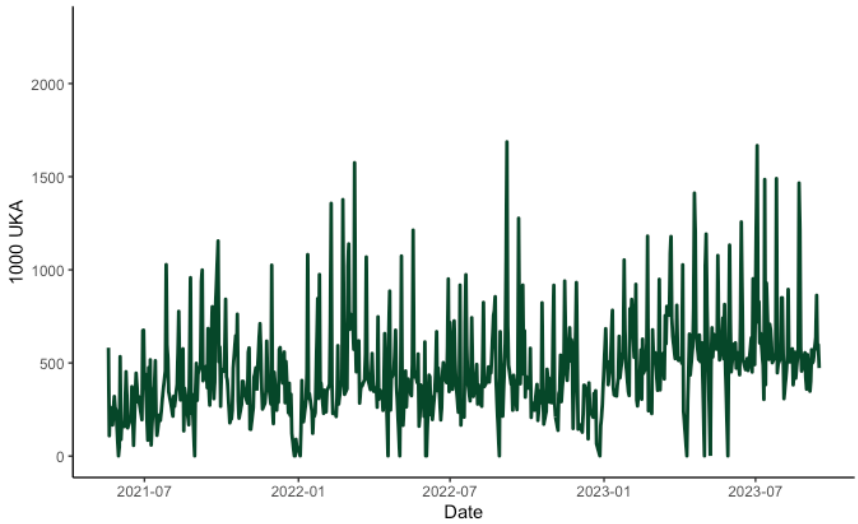
Table 6: Volume of trades in December futures contracts

UKA futures contract	Sample period	Average number of trades per day (in lots of 1000 UKA)	Average value of trades per day (£ '000)
December 2021	19 May 2021 – 30 November 2021	394	21,246
December 2022	1 December 2021 – 30 November 2022	447	35,304
December 2023	1 December 2022 – 15 September 2023	493	35,948
Combined time series	19 May 2021 – 15 September 2023	476	31,965

Source: Secondary market data analysis, ICE data.

As well as a gradually increasing trend in trading activity (as shown in Figure 8), there were significant variations in secondary market activity, including variation between auction and non-auction weeks. The secondary market data analysis for the period 19 May 2021 to mid-September 2023 found that the mean daily trade in auction weeks was 540 thousand UKA/day, while in non-auction weeks it was 416 thousand UKA/day.

Figure 8: Trading volumes for December future contracts (combined time series)

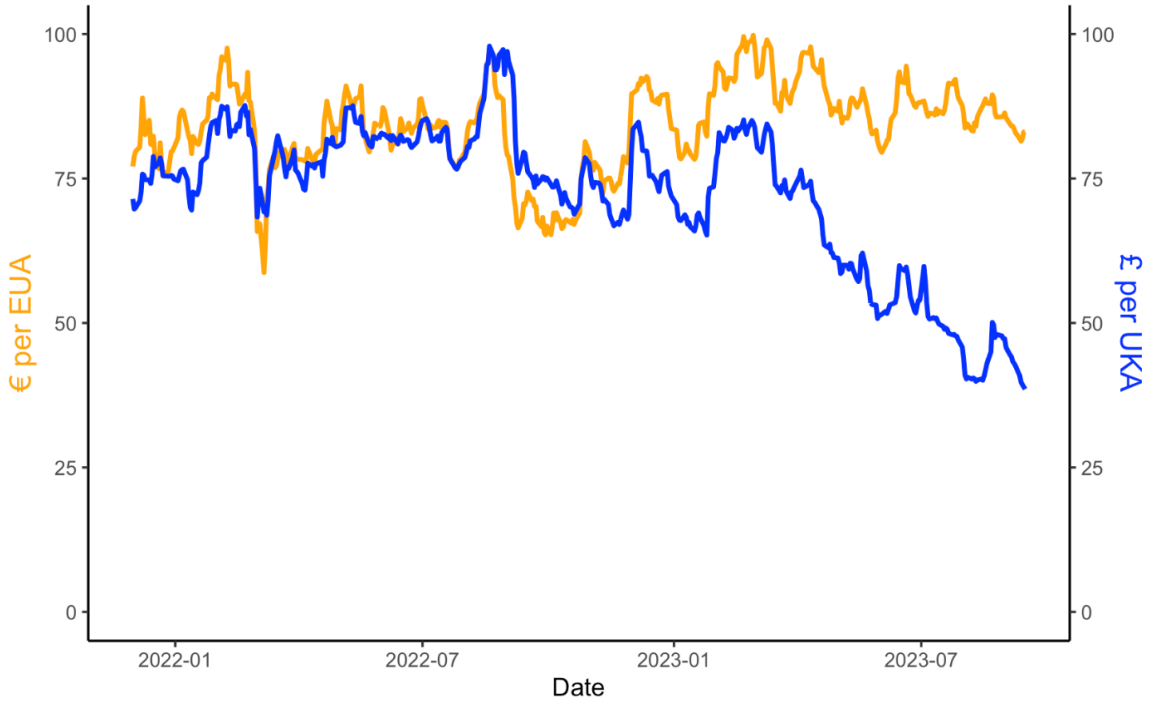


Source: Secondary market data analysis, ICE data.

The price of UK ETS December futures rose at the start of the scheme, initially exceeding EU ETS prices after exchange rates were taken into account. Qualitative research with traders and operators/AOs suggested that UKA futures prices were initially strong because of 'catch-up' purchases by firms (particularly power generators and AOs) that were unable to purchase UKA as part of their usual hedging strategies between 1 January and 19 May 2021. For example, the price increased from £54/tonne in November 2021 to £80/tonne in December 2021, reaching a historic high of £98/tonne in August 2021. ICE data shows that both UKA and EUA prices rose in response to the start of the Ukraine war in February 2022. There was also some suggestion from a trader that UKA prices may have been pushed up during this period by the influence of Ofgem's energy price caps on power generator behaviour, although the mechanism for this was unclear. The price fell back to £76/tonne in September 2022 but there was a further period of high prices (over £80/tonne) around the time of compliance in March 2023.

The price declined from April 2023, reaching around £34/tonne on 21 September 2023. Qualitative research with traders suggests that this was initially caused by lack of confidence in the UK ETS Authority's adoption of a net zero consistent cap for the UK ETS, owing to delays in publication of the response to the March 2022 consultation. The UK ETS Authority's consultation response in July 2023 did not halt this decline, despite proposed adoption of the net zero consistent cap, because some aspects of the response were perceived as lenient to industry, as discussed further in the market design section below. Qualitative research with traders suggested that the relative strength of the EU ETS market during 2023 was related to the EU Commission's progress on the 'Fit for 55' programme which includes strong commitments to net zero targets, the introduction of the Carbon Border Adjustment Mechanism and phasing out of free allowances within the EU ETS.

Figure 9: UKA and EUA prices (December futures - combined time series)



Source: Secondary market data analysis, ICE data for UK ETS and EU ETS December futures.

Volatility of prices in the UK ETS secondary market

The literature review on the quality of secondary carbon markets found that volatility in market prices is not necessarily bad: in an efficient market, prices would be expected to vary in response to new information. However, volatility can be disadvantageous for price discovery if it is driven by 'noise' rather than new information. The metrics presented in this section, informed by the literature review, distinguish between volatility that is effectively 'noise' and volatility that is driven by incorporation of new information into the market. Fuller details of the metrics are given in the literature review on assessment of carbon market quality (Annex 3).

The evidence about volatility in the UK ETS secondary market was mixed, with secondary market data analysis being positive while qualitative research views were more negative.

UKA traders and operators/AOs were concerned about the UKA market being small relative to the EU ETS, and the UKA price potentially moving in response to relatively small factors. Operators/AOs tended to dislike volatility as price uncertainty made business planning more difficult, but some traders were more tolerant of volatility because it created trading opportunities.

However, the secondary market data analysis found that (on average from 1 December 2022 to 15 September 2023), overall price volatility in the UK ETS was 0.0882, as measured by the standard deviation of 1-minute returns. This was comparable to the average for the EU ETS over this period (0.0919). However, the average volatility of the two markets differed over time: the EU ETS secondary market experienced more significant spikes in 2022, particularly at the end of February 2022 when the Ukraine war began, but the price volatility in the UK ETS secondary market was higher and more variable than the EU ETS during 2023.

Analysis of the information driven component of volatility was only possible for a limited time period because this analysis required data on bid-ask spreads which were only retained by ICE for a limited period[18]. Subject to this limitation, the UK ETS secondary market showed a higher share of information-driven volatility compared to the EU ETS between end July and mid-September 2023. This suggests that more of the volatility in the UK ETS market over this period was 'good' (meaning information driven) rather than 'noise'. It is possible that this may be explained by differences between UK ETS and EU ETS market events over this period (for example UK ETS reactions to the UK ETS Authority's July consultation paper). But it may also be explained by the much higher level of trading activity in the EU ETS market, including algorithmic trading[19]. Higher levels of trading activity may lead not only to faster incorporation of new information, but might also lead to higher levels of trading noise (although additional analysis below suggested that the UK ETS market was 'noisier' than the EU ETS over the period of analysis). Further analysis of this metric over longer time periods would be required to interpret this metric more fully.

[18] Data on bid-ask spreads is retained on the ICE platform for 30 days, covering the previous 45 days. Going forward, bid-ask spread data will be downloaded from ICE at regular intervals to provide a continuous time series.
[19] European Securities and Markets Authority (March 2022), Final report – emissions allowances and associated derivatives.

Further details of price volatility analysis for the UK ETS are presented in Annex 4.

Price efficiency in the UK ETS secondary market

The UK ETS performed slightly worse than the EU ETS on price efficiency measures, during the period of analysis. The literature review found that – over short periods of time - prices move randomly over time in a fully efficient market, but that prices and returns move more predictably in a less efficient market, meaning that price movements are more likely to be predicted by other market variables, such as trading activity.

The predictability of returns by trading activity required use of bid-ask spread data and could therefore only be calculated for a limited time period from end July to mid-September 2023. Over this period, the average predictability of returns in the UK ETS secondary market (0.0453) was slightly higher than in the EU ETS secondary market (0.0311). This means that the UK ETS was slightly less price efficient than the EU ETS over this period. There was also more variability in the predictability of returns in the UK ETS secondary market.

The ‘signal’ to ‘signal plus noise’ ratio was estimated over a longer time period, from December 2021 to September 2023. When the ‘signal’ to ‘signal plus noise’ ratio is relatively high, it indicates a relatively low level of noise during the trading interval, with price changes primarily influenced by the integration of new information. The UK ETS market was found to have slightly higher levels of noise than the EU ETS which implied slightly worse price efficiency. Over the working day, the ‘signal’ to ‘signal plus noise’ ratio for the UK ETS varied from 0.0889 to 0.5040 while for the EU ETS it varied from 0.9362 to 0.5954. For both markets, the ratio was highest in the morning, over this time period, implying that more market information was incorporated into trading during the morning than the afternoon of the trading day. Theoretically, in a perfectly efficient market, the ’signal’ to ‘signal plus noise’ ratio would be consistent throughout the trading day, but the decline over the day observed for the UK ETS was similar to that observed for the EU ETS.

Further details of the analysis of price efficiency in the UK ETS secondary market are presented in Annex 4.

Liquidity of the UK ETS secondary market

Market liquidity is relevant to whether transactions in the secondary market can be executed promptly without generating significant or enduring price impacts. The literature review (see Annex 3) identified five dimensions of market liquidity: tightness, depth, immediacy, resilience and breadth. Tightness corresponds to the difference between the fundamental price and the transaction price, depth is the ability of the market to absorb quantities without their having a large effect on price, while immediacy is the speed of order execution. Resilience reflects the time it takes for prices to move back to equilibrium after a large trade, while breadth corresponds to the number of market participants who do not wield significant power.

The literature review found that the most widely used indicators of market liquidity typically rely on proxies derived from bid-ask spreads. These measures intuitively capture the probability that a trader will be able to execute a regular sized order quickly, at a fair price, and with little

or no price impact. This means that bid-ask spread measures capture at least three of the five dimensions of liquidity (namely the tightness, depth, and immediacy dimensions of liquidity). Resilience and breadth are also captured to some degree by bid-ask spread measures, but to a lesser extent than tightness, depth, and immediacy dimensions. The literature review recommended use of a low frequency liquidity measure (the Amihud (2002) price impact ratio[20]) to capture the resilience and depth dimensions of liquidity more fully (meaning the time it takes for prices to move back to equilibrium after a large trade). For further explanation of the metrics presented in this section, see the literature review in Annex 3 and the secondary market data analysis in Annex 4.

This section presents analysis of secondary market data based on the bid-ask spread and Amihud (2002) price impact ratio. Together with findings from qualitative research, the analysis covers all five dimensions of market liquidity.

Findings on the liquidity of the UK ETS market were mixed. Qualitative research found considerable concern about the liquidity of the UK ETS market amongst organisations involved in UKA trading. Some reported that they chose to limit the size of trades, or stagger trades over a long period, to avoid the risk of moving the market price in an unfavourable way or finding themselves unable to exit from a trading position.

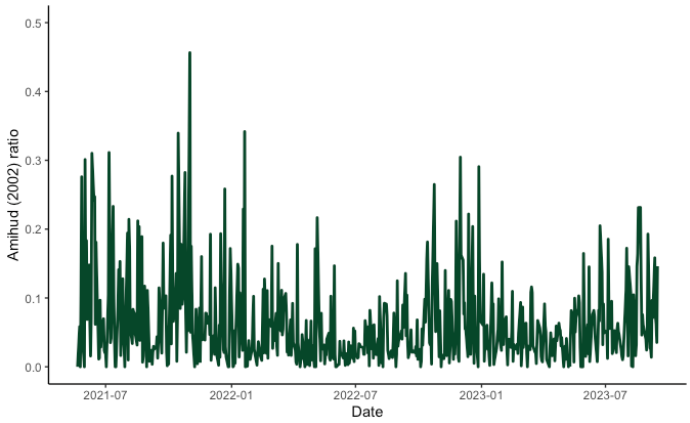
> *The bid offer, the volume on the bidding offer is pretty small, and if you try and lift an offer or get a bid, there isn't the depth of market that you have in the EUAs. So, if you went and bought 50 kt [50,000] of UKAs, you'd more than definitely move the market. (Trader)*

However, some traders and wider stakeholders commented that the UK ETS performed relatively well on liquidity, given its size, and that liquidity had improved over time. This was supported by the secondary market data analysis which found that, on the data currently available, the liquidity of the UK ETS had improved and was now reasonable given its size.

Secondary market data analysis included calculation of the Amihud price impact ratio, which is a measure of liquidity over a trading day and considers the influence of large trades which can potentially induce substantial price movements. The declining trend in the Amihud price ratio shows that liquidity was comparatively low during the initial stages of the UK ETS secondary market but has improved as the market has evolved and matured. The mean Amihud price impact ratio over the whole period was 0.063. This metric cannot be directly compared to the EU ETS scheme because of the different currencies used for the two schemes, combined with the lack of sufficiently detailed exchange rate data to enable currency conversion of ICE data. The decline in the Amihud price impact ratio suggests that the UK ETS market has become more capable of executing large orders, without triggering price changes, since the start of trading in May 2021.

[20] The Amihud (2002) price impact ratio is defined as an average ratio of the daily absolute return (in %) to the trading volume on that day (in £). See Annex 3 for further details.

Figure 10: Liquidity - Amihud price impact ratio (May 2021 to September 2023)

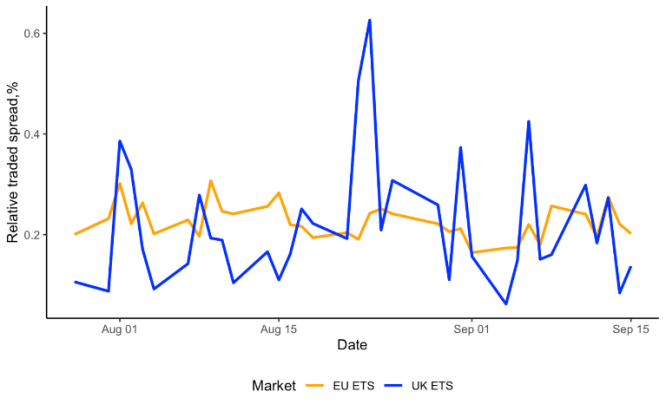


Source: secondary market data analysis, based on ICE data for December futures. The Amihud (2002) price impact ratio is defined as an average ratio of the daily absolute return (in %) to the trading volume on that day (in £).

More detailed analysis of liquidity was possible for the period July to September 2023, using bid-ask spread data from ICE for both the UK ETS and EU ETS. The literature review on carbon market quality identified a number of metrics based on this data, which are presented in more detail in Annex 3. This analysis focused on the mean and median relative traded spread which represents the cost of doing a complete trade (meaning buying and then selling, or vice versa) relative to the market price. These are robust measures of shorter-term liquidity, within the trading day, which can be calculated for both the UK ETS and EU ETS.

Detailed analysis showed that the mean relative traded spread was actually slightly lower (so liquidity was slightly higher) for the UK ETS than the EU ETS over July to September 2023 (0.2187 compared to 0.2252). The median relative traded spread for the UK ETS was noticeably lower (0.1833 compared to 0.2209), although there was considerably more variation in the spread within the UK ETS than the EU ETS. It is possible that traders' perception of poor liquidity is linked to variability in bid-ask spreads over time. Further analysis of this metric over longer time periods would be required to provide fuller interpretation.

Figure 11: Liquidity - relative traded spread (28 July to 15 September 2023)



Source: secondary market data analysis, based on ICE data for December futures. The relative traded spread is the difference between the best price of buyer-initiated trades and the best price of seller-initiated trades, divided by the average of these two prices (in %). Spread measures are calculated for 5-minute trading intervals and then averaged for each trading day.

Qualitative research suggested that some of the concerns about liquidity related to the early stages of the UK ETS, and that some related to trading in daily futures or 'spot' as opposed to December futures contracts. Trades from December futures to daily futures were used to provide ‘spot’ UKA for delivery to clients. One trader commented that, while the market for December futures was fairly liquid, the market for daily futures was not sufficiently liquid to support larger trades (for example 50,000 or 100,000 UKA). Where traders had clients wanting to buy large amounts of physical UKA for immediate delivery, to meet the client’s UKA procurement strategy, they therefore tended to buy at the fortnightly auctions rather than use daily futures.

Feedback on market design and processes

This section discusses feedback from qualitative research on auction and ICE processes, as well as on features of market design including the Auction Reserve Price (ARP) and Cost Containment Mechanism (CCM).

Auction process

The fortnightly UK ETS auction has worked smoothly, clearing close to, or slightly below, the secondary market price on almost all occasions. Auction volumes were varied during 2021 (being higher in the initial months and lower during the August holiday period). The auction partially cleared only once, on 6 October 2021, with unsold allowances being reallocated across the subsequent four auctions, all of which cleared fully. Volumes were fixed at 3.2 million UKA during the first 9 months of 2022, rising to 3.3 million UKA in the final auctions of 2022.[21]

As noted in the ‘auction use’ section above, auction participation was restricted to certain types of organisations and auction registration was regarded as cumbersome by some operators/AOs and traders. This may have restricted auction participation.

Amongst participating operators/AOs and traders, the ICE auction platform was generally well received. There was one comment about the potentially confusing difference between the minimum lot size on the auction (500 UKA) and on ICE (1000 UKA), and a suggestion that ICE could helpfully publish more data on the auction (for example maximum and median bids, auction coverage ratio and so on), as EEX were reported to do for auctions of other products.

In qualitative interviews, a number of traders reported that they would like auctions to run more frequently (for example weekly). They reported greater trading activity just before and after auctions, as the secondary market anticipated or reacted to price discovery in the auction. So, they argued that more frequent auctions would improve price discovery and liquidity.

[21] UK ETS Authority (2023), Functioning of the UK carbon market. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1174408/functioning-of-the-uk-carbon-market.pdf

> *And then [liquidity is] worsened by having auctions only every two weeks. So you have less data and price formation that is coming from those primary auctions. (Wider stakeholder)*

Secondary market data analysis confirmed that trading volumes were on average nearly 30% higher in auction weeks over the period 1 December 2021 to 15 September 2023. Detailed analysis of liquidity measures found some reduction in liquidity in non-auction weeks compared to auction weeks, but these differences were not statistically significant over the period of analysis. The liquidity measures that were based on the bid-ask spread were calculated over a short time period (28 July to 15 September 2023), so analysis over a longer time period would be required to confirm this finding.

ICE commented that the auction frequency had been chosen based on consultation with potential users, and that auction volumes of 2 million UKA to 3 million UKA were required to attract interest from auction participants, with the implication that more frequent auctions might be too small to attract interest.

Auction Reserve Price

At the time of the research, in June/July 2023, the Auction Reserve Price (£22/tonne) was well below the prevailing market price. Most operators/AOs and traders commented that the ARP was irrelevant because prices, up to that point, had remained well above £22/tonne and the ARP had not actually taken effect. However, the UKA price declined to £34/tonne on 21 September 2023 and it is possible that this may have affected operator views since the research.

Some traders commented that the UK ETS Authority should choose the level of the ARP to support UK ETS decarbonisation objectives, rather than basing it on historic secondary market prices. They thought that the ARP looked low and should be reviewed upwards if the UK ETS Authority was serious about incentivising decarbonisation. The California ‘Cap and Trade’ scheme was referenced as a scheme where the floor price increased at 5% plus inflation each year, contributing to increased trader confidence in the long-term direction of price movements.

Cost Containment Mechanism

The Cost Containment Mechanism is designed to address major, sharp increases in UK ETS prices. It is triggered when UKA prices rise significantly relative to recent prices. When triggered, the UK ETS Authority has a choice about whether and how to intervene in the market. The CCM was triggered on two occasions, in December 2021 and January 2022.

There was recognition amongst some traders that some form of mechanism was needed to protect the market against exceptional price movements. Some traders expressed concern about the discretionary nature of the CCM, in terms of UK ETS Authority having discretion about how and whether to intervene in the market when the CCM was triggered. They expressed concern that leaving the intervention decision to ‘judgement’ caused uncertainty that was not good for the UK ETS market or for companies that were potentially making investments to meet net zero targets.

There was some comment that triggering of the CCM in 2021 and 2022 arose because of flaws in how the CCM was specified, with calculations treating the price of UKA as zero between 1 January 2021 (when the scheme opened) and 19 May 2021 (when trading started). It was suggested that the CCM might not have been triggered if the CCM had been designed to use the EUA price during this period, as it did for the period prior to January 2021.

There were mixed views on the UK ETS Authority's decision not to intervene in the market when the CCM was triggered in December 2021 and January 2022. Some operator interviewees thought that the UK ETS Authority should have intervened to reduce prices but others welcomed high carbon prices as drivers of decarbonisation investment. Generally, heavy industry operators thought that the UK ETS Authority should have intervened by issuing more allowances to keep UKA prices lower. They wanted UKA prices to be close to EUA prices, to avoid movement of production or investment between the UK and Europe.

Some stakeholders (including some heavy industry operators and traders) reported that they could understand the UK ETS Authority's rationale for not intervening (for example because prices were on a downward trajectory or because prices reflected the fundamentals of the market at the time). However, these stakeholders also commented that the CCM, if interpreted this way, was unlikely ever to prompt intervention, even if it was triggered. There was also comment that, at this early stage of UK ETS development, intervening could have set a precedent for UK ETS Authority intervention in the market, which would have been unattractive to traders (particularly speculators).

There was general recognition that the CCM would only be triggered in the near future if prices rose to £200-300/tonne or more, which looked unlikely at the time of the research. This made the CCM seem irrelevant to many operators/AOs and traders going forward. Some operators/AOs would like to see a more sensitive mechanism that was designed to keep UK ETS prices in check if they rose to levels that put the competitiveness of UK industry at risk (for example if they rose too high relative to EU ETS prices).

ICE process

Registering to use the ICE platform was reported to be quite complex. Firms wanting to trade on the platform needed to find an 'ICE clearing partner' to handle their financial transactions. This was reported to involve significant costs and the provision of financial information, as clearing partners wanted to minimise the risk of default.

This process was easier for firms that were already members of ICE (for example because they traded in other products) and that simply wanted to add UK ETS to their trading portfolio. It was also easier for firms that were part of large financial institutions that were themselves clearing members of ICE.

Aside from concerns about liquidity, detailed above, other minor comments about the ICE platform included:

- A trader commented that it would be helpful to be able to specify 'all or nothing' trades on the platform, as done on the EEX platform. This would enable them to specify that

they want to fulfil a large transaction at a single price – at present this type of 'block trade' often has to be coordinated between brokers outside the platform.

- A broker commented that the difference in settlement terms between ICE (a few days) and operator settlement arrangements (which could be much longer, up to 30 days) could cause cashflow problems for brokers.
- Another trader commented that they would like to see more frequent uploading of trading positions on the ICE platform – these trading positions are published to meet financial regulations (for example MiFID[22]).

Process for OTC Trades

As noted earlier in this section, many operators/AOs bought physical UKAs, forwards or swaps from brokers or market makers outside ICE, for reasons explained in the section above on Over the Counter (OTC) trading'. Interviewees did not flag any problems with OTC trading and did not make any suggestions for improvement.

Risks to market quality and stability

When asked about threats to market function and stability, interviewees in the qualitative research often referred back to comments regarding liquidity, volatility and the inability to predict prices forward.

Aside from these risks, the major source of market uncertainty was reported to be government policy. This was widely reported as a threat to the scheme by operators/AOs and traders interviewed for qualitative research. One concern was that carbon markets, being a creation of policy, were highly vulnerable to changes in the political priorities of government.

> *So if there's a change in policy, a new government gets voted in, and let's say it's easy to disband the programme, that's a huge programme risk. If it's politically unpopular, if prices go to £1,000 per metric ton and no-one can fill up their [electric] car, it becomes politically unpopular, it's pretty easy for politicians to say, "Let's get rid of this thing." (Trader)*

Interviewees noted that there was more policy certainty in the EU ETS, because the nature of decision making in the EU means that it was more difficult to change tack once a policy has been agreed.

Operator interviewees stressed the long-term nature of business planning cycles and the importance of a predictable policy environment in determining whether investment happens at all or, in the case of multinational companies, whether it happens in the UK.

Other potential risks cited in the qualitative research included:

[22] The Markets in Financial Instruments Directive (2014) is EU legislation commonly known as MiFID 2.

- The risk that the phased transition to the net zero consistent cap would, in the first few years at least, lead to an oversupply of allowances, and that this would make the market less attractive to traders (particularly speculators).
- The introduction of Carbon Border Adjustment Mechanism (CBAM) in the EU which would add to the regulatory burden of exporting products from the UK, particularly for electricity (which might result in interconnectors being used less effectively). The CBAM is a new initiative introduced by the EU in 2023 which adjusts the prices of imports if they have been produced under jurisdictions with lower carbon prices or regulation. The UK government has also consulted on a potential CBAM[23].
- Potential use of algorithmic trading in a relatively small market such as the UK ETS.

Algorithmic trading is computer-led trading which uses mathematical rules to determine trading decisions (based on market patterns or differentials between markets), potentially involving very short-term trades. The evaluation research did not find evidence of algorithmic trading in the UK ETS so this appeared to be stated as a hypothetical risk. It was suggested by some interviewees that algorithmic trading should be banned in the UK market, because the small market size would make it easier to influence prices.

How could market performance be improved?

There was one overarching suggestion from operators/AOs and traders on how the performance of the UK ETS market could be improved. This was potential linkage between the UK ETS and the EU ETS, both to increase liquidity and to improve alignment of industry competitiveness in the UK and EU economies. Linkage between the EU ETS and Swiss ETS was cited as an example.

Further suggestions to improve liquidity, based on the evidence presented above, would be:

- Making it easier for operators/AOs and traders to access auctions and the ICE platform, thereby encouraging more active trading by operators/AOs and traders.
- Encouraging more market makers to participate in the UK ETS, as important contributors of liquidity.

Other suggestions from interviewees, outlined earlier in this section, were:

- Reviewing auction frequency, including consideration of whether more frequent auctions would improve liquidity.
- Reviewing the design of the ARP, including consideration of a stronger ARP.
- Reviewing the design of the CCM, including consideration of a more sensitive stability mechanism.
- Considering a ban on algorithmic trading, given the relatively small size of the UK ETS.

[23] https://www.gov.uk/government/consultations/addressing-carbon-leakage-risk-to-support-decarbonisation

- Considering how EU ETS CBAMs will affect the UK ETS.
- Reviewing whether current market weakness is a concern (in the light of traders' perception of oversupply of UKA during the transition to a net zero consistent cap).

These points are presented as suggestions from interviewees rather than as recommendations from the evaluation to the UK ETS Authority.

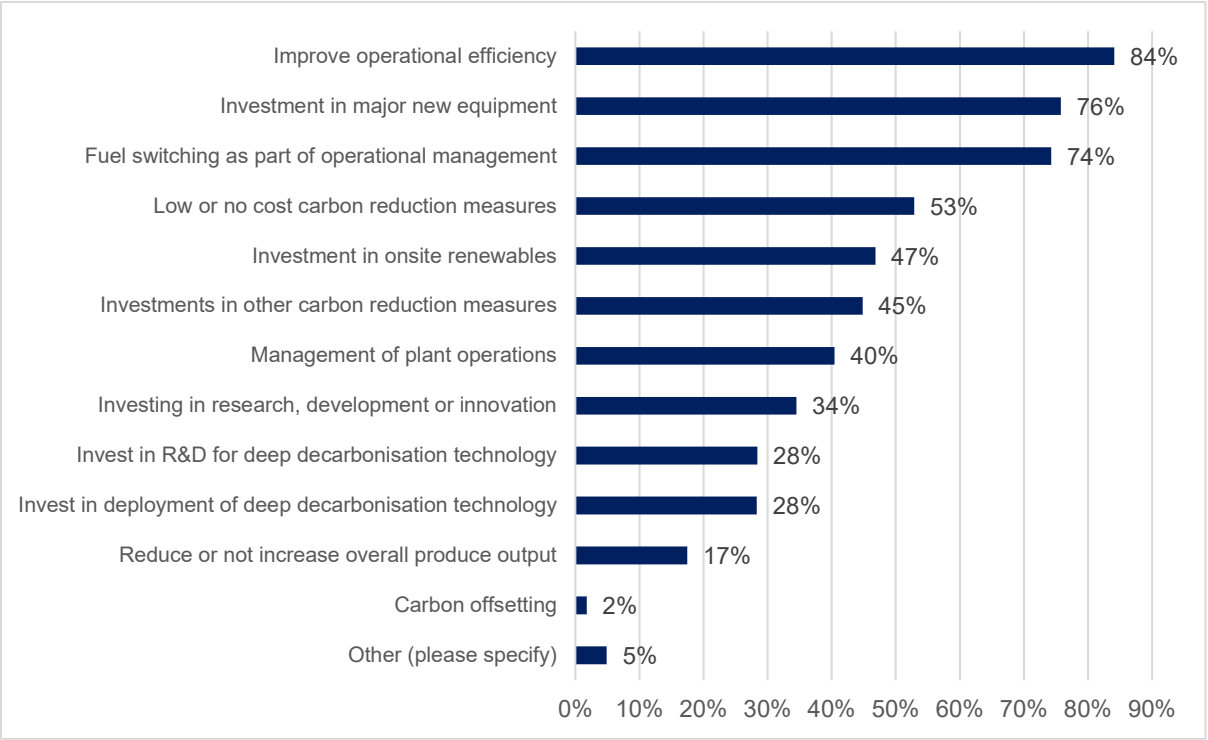
Chapter 6. Is UK ETS influencing abatement, and if so how? (Early findings)

This chapter presents evaluation findings on GHG emissions abatement behaviour by operators/AOs and the influence of the UK ETS on this behaviour, providing early insights to evaluation question C1. These findings are based on reported behaviour and views from qualitative and quantitative research. An objective assessment of UK ETS impact on abatement, based on energy and carbon data, will be undertaken in phase 2 of the evaluation. Early findings were that most UK ETS operators/AOs were actively planning to reduce GHG emissions, with differing levels of influence from the UK ETS.

Overview of abatement behaviour and UK ETS influence

The majority of operators/AOs in the quantitative survey (90%) reported having a plan to reduce carbon emissions, though 9% said they did not have one and 1% were unsure (n=184). As shown in Figure 12, most plans to reduce carbon emissions involved actions to improve operational efficiency (84%), investment in major new equipment (76%) and fuel switching (74%). By contrast, the least commonly cited types of measures were investment in deep decarbonisation technologies (28%), and to reduce or not increase overall produce output (17%). Variations between sectors are covered below in the section on 'Abatement by sector'.

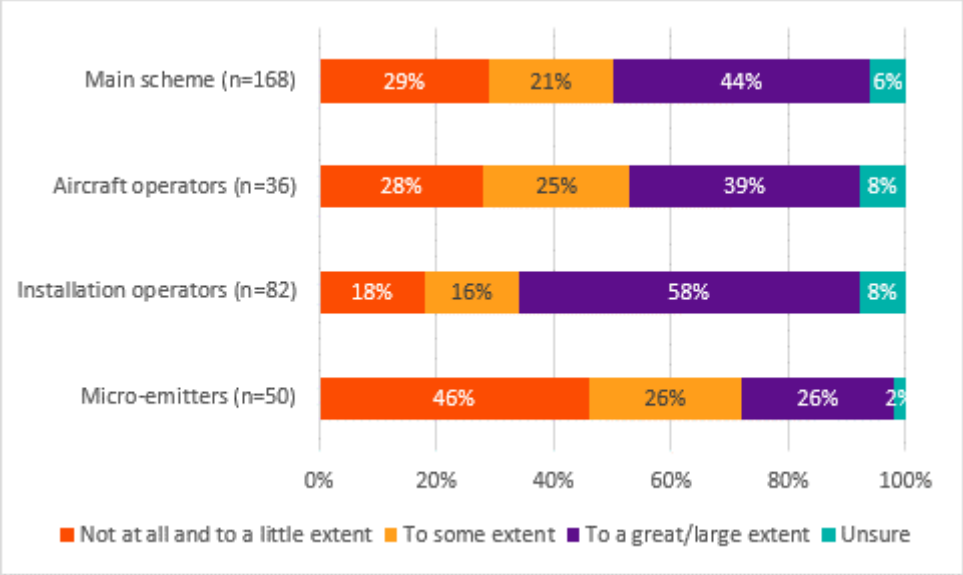
Figure 12: What types of actions do these plans to reduce carbon emissions involve? (multiple responses allowed, all participants with a plan to reduce emissions, n=184)



Source: quantitative survey with main scheme operators/AOs that had a plan to reduce emissions (including quantitative responses from qualitative sample).

The quantitative survey found that 44% of main scheme operators/AOs reported that the UK ETS influenced their awareness of carbon reduction opportunities to a 'great' or 'large' extent (n=168). As shown in Figure 13, the proportion of operators reporting influence was greater for installation operators (58%, n=82) than for AOs (39%, n=36) but this difference was not statistically significant. Micro-emitters (below 1,000 tCO2e covered by the UK ETS in 2022; n=50) were the least likely to acknowledge UK ETS' influence (with 26% acknowledging influence to a 'great' or 'large' extent): their difference with other operators/AOs was statistically significant.

Figure 13: To what extent has your awareness of carbon reduction opportunities been influenced by the UK ETS? (all main scheme participants, including breakdown into aviation, installations and micro-emitters)



Source: quantitative survey with UK ETS main scheme operators/AOs. Main scheme figures comprise aircraft operators, installation operators and micro-emitters.
(This question was not included in quantitative responses from the qualitative sample.)

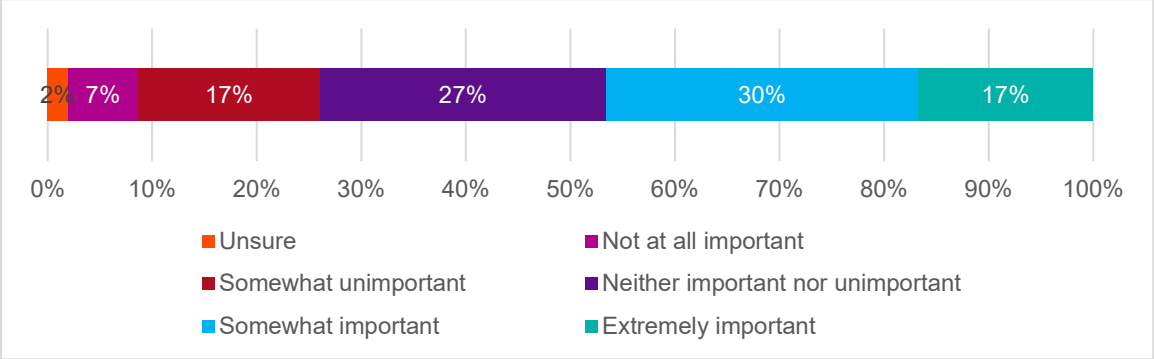
Installation operators were more likely to acknowledge that the cost of UKAs influenced decarbonisation investment, with around six in ten installation operators (62%, n=105) saying that the cost of UKAs had influenced their organisations to increase decarbonisation investment in their UK plants, equipment or machinery. Only one in five AOs (20%, n=78) said that the cost of UKAs had influenced their organisation to increase decarbonisation investment in new aircraft or aircraft upgrades[24]. This is consistent with qualitative interview findings on the limited availability of cost-effective decarbonisation options for AOs. With regards to decarbonisation investment in research and development, about two thirds of operators/AOs (67%, n=175) said there had been no influence of the cost of the UKAs.

Where operators/AOs acknowledged that the cost of UKAs had influenced decarbonisation investment, about half the operators/AOs in the quantitative survey reported that the cost of

[24] The survey question did not ask about investment in SAF facilities, where the cost of UKA or EUA might have shown greater influence.

UKAs had an important influence on increasing decarbonisation investment (47%), while 24% considered it unimportant relative to other factors and 27% considered it 'somewhat unimportant' (n=99).

Figure 14: How important was the cost of UKAs in influencing your organisation to increase decarbonisation investment? (all main scheme participants acknowledging UKA cost influence; n=99)



Source: quantitative survey (all main scheme participants acknowledging UKA cost influence).
(This question was not included in quantitative responses from the qualitative sample.)

Abatement by sector

Abatement behaviour was assessed across different industry sectors, namely aviation and three installation sectors (namely power generation, heavy industry and other industry). Abatement behaviour for each of these high level sectors is summarised below.

Aviation sector abatement

AOs ranged from micro-emitters (less than 1,000 tCO2e per annum covered by the UK ETS) to very large emitters (above 500,000 tCO2e per annum). Micro-emitters are not included in the analysis below, as their total emissions are low. Aviation firms that participated in the qualitative interviews mostly had emissions exceeding 500,000 tCO2e per annum. Most of the very large emitting aviation firms (above 500,000 tCO2e per annum) had free allowances covering 50% to 75% of their emissions. This report uses emissions figures from 2022, when aviation activity was still influenced by COVID: it is likely that aviation emissions will exceed free allocation levels in future.

Abatement behaviour

The survey found that 84% of AOs were already reducing emissions through improvement of their current operations (n=184). Qualitative research found that these activities included reduced taxiing[25], flying with the lowest possible additional fuel volumes and recoating planes to reduce drag, amongst other interventions.

[25] Taxiing means moving the aircraft on the ground, under its own power.

Most (81%) AOs reported in the quantitative survey that their carbon abatement plans included fuel switching (n=39). Qualitative interviews indicated that AOs were referring to planned use of SAF. The EA advised that SAF is generally blended with conventional fuel, so use of SAF does not necessarily involve full switching away from fossil fuels.

Several respondents in the qualitative interviews reported fleet renewal as part of their overall emission reduction strategy. For example, one firm noted that their new aircraft would have a 20% per person lower fuel burn.

All the very large emitting aviation firms (above 500,000 tCO2e per annum) in the qualitative interviews noted they were already investing or researching long-term abatement options. This investment was mostly linked to SAF facilities, but there was also research in hydrogen-based short haul flights. Several smaller aviation firms noted that the only viable long-term abatement solution for the sector was SAF, but these smaller firms were typically not actively investing in long-term abatement options.

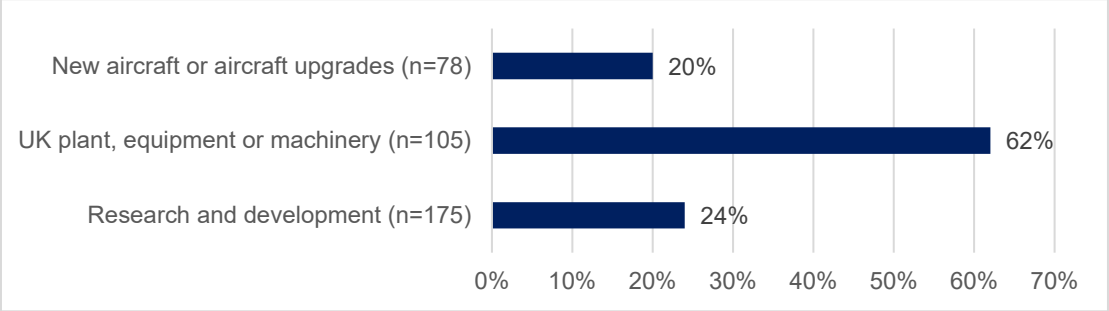
The aviation sector differed from other sectors in their approach to offsets. Many AOs noted in qualitative research that they used offsets as part of their overall abatement strategy despite these not being accounted for in the UK ETS. In some cases, these included planned compliance with offsetting requirements on international flights under CORSIA, as well as voluntarily offsetting of flight emissions.

Degree of UK ETS influence

As noted in Figure 13 above, 39% of AOs reported that the UK ETS influenced their awareness of carbon abatement options to a great or large extent, with a further 25% reporting influence to some extent (n=36). This was lower than UK ETS influence on installation operators, possibly because of the ongoing influence of the EU ETS on AOs that were operating flights within the scope of the EU ETS, and – for some AOs – because of the low proportion of their total aircraft emissions that were within the scope of the UK ETS.

Only one in five AOs (20%) in the quantitative survey said that the cost of UKAs had influenced their organisation to increase decarbonisation investment in new aircraft or aircraft upgrades (n=78). As shown in Figure 15, this low level of influence contrasted with installation emitters, where a much higher proportion (62%) of respondents noted that the cost of UKA had influenced their abatement investment decisions (n=105).

Figure 15:Thinking about the cost of UKAs, would you say that the cost of the UKAs has influenced your organisation to increase decarbonisation investment in... (% yes; all main scheme participants)



Source: quantitative survey with all main scheme participants.
(This question was not included in quantitative responses from the qualitative sample.)

However, most aviation firms in the qualitative research noted that both the UK ETS and EU ETS helped to make the business case for investment in abatement. Some respondents also noted that the UK ETS was a driver in investment of new and improved fleet, but that it was a minor influence compared to other drivers such as fuel cost, corporate net zero commitments and customers' environmental attitudes. The difference between the qualitative and quantitative research results regarding the influence of the UK ETS on abatement could be attributed to the fact that the qualitative research explored investment options beyond fleet upgrades, with interviewees highlighting SAF as a key abatement solution for the sector.

AOs pointed out that there were greater incentives for SAF use within the EU ETS than in the UK ETS, including ringfencing of EUA revenues for SAF investment. Some AOs also reported that the EU ETS took SAF into account in free allocations but this was not substantiated because free allocations for aviation are being phased out in both the EU ETS and UK ETS. Some AOs were concerned that EU ETS support for SAF could lead to distortion of SAF use in the UK and could dampen appetite for SAF supply investments in the UK.

> *The EU ETS is driving up quite a lot of great demand and investment in SAF, through how they are allocating free allowances and how they're going to be using the ETS scheme to subsidise it. That's not forthcoming at the moment with the UK scheme. (Aircraft operator)*

Power sector abatement

This sector comprised a small number of very large power companies, with multiple sites, together with some smaller operators (for example peaking plants). Most but not all of the power operators interviewed in the qualitative research had very large total emissions (above 500,000 tCO2e per annum). Very few power operators had any free allowance allocation, except where non-power generation activities were undertaken on their sites, and none of the firms that participated in the qualitative research had any free allowances.

Abatement behaviour

The power generation sector was the only sector where the abatement behaviour of frequently changing operations (day-to-day or hourly) was evident. This frequent abatement behaviour

was reported by very high emitters (above 500,000 tCO2e per annum). The power generation sector also had the highest number of respondents in the qualitative interviews indicating they were already investing in future abatement solutions. These future abatement solutions included actively investing in renewable energy such as offshore wind and innovative technologies such as building hydrogen electrolysers. Many respondents also noted investment in research in CCUS and hydrogen. Realising the financial feasibility of fuel switches to biofuels, bio-oils and hydrogen was often noted as key to achieving future abatement targets.

Degree of UK ETS influence

As with other sectors, the UK ETS had a range of influence on abatement decisions. However, the power generation sector was the only sector where some interviewees noted that the UK ETS was a key factor in daily operational decisions. For example, some power operators would consider the cost of the UK ETS (on an hourly basis) in deciding whether it would be cheaper to run their plants or buy electricity on the market. Respondents also often noted that they were able to pass UK ETS costs directly onto their customers.

Other drivers of abatement in the power sector included pressure from investors, access to subsidies, financial support mechanisms, net zero targets and public perception.

> *Everything sends a signal to you. And so, everyone is factoring in, right, what's the risk of it being this price, and nobody is operating within a world of blind to net zero. So, of course, directionally, everybody knows where they're going. It's just when. (Power sector operator)*

As with the other industries sector, in some instances, the UK ETS was helping to build a business case for abatement, but in others it had the potential to reduce funds available for investment.

Heavy industry sector abatement

The heavy industry sector included operators in the cement, chemicals, distribution of gas, iron and steel, oil and gas, refining and processing of nuclear fuel sectors. Most of the installations had emissions exceeding 50,000 tCO2e per annum. Within the smaller sample of firms that took part in the qualitative research, most had emissions exceeding 500,000 tCO2e per annum. There was a wide range of free allocation across these industries, from 0% to over 100%. A few operators in the heavy industry sector had surplus allowances, at least in the short term, because of reductions in production levels.

Abatement behaviour

A wide range of abatement behaviours were observed in these sectors except for the behaviour where day to day operations were adjusted. Most firms in this sector were actively engaged in current abatement activities (for example, fuel switching, on-site renewables and reducing flaring). However, long-term investment in future abatement options was less common, with only one qualitative interviewee in the cement sector noting they were actively

investing in future abatement solutions. Most other firms were still researching long-term abatement options.

The viability and availability of CCUS infrastructure was noted by many heavy industry representatives as a key component needed for future abatement solutions. The CCUS Cluster Sequencing programme[26] involves government support for net zero infrastructure (including CCUS and hydrogen) in a number of geographical clusters of energy intensive industry (for example the HyNet cluster in North West England and the East Coast cluster). Being part of an industrial cluster that was receiving government support for CCUS or hydrogen technology, or – conversely - concern about not being part of a geographical cluster, was highlighted as a key driver/barrier for long-term abatement investment.

Degree of UK ETS influence

As shown in Figure 13, about half (58%) of installation operators reported that the UK ETS had influenced their awareness of carbon reduction opportunities to a great or large extent (n=82). Similarly, as noted above, the results from the quantitative survey found that around six in ten installation operators (62% n=105) said that the cost of UKAs had influenced their organisations to increase decarbonisation investment in their UK plants, equipment or machinery. The results from the qualitative assessment supported this finding, with respondents from firms with high energy input-related emissions (specifically in the iron and steel, oil and gas, and refining sectors) noting that the UK ETS and EU ETS played some or a significant role in their abatement investment decisions.

Interviewees across the heavy industry sector reported varying degrees of influence on the sector's approach to abatement. For some firms, it was a central component in their decision-making process, while for others, it had a more moderate impact. In certain cases, the UK ETS was viewed merely as a tax, and for one firm it acted as a deterrent to reopening a plant. Additionally, representatives from the cement industry expressed concerns about the potential risk posed by the UK ETS on the future viability of their businesses and increasing the potential to move production outside the UK (see discussion of carbon leakage risks in chapter 7).

Other industry sector abatement

The ‘other industry’ sector included operators from the food and drink, non-metallic minerals, non-ferrous metals, paper and pulp and other sectors (including combined heat and power). Installations showed a range of emission levels but mostly had emissions between 2,500 and 50,000 tCO2e per annum. Most firms had some level of free allowances, most frequently in the range of 0% to 25% allocation of their total emissions.

Abatement behaviour

All respondents in the qualitative research interviews from the other industry sector noted they were currently conducting or investing in abatement activities. These activities included heat recovery, fuel switching and energy efficiency amongst others. Interview respondents from the

[26] https://www.gov.uk/government/publications/cluster-sequencing-for-carbon-capture-usage-and-storage-ccus-deployment-phase-2

food and drink and other industries categories reported that they were actively investing in future abatement. These firms all had emissions in the range 25,000 to 50,000 tCO2e per annum.

Several firms noted they were locked into technologies they had invested in previously (for example kilns and combined heat and power plants). Many firms also noted a number of barriers outside their control in moving away from fossil fuels like natural gas. These barriers included the availability of hydrogen as well as the capacity and process to access the local electricity grid.

Degree of UK ETS influence

Many firms across the other industry sector noted that abatement was being driven by factors other than the UK ETS. For example, corporate leadership and the price of gas were often noted as key drivers in abatement decisions. Return on investment (ROI) was noted by several qualitative research respondents as the key driver of abatement decisions, with respondents commenting that the UK ETS could have a negative or positive impact on the ROI. For example, in some instances, the UK ETS reduced the likelihood of securing internal funding as it would be more cost effective to invest in locations outside the UK. However, in other instances, respondents noted that the UK ETS price helped to make the business case for investment. One firm noted the ability to trade free allowances was a key factor in keeping the business viable, as well as providing the opportunity to invest in abatement technologies.

> *"Has the UK ETS, the EU ETS worked?" I would say it has, because we've got a kiln on site now. (Other industry operator).*

The types of abatement behaviours observed, and the reasons for different levels of UK ETS influence, are explored further through qualitative findings below. The characterisation of abatement behaviour presented below is based on realist analysis of qualitative interviews which focused primarily on large emitters (above 50,000 tCO2e per annum).

Characterisation of abatement behaviour

During the qualitative interviews, which focused primarily on high emitters (above 50,000 tCO2e per annum), representatives of operators/AOs were asked to describe their current and future abatement activities in more detail, as well as explain their reasoning for this behaviour and the influence of the UK ETS on these abatement activities. Based on the responses from these interviews, realist analysis was used to group operators/AOs into seven mutually exclusive abatement behaviour categories. Further detail of this analysis is presented in Annex 2. In summary, the main types of abatement behaviour observed in qualitative research were as follows:

- **Undertaking current abatement and researching future options:** operators/AOs that had previously implemented emissions reduction activities and were continuing to do so. They were in the process of identifying viable and feasible future abatement options but

had not yet invested in any meaningful way in these solutions. Levels of UK ETS influence varied.

- **Undertaking both current and future abatement:** operators/AOs that had already invested in abatement options and were actively investing in future abatement interventions, with varying levels of UK ETS influence. These companies were diverse in terms of size, sector, allocation of free allowances and overall emissions, but demonstrated a clear commitment to present and future decarbonisation.
- **Adjusting operations frequently (for example daily) as part of abatement:** operators that were changing their daily or hourly operations, partly in response to UK ETS costs. These operators in the power sector were constantly assessing market conditions and deciding whether it was more affordable to run their plants, change fuel source or buy electricity on the open market.
- **Undertaking current abatement but not yet long-term abatement:** operators/AOs that were currently reducing emissions but had no intention of implementing significant future abatement solutions. These firms were constrained by the amount of control they had over future investment decisions.
- **Not undertaking or planning any abatement:** operators/AOs that were not abating their emissions in any meaningful way and were not intending to implement any large-scale abatement solutions.
- **Not undertaking any abatement at present, but considering possible future options:** operators/AOs that were not currently implementing abatement activities but with potential for future abatement if technical and financial barriers could be overcome.
- **Abatement through closure**: operators that saw significant reduction in GHG emissions resulting from part or full closure of one of their plants, exacerbated by UK ETS costs.

Among these categories, the most prevalent behaviour observed in qualitative research involved organisations that were both implementing current abatement measures and were engaged in researching future abatement options. The second most frequent behaviour category consisted of companies actively reducing current emissions while also making tangible investments in future abatement solutions. Within both these common behaviour types there were variations in terms of how significantly the UK ETS influenced abatement decisions.

Although the qualitative sample focused primarily on high emitters (above 50,000 tCO2e per annum), the quantitative survey which was representative of all main scheme operators/AOs also found that most operators/AOs (58%) had plans to reduce carbon emissions that included long-term actions, beyond 2030 (n=184).

While ‘frequent abatement’ was observed only for large power sector operators in the qualitative sample, this was nevertheless important because these operators had very high emissions. The final four behavioural patterns listed above were less commonly observed in the qualitative research, with only a subset of companies exhibiting these less frequent activities. As the qualitative research focused primarily on high emitters, these behaviour patterns may be more prevalent in the main scheme population as a whole.

Other drivers for abatement

No interviewees in the qualitative research identified one single factor as driving their abatement efforts. Rather, there were multiple drivers influencing both current and future abatement strategies, with the UK ETS influence seen within the context of other drivers. Some of these other drivers were more prevalent in specific sectors. For example, in the aviation sector, the cost of fuel and customer pressure were frequently cited as key abatement drivers.

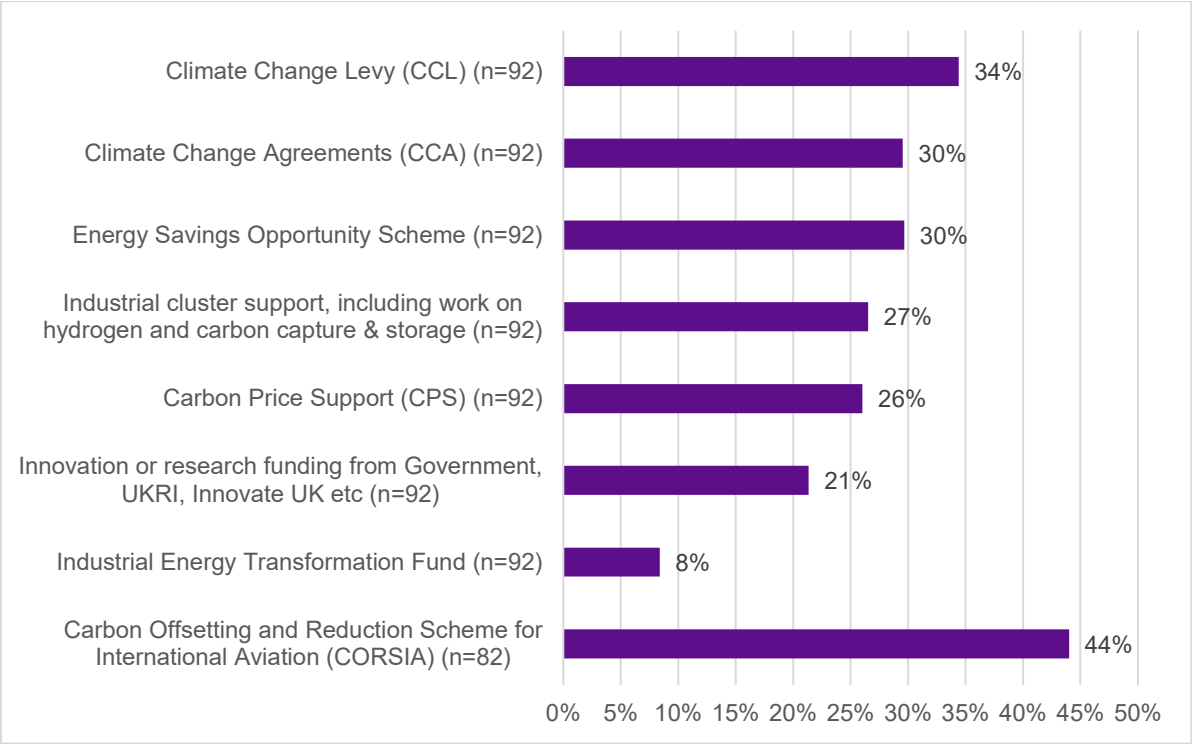
Representatives from the heavy industry sector noted investor pressure as a significant motivator, although customer pressure and energy costs were also important. Some heavy industry representatives indicated that the drivers were continually evolving, with carbon recently becoming a more significant driver than energy costs. In many of the 'other industry' sectors, internal leadership and a broader ESG (Environmental, Social, and Governance) agenda were reported to be key drivers. Comments such as *"it's the right thing to do"* and *"the company wanting to be a good citizen"* were commonly mentioned.

Representatives from the power generation sector highlighted various stakeholder related drivers, including customer demand for low-carbon energy options, increased public and NGO pressure, and investor demands. Additionally, the power sector identified other policies and regulations, such as Medium Combustion Plant Directive (MCPD) permits, as strong influences on abatement activities.

The influence of other policies was also highlighted in the quantitative survey. With regards to policies that were applicable to installation operators (n=92), the Climate Change Levy was reported to exert the most influence (34%), followed by the Climate Change Agreements (CCA; 31%). Around 1 in 4 (44%) of big installation emitters (more than 50,000 tCO2e per annum, n=37) said that their decisions about carbon reduction opportunities had been affected by industrial cluster support, compared to 27% of installation operators overall.

With regards to policies applicable to AOs (n=82), 44% of respondents acknowledged the current or future influence of CORSIA. However, respondents in the qualitative research interviews noted that CORSIA is currently less influential in driving abatement behaviour than the EU ETS or UK ETS.

Figure 16: To what extent has your awareness of carbon reduction opportunities been influenced by the following policies? (% to a great extent & somewhat; all main scheme participants)



Source: quantitative research with main scheme participants (including installation, aviation and micro-emitters). (This question was not included in quantitative responses from the qualitative sample.)

Remaining barriers to abatement

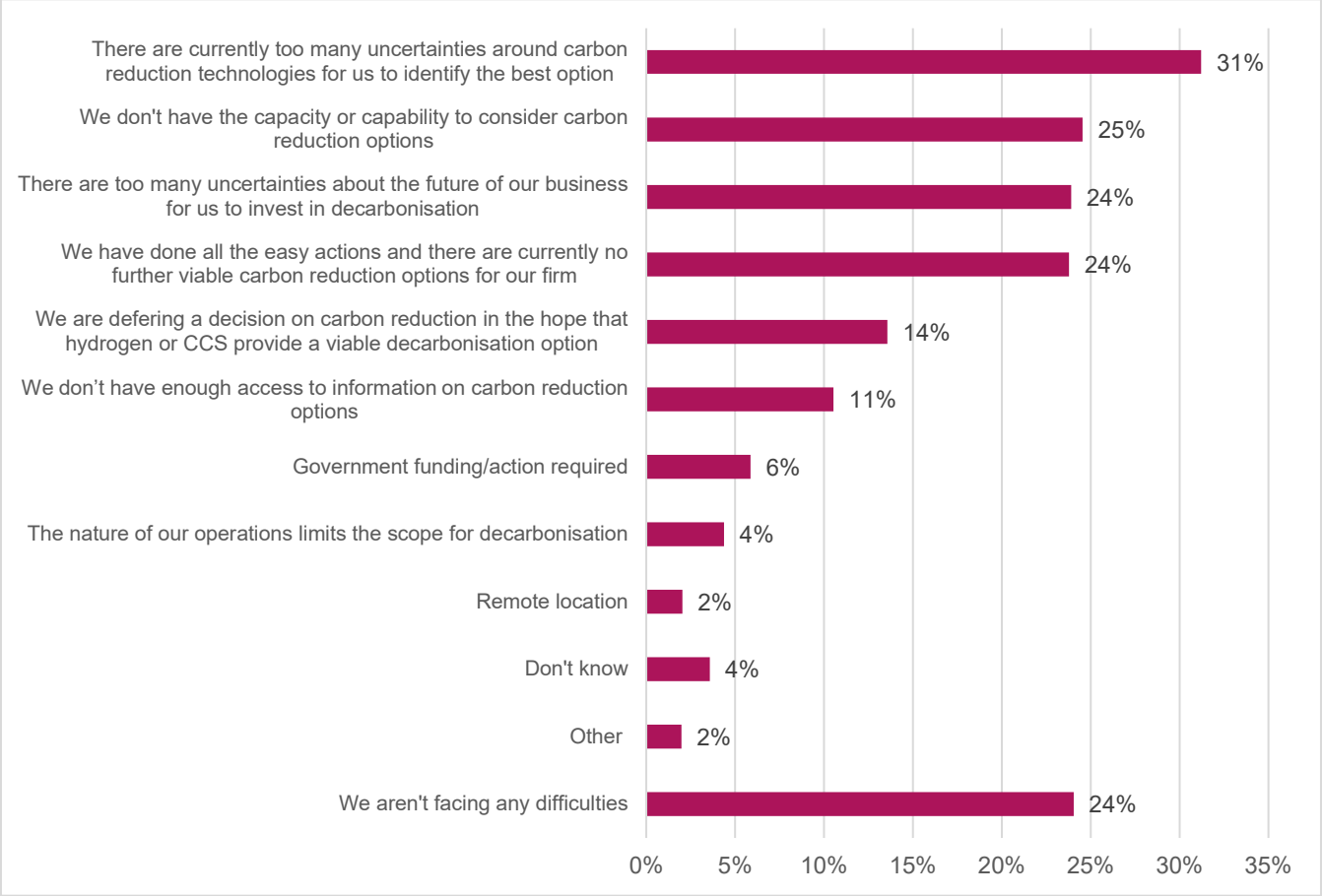
As with drivers of abatement, there were also a range of barriers to carbon abatement across different sectors. When asked about difficulties encountered in the process of reducing carbon emissions, the most commonly cited difficulties in the quantitative survey were uncertainties around carbon reduction technologies (31%, n=183). This barrier was specifically noted during the qualitative interviews with the aviation industry, with interviewees consistently remarking on the lack of technical abatement solutions for the sector (outside use of SAF and large-scale investment in SAF facilities). Similarly, many installation emitters highlighted the fact that the necessary technical solutions for large-scale abatement were still at the early stages of development.

> *Infrastructure for CCS and hydrogen has to go from nothing to everything in the next 12 years to meet UK target of carbon-free electricity by 2035. (Power sector operator)*

Many installation operators also noted that, over and above technical viability, access to future technical solutions was a potential barrier to abatement. These constraints included access to the local electricity grid, distance from CCUS infrastructure and the lack of hydrogen in sufficient volumes. Several respondents also noted the importance of being part of (or risk of not being part of) the UK industrial clusters as key in addressing access to the necessary future abatement infrastructure.

An additional barrier reported by operators/AOs in the quantitative survey was a lack of capacity or capability (25%, n=183). However, this capacity constraint was not specifically highlighted in the qualitative research interviews (which primarily focused on high emitters): where qualitative interviewees noted that when they had capacity constraints, they could mostly appoint external expertise. Other hurdles to abatement reported by operators/AOs in the quantitative survey (n=183) included the fact that all the easy options having already been taken up (24%), and uncertainties around the future of the organisation itself (24%).

Figure 17: Is your organisation facing any of the following difficulties in planning to reduce its carbon emissions? (multiple response allowed; all main scheme participants; n=183)



Source: quantitative research with main scheme participants (including installation, aviation and micro-emitters). (This question was not included in quantitative responses from the qualitative sample.)

How could abatement performance be improved?

Despite the barriers to implementing abatement measures, many companies across various sectors have already made significant strides in both low-cost and large-scale abatement interventions. To further encourage and optimise abatement, qualitative research interviewees from different sectors offered several policy suggestions for the future.

- **Increase in policy certainty**: several companies (particularly in the heavy industry sector) highlighted the importance of policy certainty, particularly given the long-term investment periods required for large-scale abatement interventions.

- **Increase investment in decarbonisation infrastructure:** many industry representatives highlighted that, to achieve their abatement targets, significant national infrastructure challenges needed to be overcome. This included increased access to CCUS and hydrogen pipelines as well as improved electricity grid access.
- **Recognise Greenhouse Gas Removal (GGR):** both the power and aviation sectors emphasised the need for including GGR technologies in the UK ETS. Extending the UK ETS to include GGR would create a stronger business case for investment in these technologies.
- **Increase availability of low carbon fuels:** many companies noted that the availability of low carbon energy needs to be significantly improved to allow for effective fuel and process switching. This low-carbon energy is needed across all sectors including aviation (for example SAF), installation operators (for example biofuels, biogas and renewable energy) and power generation (for example bio-oil and hydrogen). They reported that increasing the availability of low carbon fuels would also increase the viability of other technical solutions like CCUS.
- **Hypothecate UK ETS revenue for decarbonisation investment:** a recurring suggestion, particularly from the aviation sector, was the ring-fencing of revenue generated from the UK ETS to reinvest in decarbonisation initiatives. Respondents noted that ring-fenced revenue from the EU ETS was being invested in SAF research and production, which would likely make SAF more available in the EU in the future.
- **Create clear guidelines on methane emissions reduction:** finally, for the oil and gas sector, more clarity in communication and guidelines regarding the measurement and future reduction of methane emissions was reported to be essential for future planning and investment.

Chapter 7. Is the UK ETS influencing carbon leakage and having any unintended consequences? (Early findings)

This chapter sets out early findings on the extent to which the UK ETS contributes to carbon leakage risks for different sectors and on unintended consequences of the UK ETS, providing early insights in response to evaluation questions C2 and C3. Evidence on these topics is drawn primarily from qualitative research, primarily with larger emitters. A more objective assessment of UK ETS impact on carbon leakage, based on economic data, will be undertaken in phase 2 of the evaluation. Early findings were that carbon leakage risks were minimal for power generation and aviation, but significant for energy intensive industry (particularly for producers of internationally traded commodities)

What do we mean by carbon leakage?

The UK ETS Authority defines 'carbon leakage' as the movement of production and associated emissions from one country to another due to different levels of decarbonisation effort through carbon pricing and climate regulation. The UK ETS is designed to mitigate carbon leakage risks through increased free allocations to operators/AOs in sectors identified as being at risk. Sectoral risk factors include high levels of emissions intensity and high levels of trade in commodities produced by the sector.

Carbon pricing and climate regulation are part of wider considerations of 'competitiveness'. The perspective of international firms on the relative competitive positions of different jurisdictions may be affected by a large number of non-carbon factors including regime stability, security, location vis a vis markets and supply chains, costs of labour, energy and other inputs, energy security, policy certainty, availability of skills and expertise, tax regimes, investment incentives and wider social/environment/governance factors.

Under the definition used here, 'carbon leakage' is primarily attributable to differences in carbon pricing and climate regulation between the UK and other countries. Where levels of carbon pricing and regulation are broadly similar (for example between the UK and EU countries, subject to some variation over time), differences in competitiveness are not interpreted as carbon leakage.

Findings in this chapter are based primarily on qualitative research with larger emitters, with some contribution from the quantitative survey. These findings are tentative and may be open to 'lobbying bias'. Fuller assessment will be made in phase 2 of the evaluation, which will include objective analysis of UK ETS impact on economic activity.

A slightly different sector grouping was used to analyse carbon leakage risks, because of the competitive pressures on sectors producing commodities that are widely traded internationally.

The commodity production sectors were defined as a variant of 'heavy industry', comprising cement, chemicals, iron and steel, oil and gas but also including lime, ceramics and food-based commodities sometimes included in the 'other industry' group. The analysis below focuses on the aviation, power generation, commodity producer and remaining 'other industry' sectors.

What is the risk of carbon leakage in the aviation sector?

With a few exceptions, pass-through of UK ETS costs to customers was reported by most AOs. For some firms, this appeared to be a 'survival strategy' for firms operating in a highly competitive market with slim margins.

Flights from the UK by non-UK based airlines are also subject to the UK ETS, so AOs reported that the UK ETS did not directly distort competition for airlines flying the same route. However, some short-haul AOs reported price competition between long-haul AOs that could cross-subsidise prices against non-European flights (not subject to the UK or the EU ETS) and short-haul operators that could not cross-subsidise. The potential cost to long-haul flights of CORSIA compliance was reported to be smaller than the cost of UK ETS or EU ETS.

Some AOs reported that flight patterns, frequencies and routing may be affected by competition from flight destinations outside the UK and EU. In the quantitative survey, 23% of AOs reported that their carbon abatement plans included decisions about reducing or not increasing flight activity (n=39).

> *…short haul, low cost of travel in Europe is not going to be low cost anymore. Whereas if you're hopping in and out of Dubai, you can do bigger routes, longer routes, get people involved, and that's a significant amount of carbon leakage. (Aircraft operator)*

However, an independent study by Frontier Economics and Air Transportation Analytics[27], commissioned by the Department for Transport and Department for Business Energy and Industrial Strategy, found minimal risk of carbon leakage, based on the current scope of the UK ETS. The study undertook detailed quantitative research on the impacts of carbon pricing on UK aviation using a global aviation model. It found there was minimal risk of a trade-off between strengthening abatement incentives and reducing carbon leakage, under the current scope of the UK ETS, because of the symmetric nature of aviation itineraries (with the UK ETS incentivising carbon savings on flights out of the UK, and also potentially on the inward leg of these flights). This study did not project a large impact on the number of passengers transferring through UK hub airports because most of these passengers were travelling on intercontinental journeys for which the UK ETS had a small (or no) impact on costs.

Based on the objective analysis provided in the Frontier Economics report, this evaluation finds carbon leakage risks to be limited for the aviation sector, despite the views expressed by AOs.

[27] Frontier Economics and Air Transportation Analytics, (2022) Economic research on the impacts of carbon pricing on the UK aviation sector, Final report. https://www.frontier-economics.com/media/s1enxvsn/economic-research-on-the-impacts-of-carbon-pricing-on-the-uk-aviation-sector.pdf

There was recognition from airlines that free allowances for the aviation sector will decline in coming years, with some AOs commenting that this would impact their profitability. However, comments about free allowances also focused on the perceived unfairness of the historic baseline for the aviation free allocation entitlement (based on 2010/14 data) and the lack of an adequate mechanism to adjust free allocations in response to changes in activity by different AOs. Some aviation interviewees commented that removing free allocations for aviation would mean that UK AOs were on a level playing field with each other, even if not with AOs serving destinations outside the UK and EU.

What is the risk of carbon leakage in the power sector?

With a few exceptions, power sector operators reported using a 'cost plus' pricing model which involved passing costs on to customers, including the cost of carbon.

> *…the whole pricing of power would be incorporated into pricing methodology that we'd have for our customers. [..] So we would incorporate UKAs into that, as well as we would for anything with cost of production really. (Power sector operator)*

Imports and exports of electricity were reported to be constrained by the size of interconnectors between the UK and other countries. One operator commented that peaking generation was more at risk of competition via interconnectors.

The relative price of electricity in the UK versus the EU involved comparison of EUA prices to UKA prices plus Carbon Price Support (currently around £18/tonne). Provided that carbon pricing and climate regulation regimes in the UK and EU remain broadly similar, electricity trade via the interconnector (in either direction) would not be classed as either 'carbon leakage' or 'reverse leakage'. There was some suggestion that there was a risk of firms investing in power plant in the EU rather than UK, were EUA prices to be consistently below the total carbon price for power in the UK. But, overall, there appeared to be a low risk of carbon leakage in the power sector. Consistent with this assessment, the power sector received no free allowances within the UK ETS.

What is the risk of carbon leakage for commodity producers?

The commodity production sectors were defined as a variant of 'heavy industry', comprising cement, chemicals, iron and steel, oil and gas but also including lime, ceramics and food-based commodities sometimes included in the 'other industry' group. Firms producing internationally traded commodities reported minimal ability to pass on UK ETS costs to their customers, because the commodity price was set internationally and there was competition from potential imports with lower prices from areas with no or lower carbon costs. Operators in this category included oil, chemicals, fertilisers, metals, ceramics and some basic foodstuffs.

> *Increasingly now we are competing with products from outside the EU coming into the UK at much lower prices. So there's a lot of product coming in from the Far East.*

There's a lot of product… [from] Turkey [..]. And particularly some [product] come in from South America, particularly Brazil. (commodity sector operator)

In the cement and lime sectors, there was some indication of carbon costs being explicitly passed on to major customers in the short term. But operators reported that higher costs would stimulate international competition from imports in the longer term, linked to increased investment in import infrastructure. Operators that were competing with producers in the UK that were not covered by the UK ETS (because their thermal capacity was below the UK ETS threshold) also reported that they had problems passing on UK ETS costs.

Various forms of production and investment leakage risk were mentioned by commodity produces, attributable to the combination of UK ETS costs with other elements of production costs (for example energy costs). Qualitative research identified examples of:

- Import leakage - UK customers buying cheaper product produced at lower cost outside the UK and EU.
- Export leakage - export customers buying cheaper product from elsewhere.
- Production leakage - international firms deciding to scale up production in other countries and scale-down production in the UK, because of the combined effect of energy prices and UKA prices. The quantitative survey found that 54% of installation operators[28] reported that their carbon abatement plans included decisions about management of plant operations (including decisions to run or not to run the plant), although only 11% said their plans included reducing or not increasing overall produce output (n=93).
- Plant closure - UK-based plant closing, fully or partially, temporarily or permanently, and reporting that this was attributed (at least in part) to carbon pricing. This is consistent with the 'abatement by closure' example cited in chapter 6.
- Investment leakage - international firms deciding to invest in new (or upgraded) plant in other countries instead of making these investments in the UK.

There were also examples of investment being made in EU countries rather than the UK, but this was reported to be based on wider consideration of relative competitiveness, including energy costs and taxation, rather than carbon costs per se.

One of the reported mechanisms for carbon leakage was that the additional cost of the UK ETS eroded the profit margin of commodity operators who were unable to pass the cost on to their customers. There was direct evidence of operators closing part of their production base in the UK, in certain sectors. These operators were in sectors that were already vulnerable (as evidenced by other firms having closed in recent years), so they were less able to cope with erosion of their margins. Where companies were owned by international firms, they reported that a decision to shut or mothball a marginal plant in the UK would be made on a pragmatic basis by their parent company.

[28] This statistic is based on all installation operators, including power generators and other industry, with emissions exceeding 1,000 tonnes of CO2e per annum in 2022.

What is the risk of carbon leakage for other industries?

For the purposes of this analysis, 'other industries' excludes lime, ceramics and food-based commodities. Findings for the remaining other industries were mixed. Although paper and vehicles are not generally traded as commodities, paper and vehicle manufacturers reported that competition in their markets (within or beyond the UK) meant that they could not readily pass-through UK ETS compliance costs to customers. Some cost pass-through was reported in certain other industries (for example bespoke food products and glass). As noted for commodity sectors, industries were affected by competition from outside the UK and Europe:

The types of carbon leakage risk, and UK ETS influence, reported by other industry operators were similar to those reported by commodity sector operators. For example, operators that were part of international organisations reported active consideration of where production should take place to fulfil orders, taking into account production capacity and costs in different countries, within and beyond the UK and Europe. Carbon prices were reported to affect investment decisions by parent companies, but there was recognition that carbon prices were only one of several factors in these decisions. There were also reports of closures of plants or production lines in vulnerable sectors within these 'other' industrial sectors, as well as in commodity sectors. Again, UK ETS costs were cited as one factor that reduced the operating margins of these plants, and the two year timeframe for ALC adjustments to free allocations for installation operators was cited as a barrier to restarting production.

To what extent have free allowances mitigated carbon leakage risks?

Free allowances were reported to be very important to energy intensive industry, particularly in commodity sectors. The value of free allowances helped vulnerable industries to maintain operations in the UK.

> *…the underlying rationale for free allocation remains the same. Which is if you are exposed to international competition your ability to pass on carbon costs to your customers is limited, if not zero, and therefore free allocation is essential. [..] There are businesses that are relatively energy intensive, carbon intensive, for which this is a huge cost, like ours. And, simply, if we didn't have free allocation we would have shut down years ago, because there would just be no way of operating in the UK. (Commodity sector operator)*

Some respondents commented that free allowances had decreased significantly from Phase III of the EU ETS to the UK ETS, and that – combined with increases in UKA costs since the start of the scheme – this meant that their carbon costs had increased substantially. Some respondents, particularly but not solely in commodity sectors, reported that there was a risk of closure if free allowances were reduced further. There were comments that reducing free allowances further was likely to contribute to decarbonisation through de-industrialisation.

Some installation operators commented that the two year period for adjustment of free allocations, via the ALC mechanism, could have an adverse effect on re-opening a mothballed plant. This was particularly the case if the surplus free allocation was sold (for example for cashflow reasons) while production was reduced or closed. The ALC adjusted free allocations downwards, with a two year time lag, when production was reduced or stopped. As reported in chapter 4, in the section on 'Activity Level Changes', this could become a barrier to restarting production, since free allowances would only recover over a two year period. Some interviewees understood that a similar two year time lag applied to the New Entrants Reserve for installation operators, but the Environment Agency clarified that operators could apply for free allowances to cover activities in the year following the start of new operations.

However, in some sectors that were relatively less energy intensive, where UK ETS liabilities and free allocation were both smaller scale, changes in free allocation were not seen as having much impact.

What changes would be needed to mitigate carbon leakage risks more effectively?

Operators/AOs made a number of suggestions in interviews about how to mitigate carbon leakage risks more effectively. Some were sector-specific, such as a suggestion from AOs that a comprehensive carbon pricing international system for aviation would be preferable to multiple ETS systems, because it would avoid distortion of flight activity and routing. However, they suggested that CORSIA would need to be ramped up, and better implemented, to provide a robust equivalent to the EU ETS or the UK ETS.

Some power sector operators commented that Carbon Price Support (CPS) encouraged higher power imports via the interconnector, because it created a price differential between electricity generated in the UK and EU, irrespective of any differential between the UK ETS and EU ETS schemes. They advocated reviewing CPS.

Across a range of sectors, there was appetite for the UK to introduce the Carbon Border Adjustment Mechanism (CBAM), matching as closely as possible the CBAM system introduced in the EU ETS, to avoid distortions in trade between the EU and UK.

More far-reaching suggestions, discussed further in chapter 9 on 'wider findings', included building linkages between the UK ETS and other markets, and ringfencing revenue from the UK ETS to support decarbonisation, thereby achieving decarbonisation objectives while making the UK a more attractive place to produce and invest in the long-term.

Were there any unanticipated consequences of the UK ETS?

Findings on the unanticipated consequences of the UK ETS, other than carbon leakage, are based on qualitative research, primarily with higher emitters (above 50,000 tCO2e per annum).

A few installation operators mentioned that there was a risk of firms choosing to install smaller equipment to avoid being part of the UK ETS. The evaluation found evidence of this in one case where an operator had multiple HSE installations and was gradually replacing the equipment on these sites with equipment below the UK ETS threshold, to improve their competitive position vis a vis other producers that had equipment below the UK ETS threshold.

As explored in the chapter on abatement behaviour, some companies commented that the time and money spent on the UK ETS distracted from some firms' decarbonisation activity, rather than driving it.

As noted in other sections, some instances were cited where there was a perverse incentive to carry out an activity in order to avoid losing free allowances, even if this would lead to greater emissions. This was reported as a risk by one operator (in relation to avoiding the ALC threshold for reduction in production, which would lead to a reduction of free allowances) and by one regulator (in relation to potential flaring of gas in the offshore oil sector, in order to obtain/retain free allowances).

And, as noted above, the two year timescale for adjustment of free allocations to installation operators, under the ALC mechanism, was reported to have the effect of disincentivising the restart of production where a plant or production line had been closed for some time.

Chapter 8. Preliminary assessment of the UK ETS overall

The executive summary summarises findings from previous chapters against the evaluation questions. This chapter brings together overall findings into a preliminary assessment of the Theory of Change and a preliminary contribution analysis, considering how far the UK ETS is contributing to its objectives, based on evidence available to date. This assessment is highly tentative at this stage and will be reviewed after phase 2 of the evaluation.

A summary of findings against evaluation questions A-C is given in the executive summary.

Overview of whether the UK ETS is working as intended

As outlined in chapter 2, the Theory of Change (ToC) for the UK ETS evaluation describes in diagrammatic form how the UK ETS policy intervention is intended to work. The main components of the ToC are summarised in chapter 2. It is too early to assess the overall functioning of the ToC: this will be undertaken in phase 2 of the evaluation. But, in phase 1, a preliminary assessment has been made of the level of support for assumptions underlying the ToC, which need to hold if the scheme is to operate as intended.

In total there are 41 assumptions in the full ToC, each of which has been assessed against the research evidence to determine their validity. A table, showing a provisional assessment for each ToC assumption, is provided in Appendix 3. In summary, the table shows:

- Fourteen of the assumptions were provisionally assessed as ‘proven / supported’.
- Eleven were provisionally assessed as ‘partially proven / supported’.
- One was provisionally assessed as ‘unsupported’.
- Insufficient evidence was available to enable an assessment to be made of 15 of the assumptions (meaning that they were unproven). In some cases, the phase 1 research may simply not have generated, or been intended to generate, the evidence required to enable an assessment to be made.

The assessment of the assumptions should be considered as provisional: they will be reviewed and subject to revision following the phase 2 work. Nevertheless, the fact that some assumptions have been assessed as partially proven / supported or unsupported at this point may indicate that the UK ETS is not operating fully in line with the scheme design and may warrant mitigating action. Not all assumptions are of equal importance, but the following assumptions (numbered as shown in Appendix 3) are felt to be potentially consequential in terms of their potential impact on the achievement of UK ETS objectives.

A14: Regulated firms are aware of technical abatement options and costs.

The quantitative and qualitative research suggest that there is a good level of understanding of available abatement options within the operator/AO population. However, a significant proportion (25%) of operators/AOs reported that they did not have the capacity or capability to consider abatement options, whilst 31% reported that there were considerable uncertainties associated with carbon reduction technologies (n=183). On balance therefore, this assumption is provisionally assessed as partially proven.

A16: Assumed that firms pursue a mix of responses (hold, abate, buy, sell) and that they aim to respond in the most cost-effective manner through active trading as opposed to 'compliance' behaviour.

The quantitative survey found that 90% of operators/AOs had a carbon reduction plan in place (n=203). Such plans were found to include a range of decarbonisation options. Whilst some operators/AOs (24%, n=183) reported no barriers to plan implementation, others identified a range of barriers. The intervention theory suggests that those facing barriers to abatement will rely on submitting UK ETS allowances and will obtain them in the most cost-effective fashion (namely through active trading rather than end of year ‘compliance’ behaviour).

In practice, 44% of survey respondents reported that they only buy allowances once a year, which appears to be simple ‘compliance’ behaviour (n=169). The qualitative evidence identifies a range of compliance behaviours available to operators/AOs but also finds that some operators/AOs are prepared to accept the risk of higher costs associated with simpler forms of procurement activity, owing to various internal situational factors and constraints. Overall, the research indicates that operators/AOs are practicing multiple forms of compliance behaviour, but a significant proportion are not trading in the most cost-effective manner and therefore this assumption is provisionally assessed as being partially proven.

A22: Sufficient liquidity achieved despite limited number of market actors (buyers and sellers).

The secondary market data analysis found that, for the periods analysed by the evaluation to date, the UK ETS was sufficiently liquid to be considered a functioning market. Qualitative evidence was mixed, but there was a widely reported view that the UK ETS suffered from poor liquidity. Some, however, suggested that, whilst naturally constrained by the size of the UK ETS market, there was sufficient liquidity to enable the market to function. Whilst there was widespread concern about liquidity in the qualitative research, the identified disagreement, and in particular the findings from the secondary analysis, mean that this assumption is provisionally assessed as partially proven.

A32: Firms are confident in long-term direction of travel - in relation to decarbonisation policy - and are therefore prepared to make long-term capital investments to deliver decarbonisation.

The qualitative research suggests that, at the time of the research, there was a lack of confidence amongst operators/AOs and traders in the long-term direction of travel for UK and

devolved government net zero policy. This was reported to undermine operators/AOs' ability to plan and deliver major capital projects. This assumption is therefore provisionally assessed as being unsupported.

Summary of findings from contribution analysis, by high level sector

This section sets out our assessment of phase 1 evidence against the evaluation's contribution hypotheses. These are initial findings only, based on self-reported evidence from operators/AOs, which may be subject to bias. A full assessment, based on both objective and subjective evidence, will be made in phase 2 of the evaluation. The table below presents a tentative summary assessment across the UK ETS as a whole. A preliminaryassessment by high level sector is presented below.

Table 7: Tentative assessment of support for contribution hypotheses, based on subjective evidence

Contribution hypothesis	Level and nature of support
Primary ToC hypothesis: The operation of the UK ETS brought about cost-effective emissions reductions within affected sectors, contributing to and in line with UK and devolved government net zero commitments whilst mitigating carbon leakage.	Some evidence of UK ETS influence contributing to cost-effective emissions reductions in a range of sectors, but not yet in line with net zero cap. Free allowances mitigate carbon leakage to some extent in energy intensive industry but risks remain.
Competing hypothesis 1: Emissions were reduced, and carbon leakage was limited, but this was largely driven by other factors, not the UK ETS.	Evidence of this, for some firms, with other drivers for abatement reported to include energy costs, corporate commitments to net zero, investor pressure, customer pressure, other UK policies and international policies including the EU ETS (and – for aviation - future CORSIA requirements).
Competing hypothesis 2: Emissions were reduced but this was largely because of changes in activity levels, some of which was due to UK ETS contribution to carbon leakage.	Some evidence of carbon leakage and reductions in activity levels within energy intensive industry.
Competing hypothesis 3: The UK ETS has limited liquidity or exhibits other aspects of	Mixed evidence on market quality, with secondary market data analysis indicating

Contribution hypothesis	Level and nature of support
poor market quality, so met its carbon abatement and carbon-leakage mitigation objectives in a sub-optimal way.	relatively good market quality for a market of UK ETS size, but traders still reporting some concerns about liquidity and volatility.
Competing hypothesis 4: The UK ETS made some contribution to carbon abatement but this was not consistent with the UK and devolved government net zero ambitions	Announcement of the transition to a net zero cap was made towards the end of the phase 1 research period. Until this point, the trajectory of the UK ETS cap was not consistent with the UK's net zero ambitions, although actual emission levels were below the cap.
Competing hypothesis 5: The UK ETS caused unforeseen outcomes and impacts.	Some limited findings about unanticipated outcomes, aside from carbon leakage.
Competing hypothesis 6: The UK ETS provided carbon leakage mitigation to sectors that were not in fact at risk.	At the time of this research, AOs were still receiving free allocations, despite the conclusion of the independent Frontier Economics report that carbon leakage risks were minimal for this sector. However, the UK ETS Authority announced in July 2023 that free allocations for AOs were to be phased out in 2026.

Source: evaluation team assessment.

Preliminary assessment of the UK ETS contribution hypothesis that currently appears to fit each high level sector is given in the sections below. As this analysis draws on the carbon leakage analysis, the high level sectors are again aviation, power, commodity producers and other industry. The commodity production sectors were defined as a variant of 'heavy industry', comprising cement, chemicals, iron and steel, oil and gas but also including lime, ceramics and food-based commodities sometimes included in the 'other industry' group.

Aviation

The aviation industry is actively engaged in both existing and planned carbon abatement activities, within the cost-effective options available. The UK ETS has had some influence on carbon abatement within the sector, primarily encouraging operational fuel efficiencies and planned use of SAF. However, the extent of its influence compared to other policies, such as the EU ETS (and, in future, CORSIA) is unclear. Additionally, the impact of the UK ETS on

decarbonisation investment in fleet renewal and major SAF production plants in the aviation sector appears to be limited.

Although some AOs raised concerns in interviews about potential changes to routes and frequencies involving destinations outside the UK and EU, an independent study by Frontier Economics and Air Transportation Analytics[29] found minimal risk of carbon leakage (based on detailed quantitative research on the impacts of carbon pricing on UK aviation using a global aviation model). As noted above, free allocations were still available to the aviation sector at the time of the research. This was a temporary situation as the UK ETS Authority announced plans to phase out free allocations for aviation in 2026.

The tentative assessment is that a combination of 'competing hypothesis 1' and 'competing hypothesis 6' currently appears to apply to the aviation sector:

- The operation of the UK ETS has brought about some (but not universal for all firms in each sector) cost-effective emissions reductions within affected sectors, contributing to UK and devolved government net zero commitments to some degree, but potentially not as much as other policies/factors.
- Based on an objective study of the aviation sector, carbon leakage risks appear to be low for aviation, despite concerns raised in interviews by AOs. Most AOs currently have access to some free allocations, despite low carbon leakage risks, but these will be phased out in 2026.

Power generation

Companies in the power generation sector are engaged in various existing and planned abatement activities, with some companies demonstrating a clear commitment to decarbonisation. However, the level of commitment and the specific abatement activities vary across different companies in the sector.

The UK ETS influences abatement decisions in the power generation sector by impacting the financial viability of running plants or processes and by influencing investment strategies focused on current and future abatement options. However, the level of influence varies between companies, with some companies reporting that the UK ETS plays a key role in making a business case for abatement, while others report that other factors are more significant drivers of abatement investment decisions.

There is a low risk of carbon leakage in the power sector. However, concerns were raised that there could be risks to the competitiveness of UK investment in this sector if the combined price of UKA and CPS were to exceed EUA on an ongoing basis.

For the power sector, an adaption of the primary hypothesis blended with an adapted 'competing hypothesis 4' currently appears to be appropriate:

[29] Frontier Economics and Air Transportation Analytics, (2022) Economic research on the impacts of carbon pricing on the UK aviation sector, Final report. https://www.frontier-economics.com/media/s1enxvsn/economic-research-on-the-impacts-of-carbon-pricing-on-the-uk-aviation-sector.pdf

- The operation of the UK ETS has brought about some (but not universal for all firms in each sector) cost-effective emissions reductions within the power sector, contributing to UK and devolved government net zero commitments to some degree.
- The risk of carbon leakage in the power sector is low, irrespective of the UK ETS.

Commodity producers (a variant of the heavy industry sector)

Various commodity producers are at different stages in their carbon abatement journey. Some are actively investing in current and future abatement solutions, while others are still researching potential options or are constrained by external factors.

The UK ETS has had a mixed impact on carbon abatement for commodity producers. While some firms are committed to decarbonising and investing in abatement options, others treat the UK ETS as a carbon tax and have not yet explored potential decarbonisation options.

While the UK ETS has implemented measures such as free allowances to mitigate carbon leakage risks, there are still significant challenges faced by commodity producers in passing on costs and competing with lower cost products from other jurisdictions. This has resulted in closures of some plants or production lines and increased imports, contributing to carbon leakage.

For commodity producers, the closest hypothesis currently appears to be an adaption of the primary hypothesis blended with ‘competing hypothesis 4’ and ‘competing hypothesis 2’:

- The operation of the UK ETS has brought about some (but not universal for all firms in each sector) cost-effective emissions reductions within affected sectors, contributing to UK and devolved government net zero commitments to some degree, although emissions reductions also occurred due to carbon leakage.
- There are carbon leakage risks arising from the UK ETS which are not fully mitigated through free allocations.

Other industries

Firms in other energy intensive industries are carrying out or investing in abatement activities. These activities included heat recovery, fuel switching, and energy efficiency, among others. However, several firms noted they were locked into technologies they had invested in previously, such as kilns and combined heat and power plants. Many firms also noted barriers outside their control in moving away from fossil fuels like natural gas, including the availability of hydrogen and the capacity and process to access the local electricity grid.

In some cases, the UK ETS price has helped to make the business case for investment in abatement technologies. For many other energy intensive industry companies, however, abatement is being driven by factors other than the UK ETS. Corporate leadership and the price of gas were often cited as key drivers in abatement decisions, ROI was identified by several respondents as the primary driver of abatement decisions.

The UK ETS has contributed to carbon leakage in other energy intensive industries. Competition in both UK and export markets has made it difficult for paper and vehicle

manufacturers to pass through UK ETS compliance costs to customers, for example. Furthermore, operators in other industries actively consider the cost of production in different countries when fulfilling orders, another form of carbon leakage. For example, if a non-ETS country can produce a product cheaper due to lower energy and carbon costs, then the product will be made in that country instead. This has possible implications for the long-term viability of UK production lines.

For the other industry sector, the closest hypothesis currently appears to be an adaption of the primary hypothesis blended with competing hypotheses 2 and 4:

- The operation of the UK ETS has brought about some (but not universal for all firms in each sector) cost-effective emissions reductions within affected sectors, contributing to UK and devolved government net zero commitments to some degree, although emissions reductions also occurred due to carbon leakage.
- There are carbon leakage risks arising from the UK ETS that appear not to be fully mitigated through free allocations.

A fuller assessment of the contribution and competing hypotheses for high level sectors, based on both objective and subjective evidence, will be made in phase 2 of the evaluation.

Chapter 9. Wider findings on the UK ETS

This chapter presents wider comments and suggestions about the UK ETS from qualitative research, relating to fundamental aspects of the design of the UK ETS. The strongest call was for alignment or linkage between the UK ETS and EU ETS.

Calls for closer alignment of the UK ETS and EU ETS

There was a strong theme from many operators/AOs that they would like prices and rules in the UK ETS to be closely aligned with the EU ETS. Traders also commented that the UK ETS tended not to be viewed in isolation, but in relation to the EU ETS, and that their energy markets were interlinked.

> *But one thing that needs to be taken, which is important to understand, is that all of the entities that operate on the UK ETS also are taken as a reference or a comparison with the EU ETS, right? So you don't simply assess the dynamics in one market, you always reference to the other one. (Trader)*

A number of reasons were given by those who wanted to see alignment of the two systems:

- **Reducing differences in competitiveness between the EU and UK:** maintaining a 'level playing field' between the UK and EU would help to avoid the distortion or movement of activities between the EU and UK. This point was raised by respondents in a range of sectors, including aviation, industry and power generation, as explained in the carbon leakage chapter above.
- **Providing more certainty about the future of the UK ETS:** where operators/AOs were considering major investments, including future decarbonisation investments, they saw alignment between the UK ETS and EU ETS as providing more certainty and hence supporting their investment decisions. This was particularly an issue for organisations with international parent companies.
- **Reducing the potential for compliance loopholes:** some operators/AOs commented that differences in scope might allow the development of loopholes. For instance, the EU ETS is proposing to bring international shipping into the system, while the UK ETS is only proposing to bring in domestic shipping. This might provide incentives for international shipping to route via the UK. Similarly, the application of CBAM within the EU ETS might give rise to other compliance loopholes.

The overall message was that the interaction and level of alignment between the UK ETS and the EU ETS has implications for operators/AOs, particularly for sectors like aviation which are continually operating in both systems.

Calls for linkage between the UK ETS and EU ETS

There were also strong calls from operators/AOs and traders for some form of linkage between the UK ETS and the EU ETS, both to increase the size of the UK ETS market and to ensure future alignment of the two systems. Many interviewees were aware that linkage was a possibility envisaged in the design stage of the UK ETS and they would like to see it pursued.

> *But I think probably more of the kind of things that I hear about it that are critical would be around linkages, and whether it's going to be big enough, for the long term, to operate in isolation, or whether the UK has sort of ceded leadership. Because, for many of us in carbon markets, the UK was always kind of the standard bearer, dating back to the UK ETS of the early 2000s. Right? And so I think there's a set of my members that are understanding all of the complexities of Brexit, but still believe that a linkage with the EU would be advisable. (Wider stakeholder)*

Operators/AOs who were subject to both the UK ETS and EU ETS referred to the added time and effort required to comply with both systems, particularly since UKA and EUA were not interchangeable. The additional burden was particularly referenced by the aviation sector, with many AOs being covered by multiple ETS schemes (for example the UK ETS, EU ETS and Swiss ETS) as well as (in future) CORSIA.

A number of reasons were given for pursuing linkage with the EU ETS:

- **Improving the liquidity of the UK ETS market** (see chapter 5 on market outcomes).
- **Being part of a larger market** that was less subject to large price fluctuations arising from relatively small events.
- **Ensuring alignment between prices and rules in the two systems**, which can lead to distortions in competition within industrial, aviation and power markets (see chapter 7 on carbon leakage as well as the alignment sub-section above).
- **Improving efficiency and reducing the management burden** for pan-European businesses that were covered by both systems.

The links between the EU ETS and Swiss ETS was cited as an example of an approach to linkage that appeared to be working well.

However, some interviewees recognised that it might be challenging to pursue linkage between the UK ETS and EU ETS while UKA prices were below EU prices. They noted that, if this changed in future, linkage might be more realistic. There was also recognition that changes in scope between the UK ETS and EU ETS would make linkage more unlikely (for example proposals for the UK ETS to cover domestic shipping while the EU ETS would cover international shipping; proposals for Greenhouse Gas Removals (GGR) to be included in the UK ETS but not the EU ETS).

Some power generators suggested that linking to EU ETS and removing Carbon Price Support (CPS) would avoid distortions in the power market, making UK ETS more efficient and thereby increase its influence on overall greenhouse gas emissions.

Calls for more certainty in the direction of travel for the UK ETS

Both operators/AOs and traders commented that the UK ETS Authority needed to clarify how the UK ETS will operate beyond 2030, to help industry plan major capital projects. They commented that the EU ETS had provided firmer long-term plans. Ideally, operators/AOs would like to see cross-party agreement on the direction of travel for the UK ETS, which would give more confidence on likely future policy.

Several stakeholders commented that policy confidence would be improved if the UK ETS Authority worked more collaboratively with industry and market players, sharing emerging thinking and using a 'working group' approach on tricky issues. This would mean that the market was better aware of emerging policy issues rather than there being a period with little or no engagement between a consultation round and a final policy decision. It was suggested that the UK ETS Authority could follow the approaches used in the power and gas markets. For instance, National Grid has a partnership with a governance body called the 'Joint Office for Gas Transporters'.

> *if government are a bit more open with us [..] None of us are experts, but together, we can be a better team, I think, really. I think everybody on our side of the fence wants to reduce emissions as much as government does, that's pretty much what I'd say. (Heavy industry operator)*

Calls for ring-fencing of UK ETS revenues for abatement

As noted in chapter 6 on abatement, a number of operators/AOs made comments about potential ring-fencing of UK ETS revenues to support decarbonisation research and investment. These comments came primarily from the aviation sector, where AOs were aware of EU ETS revenue being used to support use of SAF. At the simplest level, some operators/AOs suggested that there was a need for more transparency about how UK ETS revenues were used.

These operators/AOs would like to see hypothecation of some or all UK ETS revenues (for example to fund decarbonisation). They pointed out that the new EU ETS rules allocated three-quarters of funds raised towards decarbonisation and one-quarter to a social fund, to alleviate the social impacts of carbon prices on consumer prices.

> *The European Union has hypothecated the revenues from the EU ETS, under the new rules, so 100% of it, okay 75% towards climate initiatives, 25% towards social fund, however you want to talk about that. The UK has no commitment to any revenues being hypothecated. And that's directly the opposite direction that the EU are going and it's also in breach of what they stated post-Brexit, that the environmental obligations would not be lowered. Our environmental obligations and aspirations will not be lowered by us leaving the EU. Well, there you have it. They've got 100% hypothecated revenue, and you've got zero. (Aircraft operator)*

This was linked to a separate point that policies needed to provide incentives for decarbonisation (referred to here as 'carrots') as well as disincentives for emissions (referred to here as 'sticks') – see separate sub-section below. One wider stakeholder commented that having a fund from UK ETS hypothecated revenue might improve political perceptions of the UK ETS, as well as providing further impetus for decarbonisation.

Calls for 'carrot' as well as 'stick' policies on decarbonisation

Many stakeholders commented that there was a need for government policy to include incentives for decarbonisation ('carrots') as well as disincentives for carbon emissions ('sticks'). They viewed the UK ETS as a 'stick' policy and pointed out that there were a range of other policy tools that could be used, including CBAM, product standards, grant funding and so on.

> *I think one of the challenges is that at times it feels like the emissions trading scheme is the only decarbonisation tool the government understands. And, actually, there are other ways of influencing businesses to decarbonise. And some of the stuff they're talking about in their carbon leakage consultation is important there. Things about carbon border adjustments, product standards. There's more than one tool that needs to be in the toolbox. And certainly ETS, from our point of view, feels all stick and no carrot. (Heavy industry operator)*

Some interviewees were aware of government funding programmes for innovation (which include innovation competitions for hydrogen supply, CCUS and fuel switching, plus the UKRI's Industrial Decarbonisation Challenge Fund) and similar funding mechanisms for deployment (such as the Industrial Energy Transformation Fund, the Hydrogen Business Model, Green Gas Support Scheme and the CCUS Business Model). But they still commented that other jurisdictions, such as the EU and US, offered clearer support mechanisms for near-term decarbonisation investment and that additional funding would help to stimulate investment, provided that there was confidence in the consistency of government policy and support.

One stakeholder commented that policy makers had become better at developing policies that complemented rather than competed with ETS systems, following experiences from around 2010 to 2017/18 when renewable energy subsidies were reported to be the main driver of decarbonisation of the power sector, which had the effect of depressing EU ETS prices. In developing 'complementary policies', their potential interaction with the UK or EU ETS needed to be considered.

There was also comment that the UK ETS needed to be considered alongside other elements of policy in the UK (for example the Climate Change Levy, Carbon Price Support, Climate Change Agreements, grid network charges and the mechanisms for operating cost support for CCUS, Hydrogen and Green Gas). Operators/AOs commented that there were risks to developing policy in a 'siloed' manner, where businesses have to see the whole picture.

Calls to extend the scope of the UK ETS

As noted in chapter 6, there was considerable interest amongst interviewees about the potential inclusion of GGR in the UK ETS. This was seen as a potential incentive for investment in GGR in the UK, provided that carbon prices were sufficiently strong.

> *…[I] think there is a big opportunity, in regard to help subsidise the removals industry in the UK, of which, I think, there is a really exciting potential. Without the ETS support, currently the investments into that industry in the UK is fairly minimal. So, it's not necessarily something that the ETS has done wrong, it's just that I think it's a potential opportunity that isn't being realised. (Aircraft operator)*

A few interviewees called for the scope of the UK ETS to be extended in other ways. There were calls for the system to be extended to transport sectors beyond aviation, on the grounds that this would be fairer to the aviation sector. The California 'Cap and Trade' scheme was cited as an ETS that had a fuels directive and covered usage of transport fuels upstream. One wider stakeholder suggested that the UK ETS Authority should consider extending the scope of the UK ETS to include nature-based solutions and agriculture, taking an international lead in this area and learning from other schemes that have attempted to do this.

Calls to replace the UK ETS with a carbon tax

In the qualitative research, a few installation operators stated that they would prefer to pay a carbon tax instead of being part of the UK ETS. They saw this as easier for operators to manage, fairer to all operators and as providing more price predictability to industry, compared to an emissions trading scheme. There was a sense that these operators saw the carbon market as a distraction from their main business and from the task of decarbonisation.

> *I think having predictable pricing would be helpful, but we just have to operate it as a market. It just makes it a bit more of a thing that we're trying to manage, rather than just running our business. (Other industry operator)*

It was not clear whether these operators acknowledged the role of the UK ETS, and ETS systems worldwide, in contributing to the emergence of carbon prices.

Calls to link the UK ETS with developing country systems

Finally, one wider stakeholder commented that linkages could be made with developing countries, if linkage with the EU was not feasible. The purpose would be to access lower cost abatement opportunities, while contributing to decarbonisation in the global south. They saw this as an opportunity to use Article 6 of the Paris Agreement, which allows 'Cooperative Implementation' of national climate goals. They suggested that this could be an area where the UK could show market leadership, either through a private sector model, where companies had limited amounts of credit that they could use from other countries, or through a government purchasing option.

Appendix 1: Glossary of UK ETS terms

Term	Meaning
Abatement	Reduction in carbon dioxide and other greenhouse gas emissions
Activity Level Change (ALC)	Change in activity level from a given installation, which needs to be reported to the regulator each year.
Algorithmic trading	Computer-led trading which uses mathematical rules to determine trading decisions (based on market patterns or differentials between markets). Algorithmic trading may involve very short-term trades.
Amihud price impact ratio	A measure of market liquidity across a trading day. The Amihud (2002) price impact ratio is defined as an average ratio of the daily absolute return (in %) to the trading volume on that day (in £).
ARP	Auction Reserve Price – a floor price in the UKA auction, set at £22/tonne at the time of this research.
Auction	Fortnightly auction of UKAs run by ICE on behalf of the UK government. These are 'physical' or 'spot' UKA, not futures or other derivatives.
Aircraft operator (AO)	A person that operates flights that are covered by the UK ETS. The legal term 'person' can mean an organisation.
BECCS	Bioenergy with Carbon Capture and Storage
BEIS	Department of Business, Energy and Industrial Strategy (post reorganisation of the Departments, this is now 'the Department of Energy Security and Net Zero' – see below).
Bid-ask spread	The difference between prevailing best buy and best sell prices in a market. This is indicative of the cost to trade in a market.
Broker	A trader who buys and sells in the market on behalf of clients, for a commission or fee, without taking trading positions themselves

Term	Meaning
Cap and trade scheme	A common term for a government regulatory program designed to limit, or cap, the total level of emissions of certain chemicals, such as GHG. A cap and trade scheme reduces emissions by setting a limit on emissions and creating a market in emissions permits or allowances. The theory is that, in an efficient allowance market, participants who can reduce emissions cheaply will do so, trading allowances with other participants who cannot reduce emissions as cheaply. The marginal cost of emissions reductions should therefore be lower than for an emissions tax.
CBAM	Carbon Border Adjustment Mechanism – an initiative introduced by the EU in 2023 which adjusts the prices of imports if they have been produced under jurisdictions with lower carbon prices/regulation. This potentially puts imports to the EU from the UK at a disadvantage if UKA prices are below EUA prices. The UK government has also consulted on a potential CBAM[30].
Carbon leakage	The movement of production and associated emissions from one country to another due to different levels of decarbonisation effort through carbon pricing and climate regulation. As a result of carbon leakage, the objective of decarbonisation efforts – to reduce global emissions – would be undermined. One way that carbon pricing can cause carbon leakage is due to businesses' inability to pass cost through to end consumers. If all countries faced a carbon price, then there would be no risks to businesses in passing down costs associated with production (including carbon costs) to the end consumers as all producers would have the same costs associated with their production.
CCM	Cost Containment Mechanism – a mechanism that allows the UK ETS Authority to intervene if UK ETS prices show sudden rises over a certain level.
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage

[30] https://www.gov.uk/government/consultations/addressing-carbon-leakage-risk-to-support-decarbonisation

Term	Meaning
CHP	Combined Heat and Power
Clearing member	A financial institution that is a member of ICE and that meets the criteria for handling direct transactions on the ICE platform, including the UK ETS auction.
Clearing price	The price at which an auction settles.
Clusters	Government-funded initiative to prioritise CCUS and related hydrogen infrastructure in specific locations in the UK.
CO2e	Carbon dioxide plus other greenhouse gas emissions, converted into carbon dioxide equivalents.
Commodity trader	Firms whose main business is trading in financial and physical assets, which might include commodities such as metals, oil, gas, electricity as well as UKA, EUA and derivatives of these commodities.
Compliance consultant	A firm that offers energy and/or carbon compliance services to industrial or commercial clients, which may include sourcing UKA and/or EUA.
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation - a global market-based measure for international aviation emissions agreed by the International Civil Aviation Organization (ICAO). Offsetting under CORSIA is expected to start from 2024.
Cost of capital	The cost of borrowing a capital sum (namely the current interest rate).
Cost of carry	The cost of holding UKA for a period, in terms of the cost of capital required to buy and hold the allowances.
DACCS	Direct Air Capture for Carbon Capture and Storage
Daily futures	ICE futures contracts that mature into ‘spot’ or physical UKA at the end of a given contract day.

Term	Meaning
December futures	ICE futures contracts that mature into physical UKA at the end of December of a given year.
DESNZ or 'the department'	Department for Energy Security and Net Zero
Derivatives	Futures, forwards, options, swaps or other financial contracts for a specified asset.
EA	Environment Agency (regulator for UK ETS installations in England and AOs registered or resident in England or outside the UK).
EEX	A trading platform used by the EU ETS.
Eigenvector centrality	A measure of the importance of a node in a network that considers the importance of its neighbours. In other words, a node's eigenvector centrality is higher if it is connected to other nodes that are themselves highly connected.
Emissions	Emissions of carbon dioxide and other greenhouse gases.
ESG	Environmental, social and governance considerations.
ETD	Exchange traded derivatives (namely ICE-traded derivatives).
ETSWAP	Old system used by UK ETS regulators for permitting, monitoring, reporting and verification.
EU ETS	European Union Emissions Trading System
EUA	EU ETS allowances
Exchange member	Firms with accounts on the ICE trading exchange (covering not just UKA but other products as well).
FCA	Financial Conduct Authority

Term	Meaning
Financial counterparty	Financial institutions who offer banking, investment and clearing services, who may also undertake trading in commodities and derivatives.
Forwards	Contract to buy an asset at a specific price at a future date (normally refers to an off-exchange contract).
Futures	Contract to buy an asset at a specific price at a future date (in relation to UK ETS, this normally refers to an ICE-traded product).
GHG	Greenhouse gas emissions
Hedging	Buying futures or options to reduce the risk or exposure to future changes in costs/prices.
HSE	Hospitals or Small Emitters - installations with low levels of emissions, and installations serving hospitals, which have simpler UK ETS compliance requirements. HSE installations are required to submit verified annual emissions reports but do not need to surrender UKA. A civil penalty is payable if they exceed specified emissions targets.
ICE	Intercontinental Exchange – the trading platform for UKA, EUA, their derivatives and a wide range of other commodities, including oil, gas, electricity and so on. ICE also run the UKA auction on behalf of the UK government.
Initial margin	The amount of money that a trader needs to pay to open a buy or sell position on a futures contract.
Improvement report	Report prepared by the operator in response to the verifier's comments about non-conformities and improvements.
Industrial cluster	See Clusters
Installation	A single site in the UK ETS.
Installation operators	UK ETS operators that operate industrial sites, power plant or offshore oil and gas installations in the UK, as opposed to aircraft.

Term	Meaning
Liquidity	The ease with which an asset, or security, can be bought or sold without affecting its market price.
Lot	UKA futures contracts are traded on ICE in 'lots' of 1,000 allowances. The UKA primary action trades in 'lots' of 500 allowances.
Main scheme	A term used in this report to refer to UK ETS installation operators and aircraft operators (AOs), excluding HSE and USE installations. 'Main scheme' operators/AOs are obliged to comply with the UK ETS by surrendering UKA via the UK ETS Registry, which HSE and USE operators are not required to do.
Maintenance margin	The amount that a futures trader needs to pay into their account to cover potential losses. If a futures position shows a loss, the trader may need to put more funds into their account to return the margin to its original level (see initial margin above).
Market maker	A financial institution that primarily buys and sells in the market as part of its service to clients, taking some low risk trading positions.
MiFID II	EU Market regulations that require publication of trading information on financial markets. This was transposed into UK law in July 2017.
METS	Manage your Emissions Trading System – a new system for UK ETS permitting, monitoring, reporting and verification, being introduced from summer 2023.
'n= '	The sample size for a given survey statistic.
NIEA	Northern Ireland Environment Agency (the regulator for UK ETS installations and AOs based in Northern Ireland).
NRW	Natural Resources Wales (the regulator for UK ETS installations in Wales).
Off-exchange	Trades in assets which happen between two parties (for example a commodity trader and an operator) outside a formal trading exchange. Also called 'Over the Counter' (OTC) trades.

Term	Meaning
Operator/aircraft operator	Term used for a person that operates an installation or aircraft covered by the UK ETS. The legal term 'person' can mean an organisation.
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning (part of DESNZ) - regulator for offshore oil and gas operators.
Options	Contract giving an option to buy an asset at a specific price at some point in future (in relation to UK ETS, this normally refers to an ICE-traded product).
Over the Counter (OTC)	Trades in assets which happen between two parties (for example a commodity trader and an operator/AO) outside a formal trading exchange. Also called 'off exchange' trades.
Physical UKA	UKA allowances (sometimes termed as 'spot', for immediate delivery), as opposed to derivative contracts such as futures, forwards, options or swaps.
Price discovery	Being able to find an accurate, efficient price for buying or selling an asset at a given point in time.
ROI	Return on investment
Relative traded spread	A measure of market liquidity over short trading intervals. The relative traded spread is the difference between the best price of buyer-initiated trades and the best price of seller-initiated trades, divided by the average of these two prices (in %). Spread measures are calculated for 5-minute trading intervals and then averaged for each trading day.
SAF	Sustainable Aviation Fuel – a drop-in aviation fuel that is made from non-petroleum sources that meet pre-defined sustainability criteria.
SEPA	Scottish Environment Protection Agency (the regulator for UK ETS installations and AOs based in Scotland).

Term	Meaning
Speculator	A trader who buys and sells in the market for profit, taking relatively risky trading positions in the expectation of prices changing.
Spot	Physical UKA for immediate delivery. This term is sometimes used to describe 'daily futures' contracts which mature into UKA at the end of a given contract day.
Swaps	A contract to swap an asset for another asset. In relation to UK ETS, this is normally an off-exchange product.
t+[number]	The number of days between a trade being agreed and the money changing hands (for example t+0, t+1, t+2 …. t+30)
tCO2e (or tCO2e pa)	Tonnes of carbon dioxide (or equivalent greenhouse gases) (or tonnes per annum).
Third Party Intermediary (TPI)	A third party firm which handles compliance or procures energy, UKA or other matters on behalf of other companies.
UK ETS	UK Emissions Trading Scheme
UKA	UK allowances
UK ETS Registry	A secure web-based application that records UK ETS allowances held in accounts, the movement of UK ETS allowances between accounts, and details of the free allocation of UK ETS allowances, verified emissions, and UK ETS allowances surrendered by operators/AOs.
USE	A Ultra Small Emitter installation – a UK ETS installation with very low emissions that qualifies for simplified USE compliance requirements. USE installations do not need to report annual emissions or surrender UKA, but must notify their regulator if they no longer meet USE criteria.
Verifier/verification	Third party verifier
Volatility	Variability of market prices over time.

Appendix 2: Evaluation questions

The full set of evaluation questions is set out below, covering five high level evaluation questions to be addressed during phases 1 and 2 of the evaluation.

- A. Process evaluation – Was the UK ETS efficiently and effectively delivered?
- B. Outcomes evaluation – What were the outcomes of the UK ETS?
- C. Impact evaluation – What have been the impacts of the UK ETS and on whom?
- D. Impact evaluation – How and why have these impacts been delivered?
- E. Impact evaluation – What has been the contribution of UK ETS market design?

Phase 1 of the evaluation was designed to respond to high level evaluation questions A (process) and B (outcomes), as well as generating early insights on question C (impact). Phase 2 of the evaluation will be designed to answer evaluation questions C, D and E.

Under each high level evaluation question, a number of mid level questions were defined. Mid level evaluation questions for A, B and C were used to inform the design of phase 1 evaluation research and structure the presentation of findings in the phase 1 evaluation report. Detailed evaluation questions, set out below, were used to inform the design of questions in the quantitative survey and the topic guides for qualitative research. Further details about the methodology for specific workstreams are presented in Appendix 4.

Table 8: Full set of evaluation questions for phases 1 and 2 of the UK ETS evaluation

PROCESS EVALUATION
A. WAS THE UK ETS EFFICIENTLY AND EFFECTIVELY DELIVERED?
A1. Has the introduction of the UK ETS ensured a smooth continuation of emissions trading for UK emitters previously in the EU ETS scheme?
A1.1 What worked well, or less well, in the transition from EU ETS Phase III to the UK ETS, for whom and why?
A1.2 With hindsight, what aspects of the EU ETS to UK ETS transition could have been improved and is there still scope to adjust these in the UK ETS going forward?
A1.3 What can be learned from the effects on businesses resulting from the EU ETS to UK ETS transition, including implications for future policy?

A1.4 What has been the costs and disruptions associated with transitioning from the EU ETS to the UK ETS for the scheme participants, and how have these varied across sectors and types of regulated operator?
A1.5 Were regulated firms alerted to the establishment of the UK ETS and scheme details in a timely fashion, using appropriate channels and modes of communication, through information which was clear and transparent?
A1.6 Did regulated firms have enough expertise and capacity to engage efficiently with the transition to the UK ETS, or time to build expertise and capacity to do so?
A1.7 Were firms sufficiently aware of the process for allocating free allowances in the UK ETS?
A2. How has the operation of the UK ETS influenced the delivery of a functioning carbon market?
A2.1 To what extent has the capability and capacity of firms affected their ability to pursue carbon abatement plans?
A2.2 To what extent has the capability and capacity of firms affected their ability to pursue optimal trading strategies?
A2.3 To what extent have the cost and hassle of buying and selling allowances (i.e. transaction costs) influenced the way in which firm responded to the scheme? How does this vary within the set of firms under the UK ETS?
A2.4 On the two occasions when the CCM was triggered during 2022, what were the implications of the UK ETS Authority's decision not to intervene and what were operator and traders' perceptions about this?
A2.5 To what extent has the New Entrants Reserve (NER) been an effective instrument to ensures that market entrants are not at a disadvantage compared to incumbents?
A2.6 To what extent have the Hospital and Small Emitters Scheme and Ultra Small Emitters schemes (and the Small Emitters Tool for aviation) facilitated compliance of relevant firms with the UK ETS?

A3. Has the UK ETS delivery ensured that the scheme is administered efficiently and effectively (for both compliance operators in the main scheme as well as participants in the two opt-out schemes: hospitals and small emitters, and ultra small emitters)?
A3.1 What has been operators' and traders' experience of setting up a UK ETS registry account? How did this vary between types of firm and could anything have been improved?
A3.2 What has been operators' experience of the Permitting, Monitoring and Verification process? How did this vary between types of operators and could anything have been improved?
A3.3 What has been operators' experience of annual Activity Level Changes? How did this vary between types of operators and could anything have been improved?
A3.4 What has been operators' experience of the process for allocating free allowances? How did this vary between types of operators and could anything have been improved?
A3.5 What has been operators' and traders' experience of the auction platform, where they have used this? How did this vary between types of firm and could anything have been improved?
A3.6 What has been operators' and traders' experience of the ICE trading platform, where they have used this? How did this vary between types of firm and could anything have been improved?
A3.7 What has been operators' experience of using intermediaries to buy or sell allowances, where they have used them? How did this vary between types of operator and could anything have been improved?
OUTCOMES EVALUATION
B. WHAT WERE THE OUTCOMES OF THE UK ETS?
B1. What has been the behaviour of market participants and what have been the implications of observed behaviour (e.g. for ETS market functioning or for firms' decarbonisation prospects)? How has this varied across different types of firms and sectors?

B1.1 To what extent, and how often, do different types of UK ETS operators review carbon abatement opportunities and associated costs to inform their UK ETS compliance strategy?
B1.2 From which sources, and how often, do different types of UK ETS operators obtain information on carbon abatement opportunities and their costs?
B1.3 To what extent are other government policies influencing the availability of, and informing business decisions about, operators' abatement options?
B1.4 What types of allowance trading strategies have UK ETS operators and traders developed, and how prevalent are these strategies? (e.g. trading for profit, retailing allowances, hedging, periodic forecasting, periodic sales/purchases of allowances, end year compliance, building up stocks of allowances for future years, other strategies)
B1.5 How and why have types of allowance trading strategies varied across different types/sizes of operators, traders and sectors?
B1.6 Are allowance trading strategies evolving over time and if so how, for whom and why?
B1.7 What are the implications (and perceived implications) of operators' and traders' prevailing trading strategies on UK ETS carbon price and other UK ETS market outcomes?
B1.8 What are the barriers to more active participation and trading in the UK ETS market and how might these be removed or mitigated?
B2. Has the UK ETS delivered a carbon market, which is sufficiently accessible to participants and sufficiently liquid to enable its policy objectives to be achieved?
B2.1 What do market indicators suggest about liquidity of the UK ETS market in terms of its level, patterns across time or being influenced by specific events or specific actors?
B2.2 Has the market behaved efficiently, for example in terms of predictability of returns?

B2.3 To what extent has a secondary market for UK ETS developed and why, including development of different financial instruments (e.g. forward contracts, swaps, options)?
B2.4 To what extent has the secondary market allowed purchases of allowances at lower transaction costs compared to auctions?
B2.5 What aspects of UK ETS design have influenced the level / size of trading and liquidity in the primary and secondary market?
B2.6 What external factors (including factors relating to the EU ETS and other ETS systems) have influenced the level / size of trading, decision to trade and liquidity in the UK ETS market?
B3. What are the risks to the effective functioning of the carbon market and how can these be mitigated?
B3.1 What are the main risks to effective functioning of the UK ETS carbon market?
B3.2 How could these risks be mitigated?
IMPACT EVALUATION [IMPACTS]
C. WHAT HAVE BEEN THE IMPACTS OF THE UK ETS SCHEME AND ON WHOM?
C1. What has been the impact of the UK ETS on emissions and emissions intensity in the traded sector and how has this varied across sites, firms, sectors and UK regions?
C2. What has been the impact of the UK ETS on carbon leakage, investment leakage or carbon leakage risk in the traded sector? To what extent and how has carbon leakage, investment leakage and carbon leakage risk in the traded sector been influenced by carbon leakage mitigation policies, such as free allocation?
C2.1 Has UK ETS caused an increase in the level of imports and/or a decrease in the level of exports in traded sectors across sites, firms and sectors?

C2.2 Has the UK ETS influenced investment and location decisions in the traded sector across sites, firms and sectors?
C2.3 Has the UK ETS influenced activity levels and employment in the traded sectors across sites, firms and sectors?
C2.4 To what extent, and how, have free allocation of allowances, and other carbon leakage mitigation policies, mitigated carbon leakage and investment leakage?
C2.5 What changes would be needed for free allocation and other carbon leakage mitigation policies to work more effectively?
C3. Have there been any unanticipated consequences of UK ETS in the traded or non-traded sectors, and how have they varied across different types of firm or sector or UK region?
C3.1 Has the introduction of the UK ETS lead to an increase in consumers' and producers' prices as a consequence of UK ETS firms passing through carbon costs, and how has this varied between different types of site, firm and sector?
C3.2 What have been the impacts of the UK ETS on carbon emissions and economic activity of firms in the non-traded sector?
C3.3 Are there any other unanticipated consequences of the UK ETS in the traded or non-traded sectors, and how have these varied across different types of firm, sector or UK region?
IMPACT EVALUATION [DELIVERY MECHANISMS]
D. HOW AND WHY HAVE THESE IMPACTS BEEN DELIVERED?
D1. To what extent and how has the UK ETS encouraged participants to abate their carbon emissions through operational changes and deployment of technologies for energy, carbon or resource-efficiency across sites, firms and sectors?
D1.1 To what extent does access to cost-effective abatement solutions (e.g. technologies, fuels) differ by sector, firm size and geography?

D1.2 To what extent have operators' UK ETS compliance plans included abatement activities?
D1.3 How have carbon abatement strategies and decarbonisation plans evolved over time during the different phases of the EU ETS and UK ETS, what factors have influenced this evolution (e.g. allowance prices, net zero goals, other factors), and to what extent has this evolution differed by sector, and organisation capacity and capability?
D1.4 To what extent have abatement options become more cost effective across time as a consequence of the UK ETS or other supporting policies?
D1.5 To what extent has abatement been delivered through reduced activity levels?
D1.6 What has been the role of fuel substitution in decarbonisation of the traded sector?
D1.7 What has been the role of onsite renewables in decarbonisation of the traded sector?
D1.8 What has been the role and extent of operational changes in decarbonisation of the traded sector?
D1.9 Has the UK ETS delivered increased efficiency in the use of energy fuels? (e.g. reduction in wastage; reduction in gas flaring activity)
D1.10 Has the UK ETS increased investment in energy or carbon-efficient technologies and services, and if so which?
D1.11 What barriers have operators faced in implementing carbon abatement measures, and how could these barriers be removed or mitigated?
D1.12 What was the role of resource efficiency in delivering the impact of the UK ETS in the traded sector?
D1.13 To what extent has the UK ETS (and/or the existence of a UK carbon price) contributed to the development of long-term decarbonisation plans within industry?

D2. Has the UK ETS stimulated research, innovation and R&D in a way which is consistent with the long-run trajectory of the scheme?
D2.1 Has the UK ETS influenced low-carbon R&D in the traded and non-traded sector, and if so how?
D2.2 Has the UK ETS helped stimulate low-carbon innovation by operators or non-obligated firms, as measured by patents, and if so how?
D2.3 Has the UK ETS raised interest or investment in, or deployment of, long-term abatement options or deep decarbonisation technologies such as Hydrogen and CCUS, and how has this varied by type of site, firm, sector or location?
D2.4 Has the UK ETS lead to a decrease in R&D which is not related to low-carbon in the traded and non-traded sector, and if so how?
D3. Has the UK ETS influenced consumption of low-carbon products within and outside the UK?
D3.1 Has the UK ETS contributed to an increased market share for low carbon products compared to alternatives?
D3.2 Has the UK ETS contributed to a reduction in the relative price of low-carbon products compared to alternatives, through prices incorporating the market carbon price?
D3.3 Has the UK ETS contributed to an increase in the supply of low-carbon materials and services to UK ETS operators, to enable them to abate?
IMPACT EVALUATION [DESIGN AND DECARBONISATION POLICY]
E. WHAT HAS BEEN THE CONTRIBUTION OF UK ETS MARKET DESIGN?
E1. How have the details of UK ETS design (e.g. cap, free allocations and market stability policy) impacted on decarbonisation activity across sites, firms, sectors and UK regions?

E1.1 How have free allocation of allowances impacted on decarbonisation in different UK ETS sectors and UK regions?
E1.2 How has the UK ETS cap (and expectations related to the future cap) impacted on decarbonisation plans and activities across firms, sectors and UK regions?
E1.3 To what extent has an expectation that the price of allowances will rise over time increased firms' confidence in making long term investments to deliver decarbonisation?
E1.4 Have UK ETS price stability mechanisms contributed to the business case for decarbonisation investments in different UK ETS sectors?
E1.5 How have other aspects of the UK ETS (e.g. carbon price level, carbon price volatility, linkage status, policy uncertainty, liquidity or other) influenced the contribution of the scheme to decarbonisation in different sectors?
E1.6 How have complementary or competing policies in the UK interacted with the UK ETS to support or undermine the influence of the scheme on decarbonisation?
E1.7 How have external factors, including macro-economic variables, international factors, international ETS schemes and international carbon policies, affected the contribution of the UK ETS to decarbonisation?
E2. How have the details of UK ETS design impacted competitiveness across sites, firms, sectors and UK regions?
E3. How have the details of UK ETS design impacted carbon leakage across sites, firms, sectors and UK regions?
E2.1 To what extent have free allowances protected UK industry and UK airports' competitiveness and mitigated carbon leakage, and how has this varied across sites, firms, sectors and UK regions?
E2.2 To what extent has UK ETS indirectly improved the competitiveness of UK industry by stimulating innovation or investment in decarbonisation technologies, and how has this varied across sites, firms, sectors and UK regions?
E2.3 How has the UK ETS cap (and expectations related to the future cap) impacted on competitiveness and carbon leakage in different UK ETS sectors?

E2.4 How have price stability mechanisms within the UK ETS mitigated impacts on competitiveness and carbon leakage across sites, firms, sectors and UK regions?
E2.5 How have other aspects of the UK ETS (e.g. current carbon price level, future expectations of carbon price levels, carbon price volatility, linkage status, policy uncertainty, liquidity or other) influenced competitiveness and carbon leakage across sites, firms, sectors and UK regions?
E2.6 How have complementary or competing policies in the UK interacted with the UK ETS to affect impact in competitiveness and carbon leakage?
E2.7 How have external factors, including macro-economic variables, international factors, international ETS schemes and international carbon policies, affected the competitiveness of UK ETS sectors [including cost pass through] and carbon leakage?

Appendix 3: Theory of Change, including interim assessment of assumptions

The following figure and table provide an assessment of the 41 assumptions associated with the UK ETS theory of change (ToC). These have been assessed systematically, where this was feasible using the evidence gathered in phase 1 of the evaluation. The TOC assessment process involved review of evidence from the phase 1 qualitative research, quantitative survey, secondary market data analysis and preliminary network analysis.

As this is a two-phase evaluation, the majority (all but 1) of assessments are interim and will be revisited at the end of phase 2. In relation to interim assessments, the terms ‘supported’, ‘partially supported’ or ‘unsupported’ are used to indicate the outcome suggested by the currently available evidence.

The majority of assumptions, 24, were assessed as being ‘supported’ or ‘partially supported’ by the evidence. One was found to be unsupported. The evidence was found to be insufficient to make an assessment of 16 of the assumptions and these have been assessed as ‘unproven’. One assumption has been identified as proven: this is because it refers to a specific event, and this event (the alignment of the scheme cap with the UK and devolved government’s net zero target) was announced in July 2023.

This Appendix presents:

- A summary ToC diagram showing the interim assessment of each assumption in relation to the high-level causal chain in the summary ToC.
- A table presenting the interim assessment of each assumption, which summarises the evidence on which each assessment was based.
- A full ToC diagram, showing the causal chain and assumptions in full. This diagram is not readable on a single A4 page, so is spread over several pages.

The assumptions in the ToC are numbered, starting with A1 at the bottom of the diagram, running through to A41 at the top.

Figure 18: Summary Theory of Change with interim assessment of assumptions

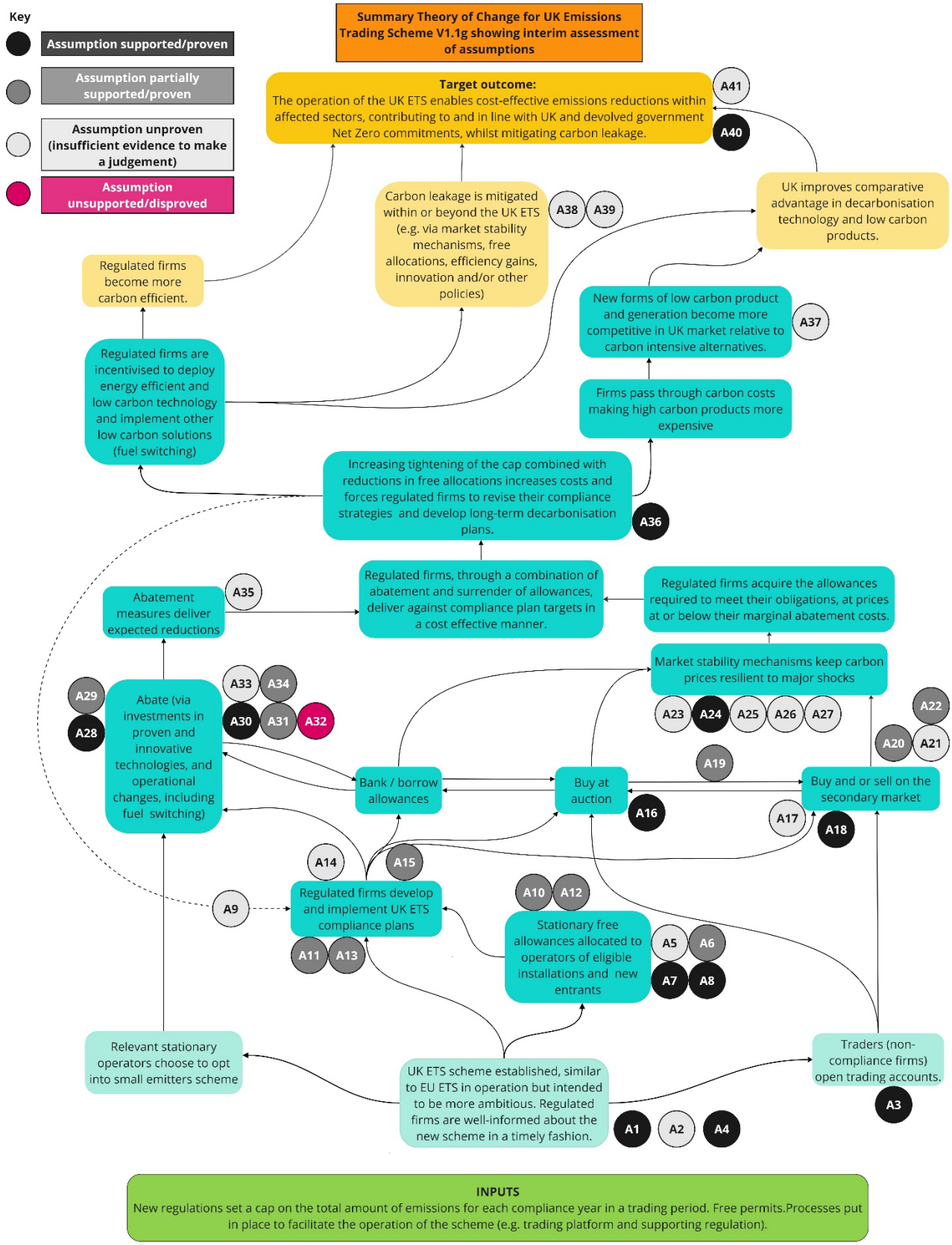


Table 9: Interim assessment of assumptions in Theory of Change (ToC)

Code	Assumption	Summary Assessment (interim assessments, based on evidence collected and analysed during phase 1 only)	Assumption supported/ proven	Assumption partially supported/ proven	Assumption unproven (insufficient evidence to allow an assessment to be made)	Assumption unsupported/ disproved	Assumption found not to be relevant
A41	Absolute level of operator emissions reduces as a result of the UK ETS.	Not being considered in phase 1. To be assessed after completion of phase 2 work. Currently this assumption is assessed as unproven.			X		
A40	Assumed that regulated firms will comply.	Non-compliance of small aircraft operators has been an issue, but phase 1 qualitative evidence suggested that incidents of non-compliance associated with this group are in decline. No other compliance problems were reported and therefore this assumption is assessed as supported.	X				
A39	Overall level of economic activity and investment is not adversely impacted by the UK ETS.	Not being considered in phase 1. To be assessed after completion of phase 2 work. Currently this assumption is assessed as unproven.			X		
A38	Carbon leakage is mitigated.	Evidence of carbon leakage will be assessed during phase 2 of the evaluation. Currently this assumption is assessed as unproven.			X		
A37	More UK firms providing more low carbon goods and services. This assumption rests on the following premises. The potential displacement of high carbon products as the UK ETS makes them more	Not being considered in phase 1. Issue not anticipated as being explored in phase 2 and may lie outside of the scope of the evaluation. Currently this assumption is assessed as unproven.			X		

Code	Assumption	Summary Assessment (interim assessments, based on evidence collected and analysed during phase 1 only)	Assumption supported/ proven	Assumption partially supported/ proven	Assumption unproven (insufficient evidence to allow an assessment to be made)	Assumption unsupported/ disproved	Assumption found not to be relevant
	expensive in comparison to low carbon alternatives. Regulated operators generate an increased demand for low carbon goods and services via their abatement activities.						
A36	From 2023/24 the cap will be aligned to UK's Pathway to Net Zero.	The scheme was aligned with the UK's pathway to net zero in July 2023 and the assumption is assessed as being proven. N.B. Some stakeholders (qualitative research) noted that the cap has been aligned with the least stringent of the net zero pathways.	X				
A35	Some level of permanent abatement occurs (deployment of low carbon technologies rather than simply reducing production).	The quantitative research identifies a range of planned/proposed abatement behaviours. If implemented these would be expected to deliver permanent abatement – for example, most of the listed options involve the deployment of decarbonisation technologies or fuel switching – but evidence relating to delivered abatement (associated with the UK ETS) will not be gathered until phase 2 of the evaluation and therefore the assumption is assessed as unproven.			X		
A34	Assumption that UK ETS signal is supported and reinforced by a coherent package of other forms of 'companion' policy and businesses are enabled to /	There was some qualitative evidence that other decarbonisation policies were interacting, in a complementary fashion, with the UK ETS. Identified policies included CCA, CCL, ESOS, Carbon Price Support, Hydrogen business model and		X			

Code	Assumption	Summary Assessment (interim assessments, based on evidence collected and analysed during phase 1 only)	Assumption supported/ proven	Assumption partially supported/ proven	Assumption unproven (insufficient evidence to allow an assessment to be made)	Assumption unsupported/ disproved	Assumption found not to be relevant
	supported in developing responses to address ever more stringent targets?	green gas support scheme. For some operators, these schemes were as influential as the UK ETS in informing their decarbonisation behaviours. Some trader interviewees made explicit links between the UK ETS and other work (hydrogen, renewables) that their wider company was involved in. However, the research provided no clear evidence that the identified forms of support have been developed and delivered in a coherent and mutually reinforcing package. In the absence of insight relating to the latter, the assumption is assessed as partially supported.					
A33	Assumption (implicit) that firms have similar levels of technological literacy / capability and are equally able to initiate / introduce innovation?	This issue was not explored in the phase 1 research and therefore the assumption is classed as unproven.			X		
A32	Firms are confident in long term direction of travel - in relation to decarbonisation policy - and are therefore prepared to make long term capital investments to deliver decarbonisation.	The qualitative research suggests that there is a lack of confidence in the long-term direction of travel for net zero policy, and that this undermines businesses ability to plan and deliver major capital projects. This assumption is therefore currently assessed as being unsupported.				X	

Code	Assumption	Summary Assessment (interim assessments, based on evidence collected and analysed during phase 1 only)	Assumption supported/ proven	Assumption partially supported/ proven	Assumption unproven (insufficient evidence to allow an assessment to be made)	Assumption unsupported/ disproved	Assumption found not to be relevant
A31	Cost of allowances is significant enough to prompt action (other than simple compliance response)	Around six in ten (62%, n=105) of installation operators reported (quantitative research) that the cost of UKAs influenced decarbonisation investment in UK plants, equipment or machinery. But only one in five aircraft operators (20%, n=78) said that the cost of UKAs had influenced their organisation to increase decarbonisation investment in new aircraft or aircraft upgrades. The qualitative research found that there were multiple factors, including non-cost factors, driving abatement. The evidence supports the view that the cost of allowances influences abatement decisions for many, but not all operators. As a result, the assumption is assessed as partially supported.		X			
A30	There are limited abatement options for aviation. This may lead to price rises being passed on to consumers.	This sector consistently reported (qualitative research) that there was a lack of technical abatement solutions for the sector beyond use of SAF. The research found that aircraft operators mainly focused on operational efficiencies and increased use of SAF. There was also evidence that the additional costs of the UK ETS are passed onto customers. This assumption is assessed as supported.	X				
A29	Assumption that abatement, to some level, is the most cost-effective response and that firms are rational actors.	The majority of participants in the quantitative survey (90%, n=204) reported having a plan to reduce carbon emissions.		X			

Code	Assumption	Summary Assessment (interim assessments, based on evidence collected and analysed during phase 1 only)	Assumption supported/ proven	Assumption partially supported/ proven	Assumption unproven (insufficient evidence to allow an assessment to be made)	Assumption unsupported/ disproved	Assumption found not to be relevant
		The qualitative research confirmed that most firms were actively pursuing current carbon abatement opportunities. Around six in ten (62%, n=105) of installation operators reported (quantitative research) that the cost of UKAs influenced decarbonisation investment in UK plants, equipment or machinery. But only one in five aircraft operators (20%, n=78) said that the cost of UKAs had influenced their organisation to increase decarbonisation investment in new aircraft or aircraft upgrades. The qualitative research found that there were multiple factors, including non-cost factors, driving abatement. The evidence supports the view that abatement is widely seen as an appropriate response to the UK ETS, but that the scheme is only one of several drivers and some of these are non-cost related. Firms' abatement decisions take account of non-cost as well as cost factors, so cost-effectiveness is only aspect of abatement decision-making. As a result, the assumption is assessed as partially supported.					
A28	At least some firms have access to abatement solutions (technology/fuels) that meet their technical needs and are	The quantitative research found that 90% (n=204) of respondents had a carbon reduction plan in place. Plans were found to include a range of decarbonisation options. Almost a quarter of respondents said their faced no hurdles in relation to their plan, but	X				

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	cost effective at expected UK ETS price levels.	others identified a range of barriers to decarbonisation, with the most commonly cited (31%, n=183) barrier being the availability of future carbon reduction technologies. The evidence indicates that many operators do not currently have access to at least some forms of abatement technology. However, the UK ETS theory anticipates that not all operators/AOs will have access to abatement solutions at any point in time. Therefore, given that 24% (n=183) of survey respondents suggested that they faced no difficulties in implementing their plans, the assumption is assessed as supported.					
A27	CCM mechanism is applied in a timely and effective fashion.	The CCM has been triggered twice so far but the intervention mechanism has not been applied. The qualitative research found mixed views on whether the CCM mechanism should have been applied. Some felt that the government should have intervened. Others felt that the decision not to intervene had been correct but suggested that if the same rationale (as they understood it) continued to apply then the CCM might only ever be applied at a price point likely to cause harm to at least some industry sectors. Another concern, was that the application of the CCM appeared to be discretionary, rather than based on a transparent metric. In summary, there is evidence of confusion in the			X		

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		marketplace about the circumstances under which the CCM mechanism should be applied. This casts doubt on the validity of this assumption, but in the absence of an actual event it is considered that it can only be assessed as unproven.					
A26	Assumed that the increases (in the price of allowances) of the scale necessary to trigger the CCM are more likely to occur in the early years.	The CCM has been triggered twice in the first two years of scheme operation. This supports the assumption that the CCM was likely to be triggered in the early years of the scheme. However, some interviewees in the qualitative research suggested that the triggering of the CCM was due to a methodological flaw, rather than market conditions alone. This matter requires clarification, until this is available the assumption is assessed as unproven.			X		
A25	CCM maintains price of allowances at a level that avoids market distortion arising from speculative pressures.	The CCM was triggered twice but no intervention was deemed necessary. It is possible that the presence of the CCM exerts a restraining influence on speculators, but there is no evidence to support this view and therefore the assumption is assessed as unproven.			X		
A24	Early years stability mechanisms (CCM, ARP) are required to offset potential disruption, associated with price discontinuity, following the UK leaving the EU ETS. (ARP expected to be	There was some support, in the qualitative research, for the presence of an ARP and CCM. Interviewees, expressed views on the operation of the ARP and CCM, including suggestions for how their operation might be improved. This suggests that at least some interviewees saw a role for these	X				

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	transitory. CCM will continue but is expected to become less reactive over time.)	mechanisms and saw them as potentially useful / necessary. The price of UK ETS allowances has exhibited considerable volatility in its first two years and the CCM has been triggered twice. Taken together, these findings suggest that the assumption that stability mechanisms would be required was well founded and the assumption is assessed as being supported.					
A23	ARP transitory - only intended as an initial stability mechanism. Assumption is that the ARP is not expected to be needed moving forward.	There was some support, in the qualitative research, for the presence of an ARP, but the prevailing view was that it was largely irrelevant as allowances were trading at a far higher rate than the ARP. This suggests that the ARP could be removed without affecting the operation of the UK ETS. Post the evaluation research period, however, the value of allowances has fallen much closer to the ARP and this raises the possibility that the ARP may yet be required. Overall, it is felt to be too early to make a judgement of this assumption and it is assessed as unproven.			X		
A22	Sufficient liquidity achieved despite limited number of market actors (buyers and sellers).	The secondary market data analysis found that, for the periods analysed by the evaluation to date, the UK ETS was sufficiently liquid to be considered a functioning market.		X			

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		Qualitative evidence was mixed, but there was a widely reported view that the UK ETS suffered from poor liquidity. Others, however, suggested that, whilst naturally constrained by the size of the UK ETS market, there was sufficient liquidity to enable the market to function. Whilst there was widespread concern about the liquidity in the qualitative research, the fact that there was some disagreement on this point, and in particular the findings from the secondary analysis, lead to an assessment of this assumption as partially supported.					
A21	Firms enabled to pursue increasingly sophisticated trading behaviours as the secondary market evolves.	The qualitative research found that some types of operator/AO (higher emitters) have moved from annual procurement to more sophisticated patterns of buying (and selling). It is not, though, clear that this has been enabled by the evolution of the secondary market. The range of products traded in the secondary market was reported as being largely limited to futures with the emergence of more complex products, reportedly constrained by a perceived lack of liquidity in the UK ETS market. On the balance of the available evidence, this assumption is assessed as unproven.			X		
A20	Level of trading activity will be dependent upon the volume of	There is some qualitative evidence of changes in operator/AO buying behaviour,		X			

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	free allowances released. As the cap tightens operators need to engage in trade (or abate) more.	buying more frequently, owing to the increased unit cost of allowances and a reduction in the volume of free allowances allocated to operators. This assumption is assessed as partially supported.					
A19	Trading platform is designed and regulated to minimise barriers to trade and to encourage / enable participation by non-compliance actors.	The qualitative research found that non-compliance actors are active participants in the auction and ICE. Some problems with registering for the auction were identified by non-UK based interviewees. Participation in the auction and ICE requires participants to have a relationship with a clearing house. In the qualitative research, clearing house interviewees noted that they set a high bar for organisations wishing to use their clearing services. This was not identified as a barrier by other interviewees but seems likely act as such. On the basis of the available evidence, this assumption is assessed as partially supported.		X			
A18	Flexible option, allows buying in real time, large / small volumes. Lower entry bar (in comparison to auctions). Allows futures / forward contracts and therefore hedging.	This assumption is interpreted in terms of smaller firms' direct access to ICE, rather than access to OTC trading. The qualitative evidence indicates that operators and traders who directly use ICE value its flexibility (in comparison to the auction), use it to buy both small and large volumes of product (some identified challenges with buying large volumes, others had found ways to address these).	X				

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		Some qualitative interviewees reported that ICE was more accessible (and flexible) than the auction as participants did not need to commit to an immediate cash purchase, this benefited organisations with affected by cash flow constraints. Evidence from the quantitative research, found that some operators felt that the bar for those wishing to access ICE was high with reasons for not directly engaging with ICE including a lack of expertise (17%, n=151) and concerns about the burden of meeting the compliance requirements (12%, n=151). This research did not, however, provide insight into the comparative accessibility of ICE and the auction. Finally, ICE was identified as an important enabler of hedging activity, mainly through trading in futures contracts. Based on the preceding evidence, this assumption is assessed as supported.					
A17	Assumption that transaction costs of trading on the secondary market (specifically the ICE platform) are not prohibitive for smaller firms.	This assumption is interpreted in terms of smaller firms' direct access to ICE, rather than access to OTC trading. The qualitative research identifies a lack of in-house expertise as the main reason for not engaging directly with the ICE, but some interviewees also identified the cost and hassle associated with registration with ICE as reasons for their not using this market mechanism. Interviewees who reported using ICE, noted that it was quite			X		

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		complex and costly to register with the platform. The qualitative research sample was intentionally biased in favour of larger operators. The perspectives of smaller operators are reflected in the quantitative survey (although reporting relating to trading behaviour also included high emitters). This found that most (78%, n=204) of survey participants did not engage directly with trading platforms, relying instead on external actors (88% use brokers, n=157) to undertake trades on their behalf. Only 3% (n=204) were found to buy derivatives on ICE on their own behalf (although this group were identified as being responsible for 27% of emissions). Of this group (n=24), 59% access the platform via intermediaries and only 23% reported that they were members of the exchange. Reasons given for not directly engaging with the secondary market included a lack of expertise (17%, n=151) and concerns about the burden of meeting the compliance requirements (12%, n=151). Overall, whilst the research found some evidence that the cost of engaging with ICE was seen as high by some large emitters (although they were using this mechanism), there is no evidence to support the view that trading costs are a barrier for smaller firms. The assumption is therefore assessed as unproven.					

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A16	Assumed auction used for purchase of large volumes. Lower per unit transaction costs, but higher entry bar (in terms of cost / complexity).	Evidence from qualitative research (trader interviews) supports the assumption that the auction is seen as a cost-effective means of procuring larger volumes of allowances. This research also supports the suggestion that participation in the auction has a high entry bar in terms of cost, and the additional complexity associated with registering to be an auction participant. This assumption is assessed as supported. NB an additional barrier, not considered within the assumption, is the need to be able to pay upfront for allowances. Not all firms have sufficient cash flow to do this, whilst others prefer not to as it ties up capital.	X				
A15	Assumed that firms pursue a mix of responses (hold, abate, buy, sell) and that they aim to respond in the most cost-effective manner through active trading as opposed to 'compliance' behaviour).	The quantitative research found that 90% (n=203) of respondents had a carbon reduction plan in place, such plans were found to include a range of decarbonisation options. Whilst some (24%, n=183) reported no barriers to plan implementation, others identified a range of barriers. The intervention theory suggests that those facing barriers to abatement will rely on submitting UKETS allowances and will look to do so in the most cost effective fashion. In practice, 44% (n=169) of survey respondents reported that they only buy allowances once a year, i.e. they are not buying at 'lowest cost' and are therefore not		X			

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		taking the most cost-effective approach available to them. The qualitative evidence identifies a range of compliance behaviours available to operators but also finds that some operators are prepared to accept the risk of higher costs associated with simpler forms of procurement activity, owing to various internal situational factors and constraints. Overall, the research indicates that operators are practicing multiple forms of compliance behaviour, but a significant proportion are not trading in the most cost-effective manner and therefore this assumption is assessed as being partially supported.					
A14	Regulated firms have differing marginal abatement costs. The trading options encourages and enables firms with higher marginal abatement costs to reallocate emissions reduction responsibility to firms with lower marginal abatement costs.	Phase 1 research did not generate sufficient information to allow for an assessment of this assumption and it is therefore classed as unproven.			X		
A13	Regulated firms are aware of technical abatement options and costs.	Both the quantitative and qualitative research suggest that there is a good level of understanding of the available abatement options within the operator population. However, a significant proportion (25%, n=183) of operators reported that they did		X			

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		not have the capacity or capability to consider abatement options. Meanwhile, 31% (n=183) of operators reported that there were considerable uncertainties associated with carbon reduction technologies. On balance therefore, this assumption is assessed as partially supported.					
A12	Free allowances provide sufficient protection for firms with expensive abatement and who can't pass the cost of allowances on (for example, owing to exposure to trade).	Qualitative findings suggest that, at the time that the research was conducted, the use of free allowances serves to mitigate the risk of carbon leakage, but the extent to which it does so varies by operator sector. Interviewees in energy intensive industries, particularly commodity producers, reported that free allowances were important in reducing the risk of carbon leakage, but cited examples of where leakage has occurred. In addition, there was evidence of concern that future reductions in allowances might lead to further carbon leakage. Consequently, this assumption is assessed as partially supported.		X			
A11	Capacity / capability constraints do not adversely affect firms (operators) ability to implement / pursue trading behaviours.	The qualitative research, particularly the realist classification of trading behaviours, suggests that many operators have internal capacity and capability constraints, but in the main such deficiencies are addressed by bringing in expert, external, support (78% (n=204) of survey respondents		X			

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		reported that they use external organisations for trading). Operators involved in the qualitative research were found to practice a range of approaches to trading, these were informed by multiple factors, but a lack of capacity and capability was not identified as a constraint on their ability to implement or pursue their preferred trading/procurement strategy. However, the qualitative research only involved high emitting operators and these findings may not hold true for other groups. This being the case, the assumption is assessed as partially supported.					
A10	Initial UK ETS free allocation approach similar to that of EU ETS Phase IV ensures a smooth transition and reduce the risk of short-term distortion of competitiveness.	Of those survey participants who received free allowances, 44% (n=104) suggested that they were satisfied with the process, however, there was evidence of significant dissatisfaction with 23% (n=104) reporting that they were dissatisfied. The qualitative research also found evidence of dissatisfaction, identifying several areas of concern. It is not known if the identified issues with free allowance allocation impacted on competitiveness, but there is sufficient evidence of dissatisfaction to suggest that this assumption should be assessed as partially supported.		X			
A9	Firms access to capacity and capability increases. More	This assumption is associated with a feedback loop in the ToC and it is not			X		

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	sophisticated compliance plans evolve over time	intended to make an assessment based on the phase 1 work (it being considered too early). Currently, the assumption is assessed as unproven.					
A8	The power sector do not receive any free allocation in the UK ETS as it is assumed that they are in a position to pass on costs (and thereby maintain profitability)	Evidence from the qualitative research suggests that, in general, power sector operators use a 'cost plus' pricing model (meaning that power prices are based on actual costs plus a profit margin) and that this enables them to pass on the cost of carbon to their customers. As such, this assumption is assessed as supported.	X				
A7	Free allowances mitigate potential negative impacts of carbon pricing on business competitiveness and reduce the risk of carbon leakage from the UK.	Qualitative findings suggest that, at the time that the research was conducted, the use of free allowances serves to mitigate the risk of carbon leakage, but their importance varies by business sector. Interviewees in energy intensive industries reported that free allowances were important in reducing the risk of carbon leakage. There was, though, evidence of concern that future reductions in allowances might lead to carbon leakage. Operators in less energy intensive sectors suggested that carbon pricing was less of a factor in their decision making. This assumption is therefore assessed as supported.	X				
A6	NER (specifically the Activity Level Change mechanism) provides a means of	Operator interviewees (qualitative) reported that the Activity Level Change (ALC) process was cumbersome and entailed the		X			

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	dynamically increasing or reducing free allocations to incumbent (stationary) installations in response to changing economic conditions.	need to bring in consultancy support. Operators also reported delays in the approval process and identified this as creating uncertainty, whilst the 2-year adjustment timeframe was associated with unanticipated negative impacts for some firms. Evidence from the quantitative survey is, however, more mixed with 48% (n=77) of participants indicating that they were satisfied with the activity level reporting process. On balance, the available evidence suggests that this assumption is partially supported.					
A5	NER ensures that new stationary market (i.e. installation operators) entrants are not competitively disadvantaged against incumbents.	Phase 1 research generated limited insight regarding the functioning of the New Entrants Reserve (NER). Some operators reported that there was a time lag associated with the receipt of allowances via the NER which could be a barrier for those considering the construction of new energy intensive plant. The Environment Agency clarified that operators could apply for free allowances to cover activities in the year following the start of new operations. This evidence is assessed as insufficient to enable a definitive assessment and so the assumption is assessed as unproven.			X		
A4	Aside from small emitters, scheme design assumes that all regulated firms have sufficient capacity and	There was some evidence, from both qualitative and quantitative research, that engaging with the new scheme and the transition process involved a considerable	X				

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	capability to engage effectively with the UKETS (this assumption relates to the introduction of the scheme).	time commitment from operators, but no evidence was found to support the view that firms had been unable to engage owing to capacity/capability constraints. However, some evidence was found to suggest that the late introduction of the scheme was a source of 'stress' for some operators. This suggests that whilst operators were able to cope, they may, in at least some instances, have been under some strain during the transition phase. Nevertheless, this assumption is assessed as supported.					
A3	Traders assumed to have been involved in EU ETS and to be monitoring the introduction of the new scheme.	Qualitative research with UK ETS traders indicates that they were involved in the EU ETS prior to the establishment of the UK ETS. It also suggests widespread awareness of and were involvement in, discussions regarding UK specific successor schemes. This assumption is therefore assessed as supported.	X				
A2	Initially tightening the cap by -5% (and not more) provides an appropriate balance between climate ambition in the context of the UK's net zero commitment and business competitiveness, which may be at risk due to early years' market behaviour.	Phase 1 research alone is considered insufficient to allow for an assessment of this assumption. Assessment is deferred until the completion of phase 2 evaluation work. This assumption is therefore assessed as unproven.			X		

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A1	Minimising change to the initial scheme minimises disruption for regulated firms (operators).	Qualitative evidence explicitly supports the assumption that minimising the differences between the EU and initial UK ETS reduces disruption for operators. Some supporting evidence can be taken from the quantitative evidence which suggests that most survey participants found the transition to have been managed successfully. This assumption is therefore assessed as supported.	X				

The full theory of change diagram is shown below, followed by close-ups of different sections of the diagram, showing how the assumptions relate to the causal links in the logic chain.

Figure 19: Full Theory of Change for UK ETS (see close-ups in subsequent figures)

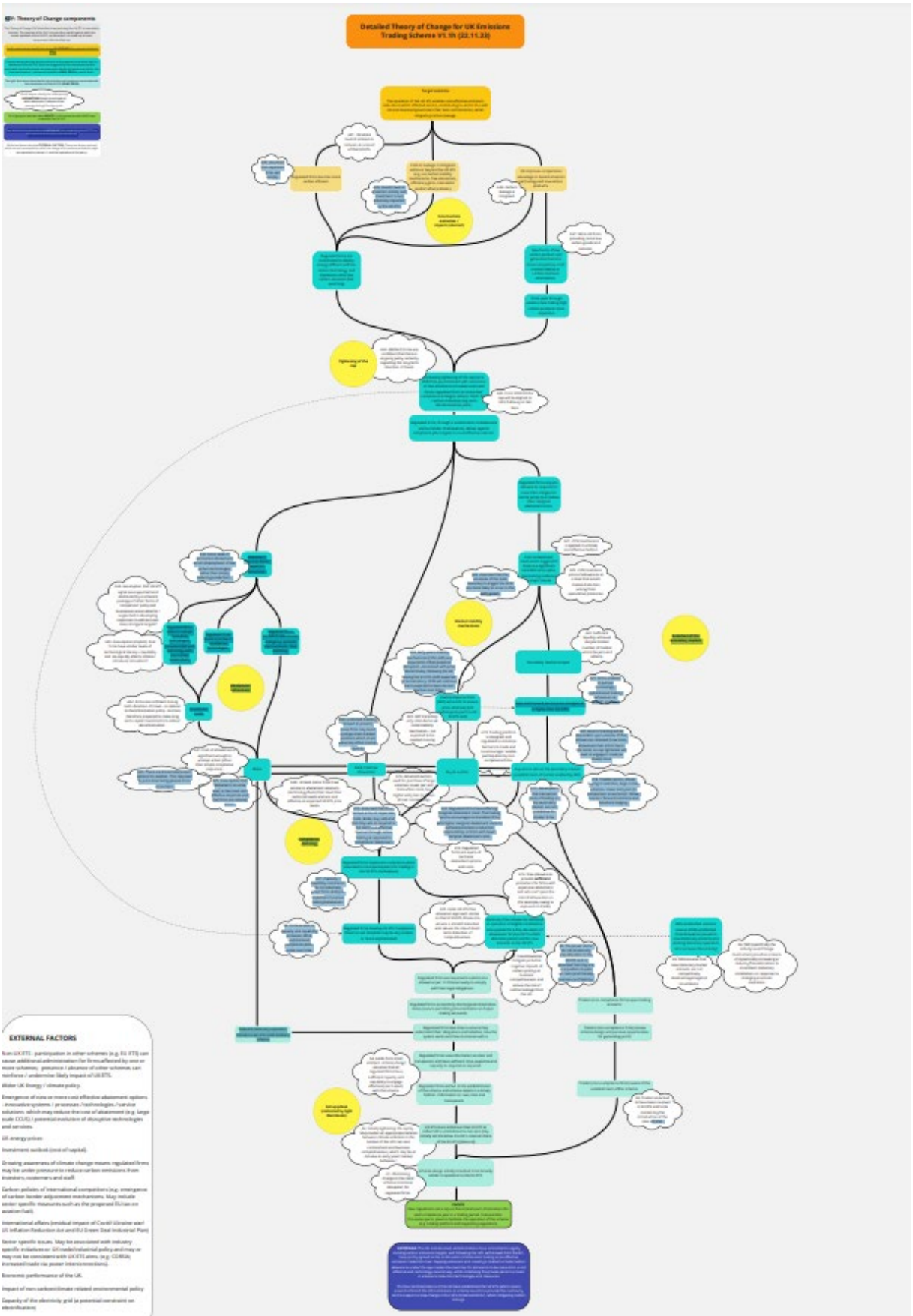


Figure 20: Close-up of Full Theory of Change – p1 (top section)

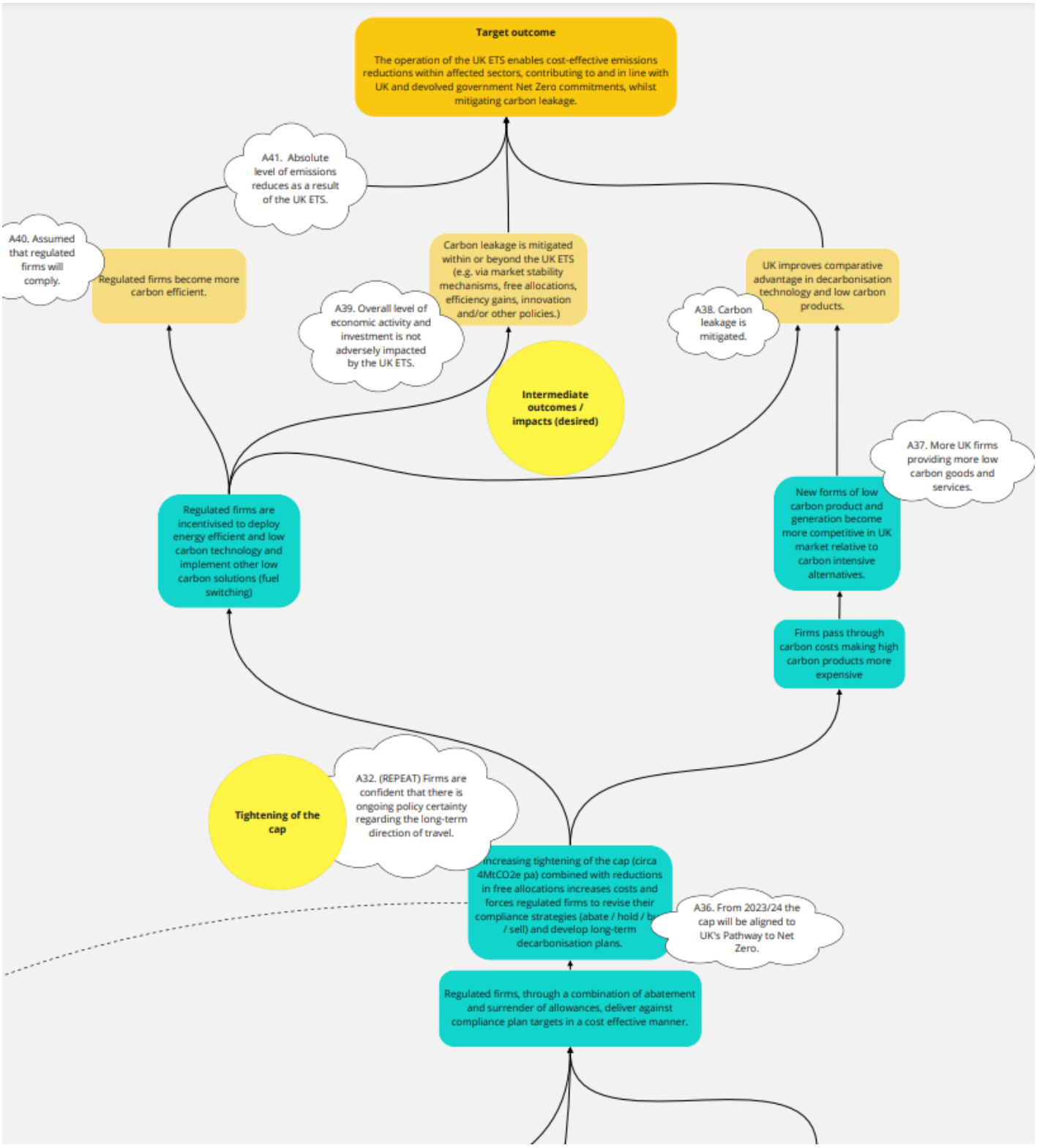


Figure 21: Close-up of Full Theory of Change – p2 (right part of central section)

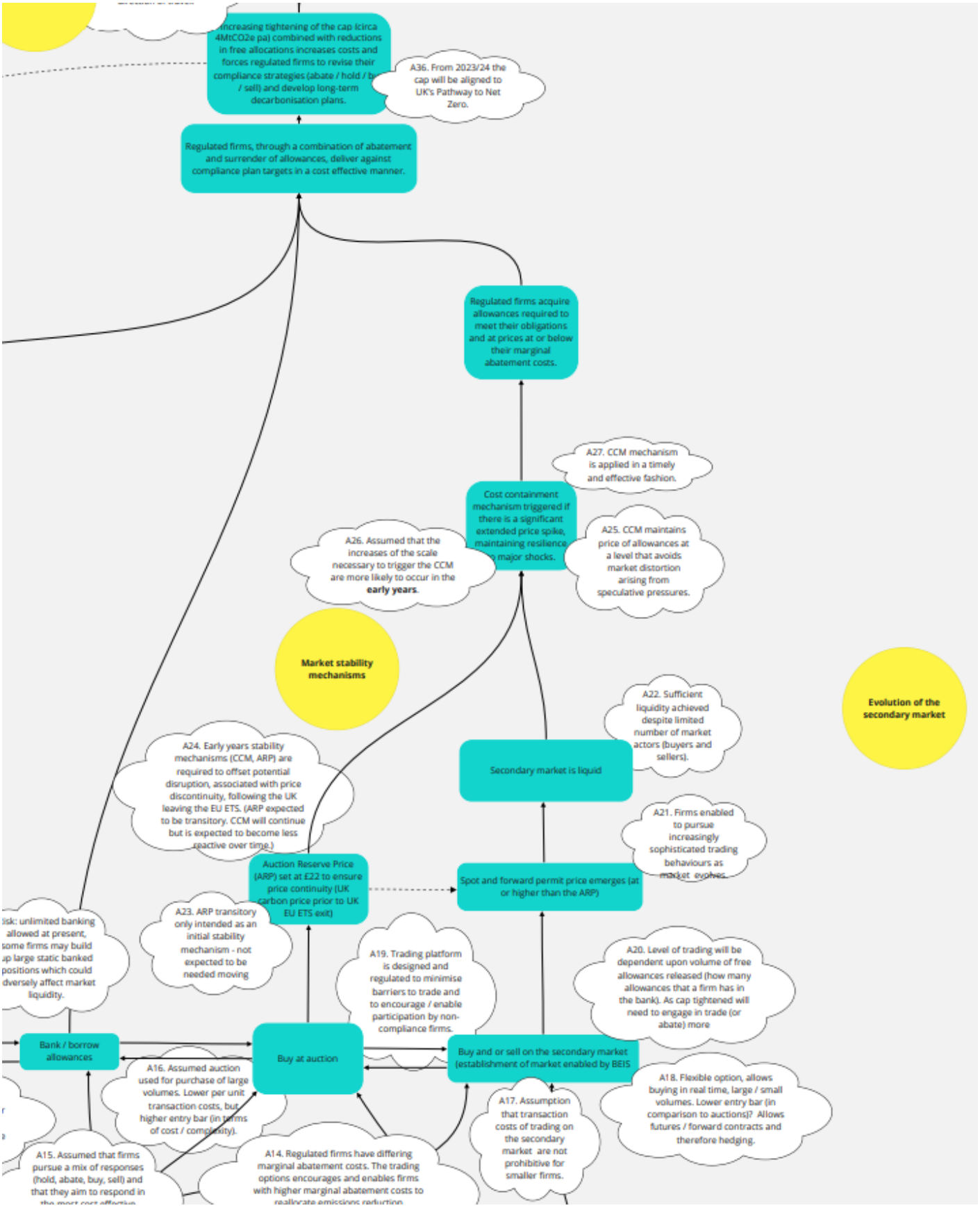


Figure 22: Close-up of Full Theory of Change – p3 (left part of central section)

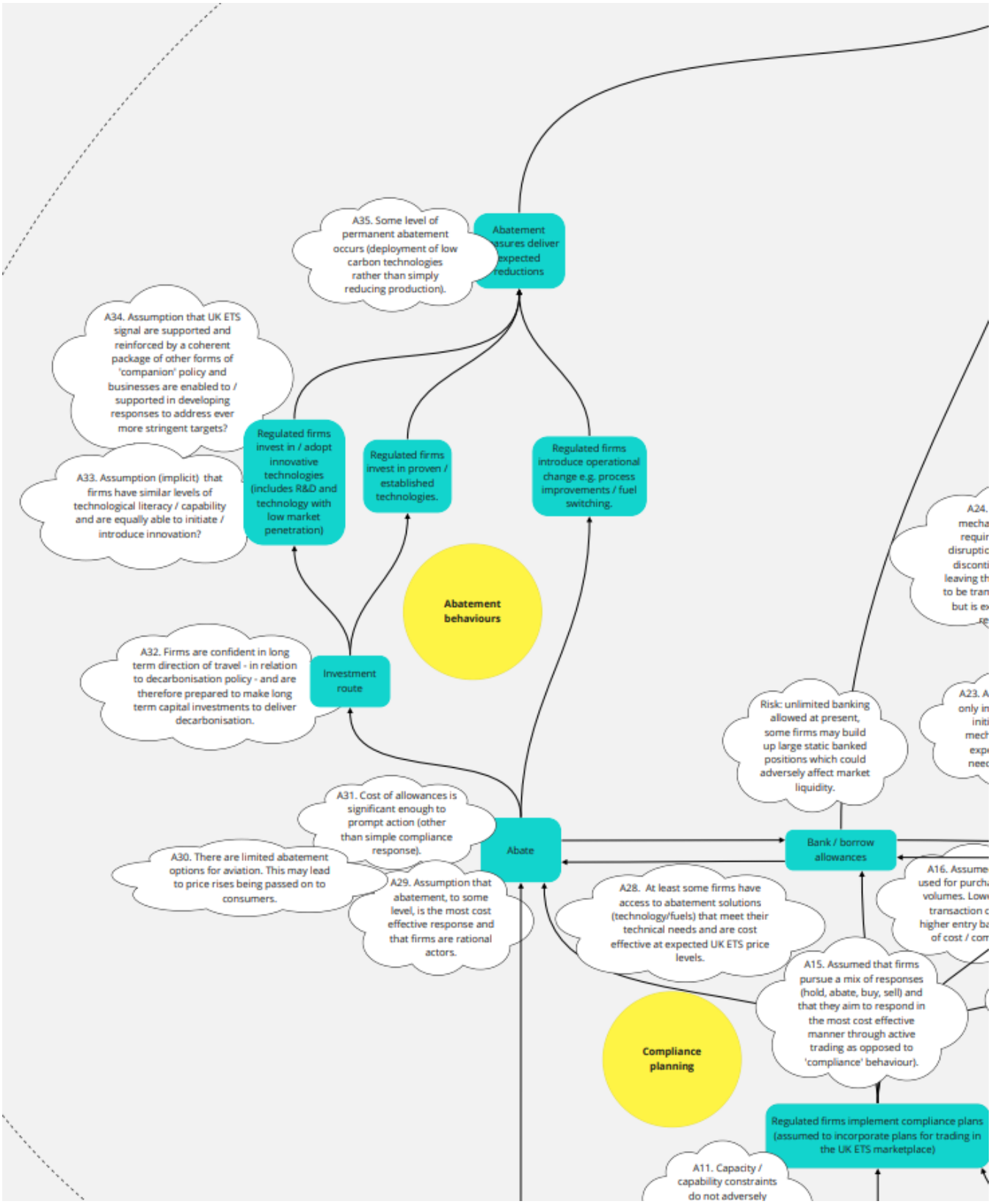


Figure 23: Close-up of Full Theory of Change – p4 (lower part of central section)

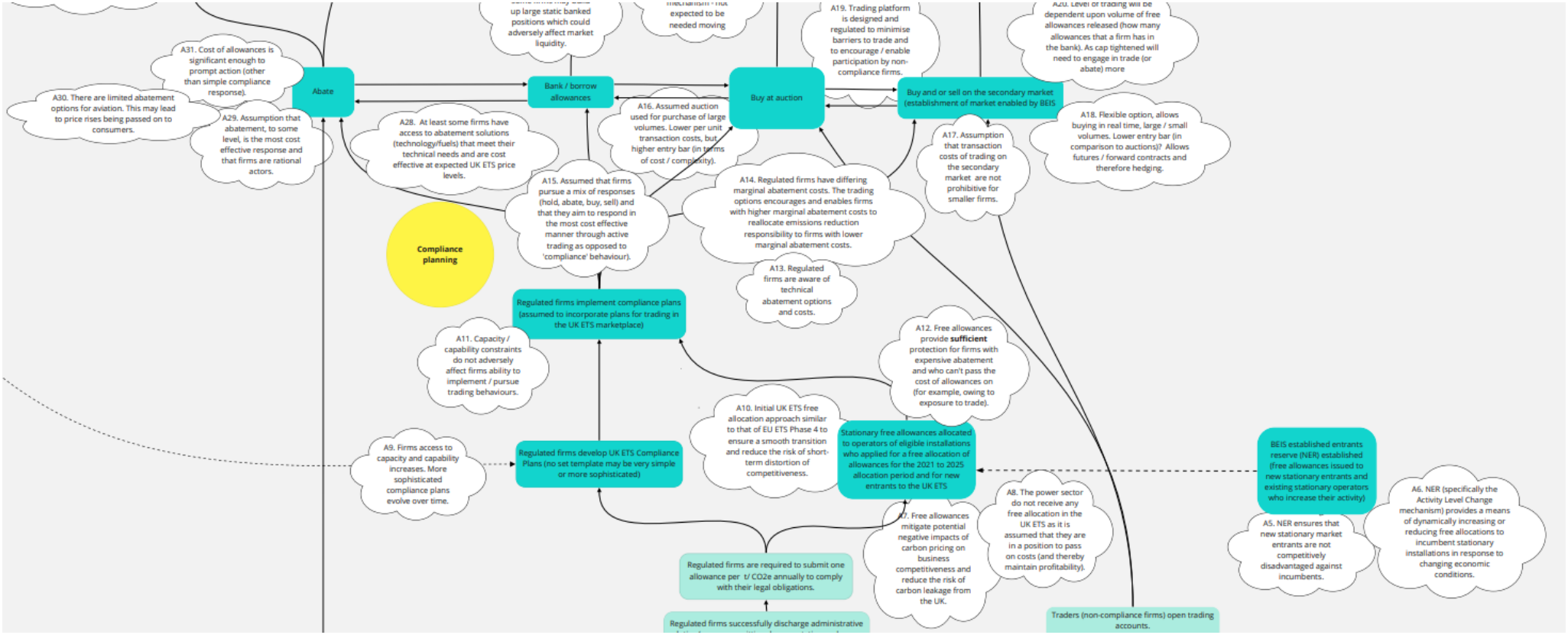
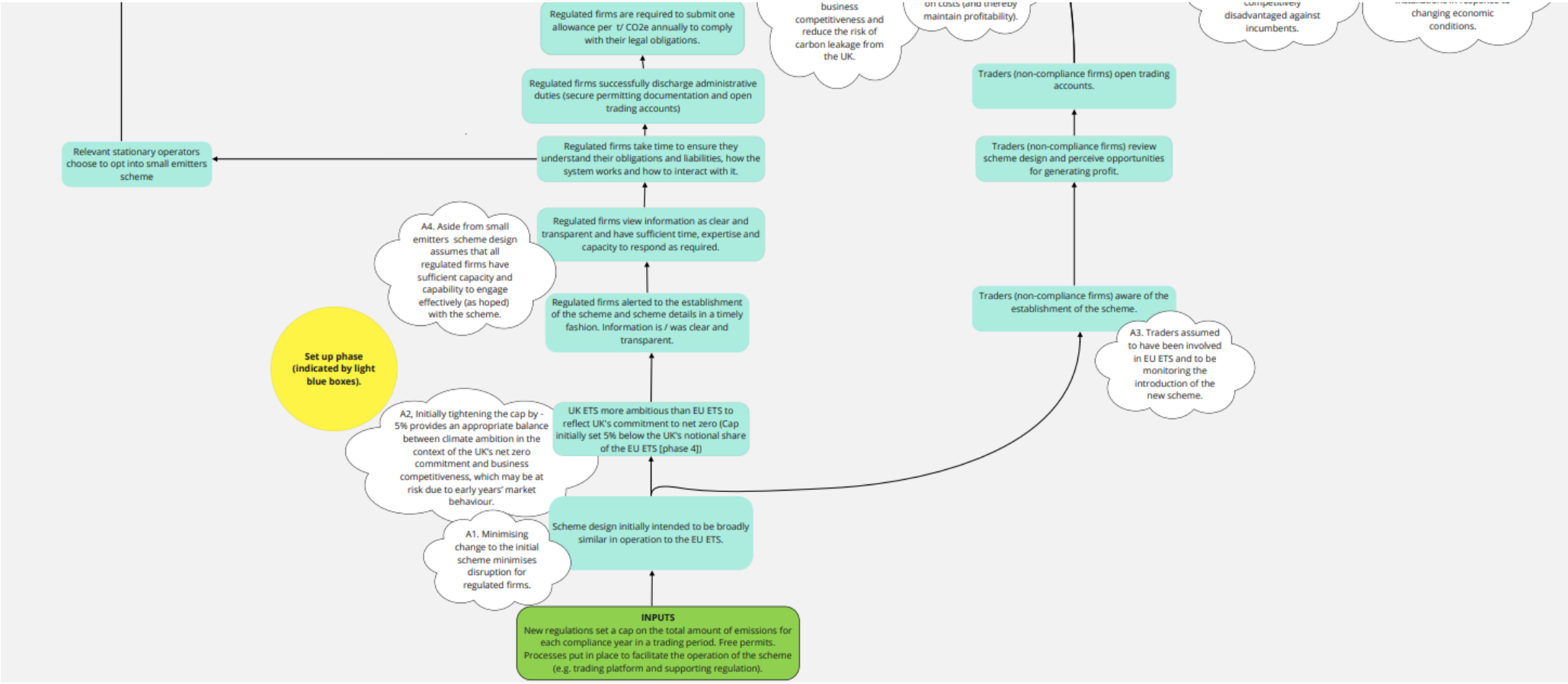


Figure 24: Close-up of Full Theory of Change – p5 (bottom section)



Appendix 4: Evaluation methodology, by workstream

This Appendix sets out the methodology used for each workstream. Each of the following seven workstreams is outlined briefly below:

- Phase 1 scoping
- Qualitative research
- Quantitative survey
- Network analysis
- Literature review on secondary market data quality
- Secondary market data analysis
- Phase 1 synthesis process

Phase 1 scoping

Building on the initial scoping of the UK ETS evaluation during 2021[31], scoping activity at the start of phase 1 included a review of key reports and interviews or workshops with UK ETS Authority, departmental staff, UK ETS operators/AOs, UK ETS traders and other stakeholders. This culminated in a review of the ToC and evaluation questions and a refined methodology for phase 1 of the evaluation. The ToC is detailed in Appendix 3 while the evaluation questions for the evaluation as a whole are presented in Appendix 2.

Phase 1 scoping included planning about how 'contribution analysis'[32] would be used to test the ToC against competing hypotheses. This involved specification of the types of evidence that would support or refute these hypotheses. Robust contribution analysis will depend on objective evidence about UK ETS impact relative to other influences which will be collected and analysed during phase 2 of the evaluation.

A preliminary assessment of the ToC and competing hypotheses, using contribution analysis, was included in phase 1 of the evaluation, together with a detailed assessment of Evaluation Questions A (process) and B (outcomes). Phase 1 of the evaluation also included a preliminary assessment of subjective evidence against evaluation qQuestion C (impact). The impact evaluation will be extended in phase 2 of the evaluation, when further evidence is available.

During the scoping stage, the role of different workstreams in the evaluation team's original proposal was adjusted in consultation with the department, to ensure sufficient exploration of priority topics. For instance, additional in-depth qualitative research with traders was

[31] Included as Annex 1 in the Mini Competition Documents for the UK ETS evaluation.
[32] Mayne, J. (2008), Contribution analysis: An approach to exploring cause and effect, May 2016, ILAC Brief 16.

substituted for a proposed online trader survey. The rationale for this was to allow more open exploration of UK ETS trading issues, accepting that initial understanding of trading roles might be inaccurate. Similarly, a decision to focus the qualitative research on operators/AOs with high emissions (to capture behaviours that were dominant in the UK ETS) led to concern about the lack of representation of high emitters in the quantitative survey. As there was insufficient time to undertake qualitative research as a follow-on to the survey, the solution to this problem was for a limited set of quantitative responses to be generated from the qualitative interviews. The workstream methodologies set out below explain this in more detail.

Qualitative research

In-depth qualitative interviews lasting 45-60 minutes were undertaken by telephone or online during June and July 2023, with:

- Representatives from 36 companies with compliance obligations in the UK ETS scheme, referred to as 'operators/AOs'.
- Representatives from 26 companies with trading accounts in the UK ETS registry, referred to as 'traders' (a few of which were the trading arms of operators/AOs).
- 9 other stakeholders, including representatives from UK ETS delivery bodies, wider stakeholders and verifiers/compliance consultants.

The sampling and interview process for each of these groups is described further below.

Operator sampling for qualitative research

Operators/AOs were sampled from the list of UK ETS operating account and aircraft operating account holders, as provided by the Department of Energy Security and Net Zero.

The qualitative sample was purposively targeted at operators/AOs with high emissions, because the behaviour of these operators/AOs was important for both abatement and trading outcomes from the UK ETS. In total, the operators/AOs interviewed for qualitative research generated approximately half of the emissions covered by the UK ETS (namely 55 million tonnes out of a total of 111 million tonnes of CO2e emissions in 2022).The sample was also purposively selected to represent a range of high-level sectors and sub-sectors across the UK ETS, as shown in Table 10 below. While operators/AOs with very high emissions (above 500,000 tCO2e per annum) were the primary focus of the qualitative research, the sample included a number of operators/AOs with medium to high emissions (25,000-500,000 tCO2e per annum) and low emissions (2,500-25,000 tCO2e per annum). Low emitters were only interviewed in those sectors where the UK ETS population included considerable numbers of low emitters (namely aviation and other industry). Within each sub-sector and emissions group, the sampling also aimed to select operators/AOs with differing levels of free allocation coverage, as far as this was relevant to the sector and possible within the other sampling constraints.

For operators/AOs with high emissions (above 100,000 tCO2e per annum in 2022), the in-depth interviews were used not only to generate qualitative findings but also to generate quantitative responses for a small subset of the quantitative survey questions. This was done to ensure that high emitters were adequately represented in quantitative survey findings. The methodology used for this process is set out in the quantitative survey section below.

Table 10: Breakdown of sample for qualitative interviews with operators and AOs

High-level sector	Number of interviewees by range of emissions (2022) at organisational level	Breakdown by sub-sector	Number of quantitative responses from qualitative interviews	Total
Aircraft operators	4 (above 500,000 tCO2e per annum) 3 (25,001-500,000 tCO2e per annum) 2 (2,500-25,000 tCO2e per annum)	9 Aviation	4	9
Heavy industry operators	10 (above 500,000 tCO2e per annum) 2 (25,001-500,000 tCO2e per annum)	2 Iron and steel 2 Refining 3 Chemicals 3 Cement 2 Offshore oil and gas	11	12
Other industry operators	1 (above 500,000 tCO2e per annum) 6 (25,001-500,000 tCO2e per annum) 3 (2,500-25,000 tCO2e per annum)	2 Food and drink 3 Paper 1 Pharmaceuticals 1 Vehicles 3 Non-metallic minerals (lime, glass, ceramics)	3	10

High-level sector	Number of interviewees by range of emissions (2022) at organisational level	Breakdown by sub-sector	Number of quantitative responses from qualitative interviews	Total
Power generation operators	3 (above 500,000 tCO2e per annum) 2 (25,001-500,000 tCO2e per annum)	4 Power generation 1 Peaking plant	3	5
Total	18 (above 500,000 tCO2e per annum) 13 (25,001-500,000 tCO2e per annum) 5 (2,500-25,000 tCO2e per annum)		21	36

Trader sampling for qualitative interviews

The sampling frame for trader interviews was the list of UK ETS trading account holders, as provided by the Department of Energy Security and Net Zero. Trading account holders included the trading arms of operators/AOs ('industry traders'), together with financial institutions registered as clearers with the ICE Exchange ('financial counterparties') and other traders (classed as 'commodity traders'). The list of trading accounts was screened to exclude inactive accounts (namely those where the UK Transaction Log showed no trading activity since the start of the UK ETS), duplicate accounts held by one organisation and 'industry trader' accounts where the primary contact was the same as an operator account (to avoid duplication with the operator interviews). The remaining 77 UK ETS trading account holders were approached for interview. A total of 26 interviews were completed and one further response was received by email. This was close to the target of 30 trader interviews agreed with the department. The breakdown of trader interviews between the three trader groups is shown in Table 11 below.

Table 11: Breakdown of trader sample

Category	Number
Financial counterparties	10
Commodity traders	10
Industry traders (including energy intensive industry, aviation and power sector traders)	6
Total	26

Wider stakeholder sampling

Three categories of wider stakeholders were also purposively selected for interview, to give a broader perspective on UK ETS. As shown in Table 20, these included UK ETS delivery bodies (specifically, representatives from regulators and from the Intercontinental Exchange) and verifiers/compliance consultants. The external stakeholders comprised representatives of the Climate Change Commission and of trade associations representing the carbon trading industry (specifically the European Federation of Energy Traders and the International Emissions Trading Association).

Table 12: Breakdown of wider stakeholder sample

Category	Number of wider stakeholder interviewees
Regulators/delivery bodies	4
Verifiers/compliance consultants	2
Climate Change Commission	1
Trade associations representing the carbon trading industry	2
Total	9

Topic guides

The topic guides for the qualitative research were designed to test realist theories about operator abatement behaviour and about the trading behaviour of both operators/AOs and traders. The topic guides also aimed to gather insights on how well UK ETS processes were working, as well as gathering early insights on UK ETS influence/impact on abatement and carbon leakage. An example topic guide is presented in the qualitative research report (Annex 2).

Permission was requested for interviews to be recorded and transcribed. Transcripts and notes were analysed using both realist and thematic analysis, as described below.

Qualitative analysis

A coding frame was developed, covering the main aspects of the UK ETS process, as well as the main elements of realist theory and potential UK ETS impacts. Transcripts and notes were then coded using a computer-aided qualitative analysis package. Themes were then identified for UK ETS process issues and for potential UK ETS impacts (for example carbon leakage).

Realist analysis

Realist methods, developed by Pawson and Tilley[33], are most commonly used to develop an understanding of the behaviours of individuals, but can also be used, as in this evaluation, to describe the behaviours of businesses and other organisations.

To do this, realist approaches involve the development of 'context mechanism outcome' configurations (CMOs) which set out theories about causality – what is happening and why. In relation to realism:

- 'Contexts' describe the factors which inform and shape (they may enable or constrain) behaviours.
- A 'mechanism' describes how contexts are understood to determine behaviours in response to a given intervention.
- 'Outcomes' describe the behaviour.

The initial 'candidate' theories about trading behaviour and abatement behaviour in the UK ETS are presented in the qualitative research paper, Annex 2. These were informed by the literature review (see Annex 3) and scoping work with UK ETS officials within the department. They are set out as a series of CMO configurations.

During the realist analysis process, each transcript was reviewed and information relating to contexts, mechanisms (thinking and rationale) and outcomes was extracted to inform the development of a set of company-level CMO configurations. Where possible, this was done using excerpts that had been coded against possible 'contexts', 'mechanisms' and 'outcomes'.

[33] Pawson and Tilley (1997), Realist Evaluation, Sage Publications. https://uk.sagepub.com/en-gb/eur/realistic-evaluation/book205276

For abatement behaviour, company-level CMOs were developed for UK ETS operators/AOs only. For trading behaviours, company-level CMOs were developed for UK ETS operators/AOs and traders. Web research and data base checks were undertaken to check the characteristics of operators/AOs and traders. Subsequently, the company-level CMOs for each topic area were reviewed and grouped, according to the level of similarity between their CMOs.

Following this sorting exercise, a set of generalised CMOs were developed to show the main types of identified high level behaviours for each topic, as described by interviewees. Where clear sub-groups were observed within a CMO group, variants were developed to reflect key differences.

Further details of the realist analysis and thematic analysis, including the realist CMO configurations, are presented in Annex 2, the qualitative research paper, which is presented in a separate volume.

Quantitative survey

Sample selection

The sample frame for the main quantitative survey was based on an installation database provided by DESNZ which contained the following pieces of information:

- Volume of emissions in 2022
- Volume of free allocation in 2022
- The existence of a linked trading account
- Sector
- Regulator
- Region

The department aggregated the installation data to ‘unique’ operator level, so that multiple installations owned by a common operator were grouped together and so that multiple operators known to be owned by the same parent company were also grouped together. ‘Unique’ operator level was deemed to be the appropriate sampling unit for the phase 1 of the evaluation.

Overall, the database contained 906 operator/AO records. From this database, 759 ‘unique’ operator/AO records were identified, of which 558 were deemed appropriate to be included in the sample frame. The remaining 201 ‘unique’ operator/AO records were excluded from the sample frame for the following reasons – please note that one operator might fall into more than one of the below categories:

- They were no longer operating.
- The account was unclaimed (namely there was no email address for them).
- They were excluded from the scheme in 2022.

- Compliance with UK ETS was managed by a consultancy (it was decided that these would be covered by the qualitative interviews).
- There was no primary contact.
- The account opened during 2023.

The final sample frame for the main stage of the quantitative survey consisted of 463 records. On top of those, there were:

- 71 records reserved for the qualitative interviews.
- 24 records for which there was a definite outcome from the pilot, either a complete interview or a refusal.

For the HSE/USE survey, sampling was also undertaken at 'unique' operator level rather than installation level. There were 148 unique HSE operators operating 249 HSE installations. No contact details were available for 3 HSE operators so the sampling frame was 145 HSE operators. Telephone numbers were available for 86 HSE operators, whereas only email addresses were available for the remaining 59 HSE operators. Similarly, there were 55 unique USE operators operating 99 USE installations. No contact details were available for 4 USE operators so the sampling frame was 51 USE operators. Only email addresses were available for USE operators.

Sampling for quantitative survey

Random sampling was used for the main quantitative survey. To achieve this, each of the 463 records in the sample frame was given an equal chance to participate in the survey. Records were contacted a maximum of seven times.

There were no strata or other quotas. However, operators/AOs with high emissions, defined as those with more than 100kt of CO2e emissions in the UK in 2022, were closely monitored throughout fieldwork.

All records in the HSE/USE sample frame were invited to participate in the HSE/USE survey. Records in the HSE sample frame with telephone numbers (n=86) were contacted a maximum of seven times, as for the main survey. All contact with HSE operators without a telephone number (n=59) and USE operators (n=51) was by email.

Population for quantitative survey

Prior to analysis, the main scheme population (for weighting purposes) was agreed to contain the following records:

- All records in the sample frame (463).
- The records for which there was a definite outcome in the pilot (24).
- The records initially reserved for the qualitative interviews (71).
- The records without a primary contact (13).

- Unclaimed accounts (19).

Overall, the main scheme population contained 590 records.

The HSE/USE survey population consisted of 148 HSE operators and 55 USE operators, but HSE/USE survey responses were not weighted.

Survey data

Data in the survey come from the following sources:

- The main quantitative survey (n=166). Interviews were conducted by telephone or online calls, lasting around 25 minutes. This represented a response rate of 36%. The topics covered by the survey were:
    - Contextual information about the organisation
    - Views on the transition from EU ETS Phase III to the UK ETS
    - Views on UK ETS processes (other than trading)
    - Trading and allowance behaviour (process and outcomes)
    - Abatement behaviour (process and outcomes)
- The pilot (n=17). Prior to the main stage, the survey underwent a comprehensive piloting and cognitive testing stage, upon which it was amended to reflect pilot findings. As changes were made, as well as various routing and other technical issues were fixed, data from the pilot was retained only for questions that remained unchanged.
- Qualitative interviews conducted by CAG Consultants (n=21): On top of the 183 responses from the quantitative survey, and for certain questions in the trading and carbon abatement sections of the survey, data was also collected by CAG Consultants through the qualitative workstream that they led, which was run concurrently to the quantitative survey. This data was integrated with the survey data upon fieldwork completion.
- The qualitative research workstream was focused mainly on operators/AOs with high levels of emissions, to ensure that the research captured reasoning and in-depth insights from major players in the UK ETS scheme. This posed a challenge for the quantitative survey, because it led to a considerable number of high emitters being excluded from the quantitative survey sample. There was a risk of high emitters being under-represented in the quantitative survey findings. Representation of high emitters in the quantitative survey was therefore boosted by asking selected survey questions of operators/AOs that undertook in-depth interviews within the qualitative research workstream. This was done for qualitative interviewees who, across all their UK ETS sites or operations, reported emissions exceeding 100,000 tCO2e in 2022. Owing to the time constraints of a 45 to 60 minute qualitative interview, Winning Moves and CAG Consultants agreed with DESNZ that a subset of questions from the full survey would be used for this. The selected questions focused solely on high priority topics that were regarded as likely to vary with scale of emissions (namely trading behaviour and

abatement behaviour). Process questions were not included because these were thought less likely to vary by scale of emissions. The selected survey questions were integrated into a 'high emitter' version of the qualitative topic guide, so that the interviewer could readily probe and assess quantitative responses in parallel with qualitative questions on a given topic. The approach to checking quantitative responses from qualitative interviews is explained further in the quantitative survey report, Annex 1.

- Overall, there were 21 records originating from CAG Consultant's qualitative interviews. Throughout this report figures based on both quantitative and qualitative interviews have been flagged. Please note that organisations participating in the qualitative interviews were of a much larger scale than those which participated in the quantitative interviews: their median emissions in the UK in 2022 were about 1 million tCO2e. By contrast, the median emissions of quantitative survey respondents referred to as big emitters throughout this report were approximately 100,000 tCO2e. Likewise, their median free allocation in 2022 was about 360,000 free allowances. By contrast, the median free allocation of quantitative survey respondents referred to as big emitters throughout this report were approximately 30,000 free allowances. Their trading behaviour was probably linked to the size of their operations. Respondents from the qualitative surveys were more likely to report buying/selling derivatives on the ICE exchange and buying allowances spot on a daily basis. Despite differences owed to their much larger size, their responses did not significantly diverge from those of quantitative survey respondents referred to as big emitters throughout this report.
- The separate survey of HSE/USE operators was undertaken by telephone with a self-administered online response option. From the sample frame of 145 HSE operators, 24 responses were received (a response rate of 17%). No responses were received from the sample frame of 51 USE operators, possibly because no telephone contact data was available and some email addresses were out of date.

Weighting

All percentages of main scheme participants cited in the synthesis are weighted. The only exception are percentages of HSE participants, which are unweighted.

There were two sets of weights in the analysis:

- One for questions where data from the qualitative interviews was included.
- One for all the remaining questions, which came solely from the quantitative survey.

Both sets of weights were calculated based on the volume of emissions in the UK in 2022. The following categories were used:

- Zero 2022 emissions
- Less than 2,500 tCO2e
- 2,500 – 25,000 tCO2e
- 25,000 – 50,000 tCO2e

- 50,000 – 250,000 tCO2e
- 250,000 – 500,000 tCO2e
- More than 500,000 tCO2e

Percentages emissions cited in the trading and carbon abatement sections are not weighted, as the existing sets of weights are already based on emissions.

Analysis

Originally, the statistical significance threshold was set at 95%, as is the standard in similar pieces of research. However, due to the small sample size of this survey, the statistical significance threshold for the second draft of the analysis was set at 90%, which is the threshold used in this report. As explained in the methodology section, random sampling was used in this survey and, therefore, statistical testing is appropriate.

At 90% confidence, the maximum margin of error for findings from the whole sample of 204 operators/AOs is 5.8% (assuming a 50:50 split in responses). Margins of error are wider for sub-samples: for example for the sub-samples of 108 installation operators and 41 aircraft operators and 55 micro-emitters, the maximum margins of error are 7.9%, 12.8% and 11.1% respectively.

Participants with less than 1,000 tCO2e emissions in the UK in 2022 have been analysed as a separate category in all crosstabulations, referred to throughout this report as ‘micro-emitters’. Throughout this report, all figures on installation and AOs do not include micro-emitters (namely these figures show findings for participants with at least 1,000 tCO2e emissions in the UK in 2022). This was done because analysis showed that these participants, usually from international aviation, were different to the rest of the sample. Overall, there were 55 micro-emitters in the sample. Please note that micro-emitters are included in all overall ‘main scheme’ figures.

After this change, cross-tabulations in the analysis were done with respect to the following variables:

- Type of major installation (from database)
- Volume of free allocation in 2021 as proportion of 2022 emissions (from database)
- Volume of 2022 emissions (from database)
- Number of full-time staff in organisation (from survey data)
- Existence of EU ETS account (survey data)
- Is there a staff member/team whose sole responsibility is ETS compliance? (survey data)
- Region (at least one installation in England vs no installation outside England)

Additional analysis was also conducted on survey responses for trading behaviour and carbon abatement. In addition to percentages of participants choosing a response option, the proportion of total emissions accounted for by those respondents was also calculated[34]. By 'emissions', we mean CO2e emissions in the UK in 2022 as those were provided by the department. This was done because, even though certain types of trading and carbon abatement behaviour were taken up by small proportions of participants, these participants accounted for much larger proportions of total emissions. About three quarters (76%) of total emissions covered by this survey were accounted for by the 21 records provided to Winning Moves by CAG Consultants. This is expected as CAG Consultants had purposively reserved many high emitters for their in-depth qualitative interviews. For that reason, the additional emissions analysis was only conducted for questions for which data from CAG Consultant's in-depth interviews was available.

Further details of the quantitative survey methodology and findings are presented in Annex 1, the quantitative survey report, in a separate volume.

Network analysis

Network and cluster analysis was undertaken for UKA transactions in the UK Transactions Log (UKTL). This analysis was undertaken by calendar year, comprising initial transactions during 2021 (May to end of December), the full trading year in 2022 and the first part of the 2023 trading year (January to June). This dataset includes data on transaction type (indicating the purpose, such as auction delivery or allowance transfer), a unique transaction ID for each interaction, details about the sending and receiving allowance accounts, transaction volume, and the specific time of each transaction. The UKTL data was highly confidential, so pseudonyms were used when discussing the analysis within the evaluation team. DESNZ played an important role in quality assurance of this analysis because departmental team members had access to non-anonymised UKTL data, while members of the evaluation team outside the network analysis team did not. The network analysis was preliminary and may be extended later in the evaluation.

This workstream characterised the size and density of the network of UKA transactions and analysed the most important UKA accounts using standard metrics for network analysis. The first step to conducting network analysis on the UK ETS system was to collect and prepare the UK ETS transaction data, which included the allowance transactions between different accounts. This data was formatted as a directed graph, where the accounts were 'nodes' and the transactions between them were 'edges'. Then the network was constructed from the data. After constructing the network, centrality measures were calculated for each node or account.

Eigenvector centrality

The network chart in the main report shows the size of each node in terms of 'eigenvector centrality'. This is a measure of the importance of a node in a network that considers the

[34] Except for the question related to how free allocation is used, the proportion of total free allocation accounted for by each response option was calculated instead.

importance of its neighbours. In other words, a node's eigenvector centrality is higher if it is connected to other nodes that are themselves highly connected.

To calculate eigenvector centrality, an adjacency matrix was calculated for the network. This matrix is a square matrix where the (i, j)-th element is 1 if there is an edge between nodes i and j, and 0 otherwise. The eigenvector corresponding to the largest eigenvalue of this matrix was then calculated. The eigenvector gives a set of centrality scores for each node in the network, where the score for node i is proportional to the sum of the scores of its neighbours.

In the context of the UK ETS transaction data, eigenvector centrality helps to identify clusters of accounts that are tightly interconnected. Identification of these clusters can give insights into the behaviour of different groups of market participants, and how they interact with each other.

Trading typologies

Additional network analysis explored patterns of trading associated with trading typologies that were identified through the qualitative research. Where feasible, the network analysis made a tentative identification of trading accounts exhibiting different types of behaviour. Table 13 sets out the key factors for identifying trading patterns, based on the findings from realist qualitative analysis of trader and operator interviews. The qualitative realist analysis identified behaviours and noted that some organisations undertook more than one type of behaviour (for example clearing and market making), so the network analysis expected to find some accounts with mixed behaviours.

Table 13. UK ETS traders' trading pattern from qualitative interview data

Pattern type	Transaction type	Motive for trading	Trading objective	Common actor type	Other information
Brokerage	UKA spot and futures contracts	Charge fee or commission. No trading positions taken.	Buy to meet clients' need	Banks Commodity traders Energy project developers	Executing decisions, not making them
Market Making	UKA spot and futures contracts	Relatively low risk positions taken	Generate income on the difference between buy and sell price	Commodity traders Banks	

Pattern type	Transaction type	Motive for trading	Trading objective	Common actor type	Other information
		Make margin on 'bid-ask' spread			
Speculation	Longer term positions, trading intermittently (for example weekly or monthly)	Profit making – longer term and large positions taken	Profit making	Commodity traders Banks	Primarily speculators,
In-house 'buy to comply' industry traders	May buy both UKA spot and futures (December and March futures)	To meet compliance obligations of linked operator accounts	Some buy regularly (daily to fortnightly) Some buy when they perceive the price to be favourable	Large businesses subject to the UK ETS	In-house staff undertake trading undertaken on behalf of the business
Clearer	Low and irregular	Fixed fee on clearing service	Clearing	Financial counterparties (banks with ICE Clearing accounts)	Executing decisions, not making them

The trading patterns used to identify trading behaviours were as follows.

Table 14. Trading Pattern Checklist

Sorting strategy	Industry trader (buy to comply)	Clearer	Market maker	Speculator	Broker
Many small purchases and very	√√				

few big sales (typically March and December)					
Same day clearing		√√ (Clearing mMember of ICE; always clear on same day)			May clear on same day
Daily transaction count	Very small		Large	Medium	Medium
Account reach	Very small		Large	Small	Medium
Same day turnover		√	√		√
1-3 day turnover			√		√
Longer turnover	√				
Irregular turnover				√	
Main trading partner - Traders		√	Few	√	
Main trading partner - Operators/AOs	√		√	Few	√
Balanced position		√	√		√
High holding positions	√			√	
Profit by commission	√				√
Profit by bid and sell			√	√	

Note: The two cells with double ticks are the unique significant characteristics of industry traders and clearers observed for no other categories. Therefore, these two indicators were used to identify these two trading patterns first.

As expected from the qualitative analysis, some account types appeared to demonstrate mixed behaviours. In particular, some clearing accounts also showed market making behaviour, possibly because one part of the organisation undertook clearing activities while another offered marking making services to clients. A few accounts showed a mixture of market making, broking and speculation behaviour, which may reflect different types of activities being offered by different parts of a n organisation.

Literature review on secondary market data quality

A review of economics literature was undertaken to investigate the market quality characteristics of emission allowances. The review covered an 18-year period (2005 to 2023) and cited 116 papers, including 55 studies of emissions trading schemes, including studies of the EU ETS. A list of the papers reviewed is presented in the literature review report in a separate volume (Annex 3).

The literature review report provided an introductory background into the key theoretical issues underpinning the evolution of the two fundamental market quality characteristics: liquidity, and price discovery/informational efficiency. It then reviewed the literature investigating these and associated characteristics in the context of emissions allowances trading. It concluded with a list of suggested market quality proxies that could be employed in evaluating the quality of the trading process on the market platform(s) that facilitate the exchange of allowances and associated financial instruments within the UK ETS.

The recommended market quality proxies are listed in Table 15 below. They are explained further in the secondary market data analysis section below and are detailed further in the literature review paper in Annex 3.

Table 15: Recommended proxy indicators

Aspect of market quality	Recommended market quality proxy for price discovery and market efficiency
Price discovery and market efficiency	Efficiency and noise components of price based on Hasbrouck (1993)[35] vector autoregression (VAR) model.
Price discovery and market efficiency	Signal to signal plus noise ratio estimated from unbiasedness regressions.

[35] Hasbrouck, J., (1993) Assessing the quality of a security market: A new approach to transaction-cost measurement. The Review of Financial Studies, 6(1), 191-212.

Price discovery and market efficiency	$\overline{R^2}$ (Coefficient of determination) estimated from predictive regressions.
Price discovery and market efficiency	Price volatility in time series: standard deviation of intraday returns.
Liquidity	Spread estimates from quotes and transactions: • Effective spread. • Relative quoted spread. • Realised spread. • Relative traded spread.
Liquidity	Low frequency liquidity measure: • Amihud (2002)[36] price impact ratio.

The literature review was unable to identify a proxy for market integrity in the ETS literature. section 1 of the literature review report (see Annex 2) explains the difficulty of objectively measuring this market quality aspect. However, Hintermann (2017)[37], cited in section 2 of the literature review report, provides some contextual guidance on how excess emission allowances might provide some indication of price speculation and market manipulation.

Secondary market data analysis

The market quality proxies recommended in the literature review were implemented, as far as feasible, in the secondary market data analysis. This analysis focused on trading price and volume data available from the ICE Exchange. This related to UKA derivatives (specifically futures contracts) and focused on December futures contracts because these were the most liquid products.

Where data permitted, market proxies were calculated for ICE trading in December futures for both the UK ETS and EU ETS, to allow comparison of liquidity and price discovery in these two markets. This analysis did not include trading in EU ETS futures on other exchanges (for example EEX).

[36] Amihud, Y. (2002) Illiquidity and stock returns: cross-section and time-series effects. Journal of Financial Markets, 5(1), 31-56.
[37] Hintermann, B. (2017) Market Power in Emission Permit Markets: Theory and Evidence from the EU ETS. Environmental and Resource Economics, 66 (2017), 89–112.

Data and sample selection

The UK ETS secondary market data was provided through the ICE Connect portal and consisted of two parts.

- The first type of data comprised trading summaries for 1 minute trading intervals and includes data on transaction opening and closing prices, trading volume (namely the number of UKAs traded) over the interval, and the highest and lowest prices. This data was available from the start of the trading in the UK ETS secondary market on 19 May 19, 2021.
- The second type of data was real-time tick-by-tick UKA futures contract trade data which included information about bid and ask prices, as well as information about executed trades (price and volume of each trade). This data was only available for the last 30 trading days.

The secondary market data analysis made use of both types of data described above and formed two samples. The first sample included data on 1 minute trading intervals (opening and closing prices, the lowest and the highest prices, traded volume). To construct this sample, we followed the existing literature and considered only futures contracts expiring in December since the inception of the secondary market (December 2021, December 2022, and December 2023 contracts). This was because the level of trading activity for other expiries was relatively low, while most of the market quality measures to be considered in the secondary market data analysis can be correctly calculated only in case of the reasonably high level of trading activity. The average traded volumes for the futures contracts with different expiry dates are presented in Annex 4 on the secondary market data analysis, which is presented in a separate volume.

In the secondary market data analysis, data on futures contracts expiring in December 2021, 2022, and 2023, were combined or ‘rolled over’ in the following way:

- Data on the contract to be delivered in December 2021 was used for the period 19 May 19, 2021 – 30 November 30, 2021.
- Data on the contract to be delivered in December 2022 was used for the period 1 December 1, 2021 – 30 November 30, 2022.
- Data on the contract to be delivered in December 2023 was used for the period 1 December 1, 2022 – 15 September 15, 2023.

The futures contracts expiring in December 2021 and December 2022 were truncated a full month before the expiry because of the high level of volatility and noisiness of trading which are usually observed in the closing stage of the contract’s life. The similar rollover procedure was previously used, for example, by Medina et al. (2014). The rollover procedure allows for significant expansion of the period with relatively high level of trading activity. For example, for the futures contract expiring in December 2023 a reasonably high level of trading activity can be observed only starting from December 2022. Before this month, the average daily traded volume did not exceed 100 lots (see Annex 4). Thus, the inclusion of data on contracts expiring in December 2021 and December 2022 considerably increased the number of 1 -minute trading intervals with non-zero trading activity.

The second sample used for the analysis was based on the real-time tick-by-tick UKA trade data containing information about bid and ask prices, as well as information about executed trades (price and volume). This type of data was only available on the ICE Connect portal for the last 30 trading days. This data was downloaded three times: on 20 July 2023, 31 July 2023 and 18 September 2023, and the downloaded data was combined to extend the period for which this type of data was available. The final sample used for the analysis spanned from 22 May 2023 to 15 September 2023.

Therefore, the following samples form the basis for assessing the UK ETS secondary market quality:

- Sample 1. Data on opening/closing prices, the highest/lowest prices, and traded volume for each 1 -minute trading interval during the period 19 May 19, 2021, to 15 September 15, 2023 (602 trading days).
- Sample 2. Real-time tick-by-tick data on bid and ask prices, prices of executed trades, and volumes of executed trades for the period 22 May 22, 2023, to 15 September 15, 2023 (83 trading days).

Descriptive analysis of the sample used in the analysis is presented in Annex 4.

The UK ETS secondary market quality analysis based on these samples has two important limitations. First, a descriptive analysis of these samples shows that the level of trading activity was relatively low after the start of the secondary market in 2021. This makes it difficult to estimate some of the market quality proxies. Second, sample 2 includes only 83 trading days. Thus, the market proxies based on this sample does not cover the initial stages of the UK ETS secondary market.

Market quality characteristics

A well-functioning financial market is characterised by its ability to offer a reliable and trusted price discovery mechanism and ensure liquidity in both regular market conditions and times of heightened uncertainty (O'Hara, 2003)[38]. Price discovery is a process of incorporation of available information (both private and public) into prices. The main goal of this process is to achieve informational efficiency when all relevant information is reflected in the prices (Ibikunle, 2023)[39]. Liquidity in this case means the ability of the market to undertake transactions without triggering substantial or enduring changes in prices (Ibikunle, 2023)[40].

The existing literature suggests that these two dimensions of market quality can be closely related. For example, Chordia et al. (2008)[41] describe the following mechanism by which liquidity can be linked to the price discovery process. If market makers have limited risk-bearing capacity, they will find it difficult to execute all incoming orders if the number of buy

[38] O'Hara, M. (2003) Presidential Address: Liquidity and Price Discovery. The Journal of Finance, 58(4), 1335-1354.
[39] Ibikunle, G (2023). Market quality in emissions trading schemes: a literature review. Presented in Annex 3.
[40] Op. cit.
[41] Chordia, T., Roll, R., & Subrahmanyam, A. (2008). Liquidity and market efficiency. Journal of Financial Economics, 87(2), 249-268.

and sell orders becomes significantly imbalanced. This situation leads to a deviation of the price from its fundamental level. As a result, it is possible to predict returns based on information about order imbalances in the previous periods. 'Informed market participants' can identify such deviations and place arbitrage trades to profit from the price deviation from them. 'Informed traders' refers to those who trade to exploit private information (value traders, technical traders, dealers and arbitrageurs). Another type of trader in the market is the 'uninformed trader' (or 'liquidity trader'), whose trading is not primarily driven by the need to profit from the movement in price (for example, an industrial producer trading in emission permits to offset its carbon footprint in accordance with the law). Arbitrage trades by 'informed traders' will push the price back to the fundamental level. However, informed traders are more likely to place arbitrage orders in conditions of high liquidity. Therefore, when the market is relatively liquid, the price deviation from the fundamental level is eliminated more quickly, indicating better quality in the price discovery process.

The focus of the secondary market data analysis was thus on the price discovery and liquidity in the UK ETS secondary market using a set of market quality proxies selected based on Ibikunle (2023)[42], as well as the relationship between market quality proxies related to these two dimensions of market quality. The sections below discuss the nature of these proxies, their limitations and how they relate to each other.

Price discovery

The secondary market data analysis explored three dimensions of the price discovery process in the UK ETS secondary market.

- First, we analysed price discovery in terms of the UKA price volatility. We then decomposed the price volatility into two parts - the fractions explained by the market incorporating new information and by trading noise (price volatility, volatility decomposition into the efficiency price and pricing error).
- Second, we assessed the price discovery process in terms of price efficiency. This is measured by the extent to which the price can be predicted based on trading information from previous periods (coefficients of determination from returns predictability regressions).
- Finally, we looked at how the process of price discovery unfolded over the course of a typical trading day (signal-to-signal plus noise ratio).

These three dimensions therefore allow us to assess both the process of price discovery and the outcome of that process, namely the extent to which the market can establish an efficient and reliable price for UKA. Overall, four different proxies for market quality were used to examine the price discovery process in the UK ETS secondary market, as defined below.

Price volatility

We measured price volatility as the standard deviation of the daily 1 -minute returns, as shown in Annex 4. This proxy aims to capture the excess volatility which is unlikely to be driven by

[42] Op cit.

incorporation of new information. The concept here is that information crucial for determining the price of an instrument is not typically released at very short intervals during a trading day. Therefore, substantial price fluctuations could be considered as an indication of reduced informational efficiency. A limitation of this proxy, however, is that it does not differentiate between the contributions of information and noise in driving price volatility.

Price volatility decomposition

To overcome the limitation mentioned above, we made use of the volatility decomposition approach proposed by Hasbrouck (1993)[43]. The aim of this approach was to decompose the price change into a 'random walk' component (efficient price) and a residual component (pricing error). Thus, the decomposition approach of Hasbrouck (1993) allows for a quantitative estimation of the roles of two main drivers of price changes - the incorporation of new information by the market and the pricing errors. The market quality proxy calculated based on the volatility decomposition is a share of information -driven volatility (Q) which ranges between 0 and 1. A value of Q close to 1 corresponds to a high level of market quality with respect to the price discovery process. Specifically, an increase in Q signifies improved market quality, indicating that price volatility is largely a result of information rather than noise (which is not driven by information).

A potential limitation of this proxy is that it is based on the premise that neither the pricing error variance nor the deviation between the efficient price and the actual transaction price directly reveals anything about the private or social costs of foregone transactions (Hasbrouck, 1993)[44]. However, this limitation applies to most measures based on trade data, and can be overcome, for example, by excluding from the analysis certain trades that are likely to be based on superior information.

Price efficiency

An efficient price is expected to follow a 'random walk' process (Fama, 1970)[45], which implies that current price cannot be predicted using other market variables, such as trading activity. Therefore, to assess price efficiency, we test the hypothesis that price (returns) can be predicted based on trading information from previous periods using the return predictability model (Chordia et al., 2008[46]; Ibikunle et al., 2016[47]). In this model, the order imbalance ratio in the previous period is used as a predictor of current returns. The order imbalance is defined as a ratio of the difference between buyer-initiated trades volume (in £) and seller-initiated trades volume (in £) to the total traded volume (in £).

We then used the coefficient of determination from the return predictability regression as a quantitative measure of short run price efficiency. This reflects the share of returns variation that can be explained by the variation of order imbalance in the previous period. A higher value

[43] Op.cit.
[44] Op.cit.
[45] Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. The journal of Finance, 25(2), 383-417.
[46] Op.cit.
[47] Ibikunle, G., Gregoriou, A., Hoepner, A. G. F. & Rhodes, M. (2016) Liquidity and market efficiency in the world's largest carbon market. The British Accounting Review, 48(4), 431- 447.

of the coefficient determination indicates that more of the variation in short run returns can be explained by trading activity, suggesting that the price is less efficient.

Signal to signal plus noise ratio estimated from unbiasedness regressions

The three proxies described above provide a snapshot of the overall price discovery quality at a point in time for example, a trading day. However, the quality of the price discovery process may vary between the different time periods of a typical trading day.

One way to look at the evolution of the price of an instrument is that it is a combination of an efficient price change and a price change due to noise. This approach is based on estimating the extent to which price change is due to the incorporation of information (Ibinkule, 2023)[48].

To assess how price discovery evolves over the course of a typical trading day, we follow Ibikunle (2013)[49], and estimate signal -plus -noise ratios for each 1-hour trading interval (see methodological details in Annex 4). This is defined as the ratio of the 'signal' (meaning the information that leads to an enduring price change) to 'signal plus noise' (meaning a price change that reverses quickly). More specifically, we employ an unbiasedness regression model to estimate the 'signal plus noise' ratios for each time interval (1 hour) during the trading day. Relatively high values of 'signal' to 'signal plus noise' ratio in this case mean that the level of noise during the trading interval is low and that price changes are mostly driven by the incorporation of new information.

An important limitation of this measure is that it is very aggregated (especially when calculated over long time periods) and does not consider variations between trading days (which can be significant).

Liquidity

Following existing literature on the financial markets' microstructure (Ibikunle, 2023)[50], we considered two types of liquidity measures:

- The most widely used indicators of market liquidity in the market microstructure literature typically rely on proxies derived from bid-ask spreads (Ibikunle, 2023). These measures intuitively capture the probability that an economic agent will be able to execute a regular -sized order quickly, at a fair price, and with little or no price impact (meaning that they capture at least three of the five dimensions of liquidity, namely the tightness, depth, and immediacy dimensions of liquidity). Tightness corresponds to the difference between the fundamental price and the transaction price, depth is the ability of the market to absorb quantities without their having a large effect on price, while immediacy is the speed of order execution (Ibikunle, 2023). The other dimensions of liquidity are breadth and resilience. The resilience reflects the time it takes for prices to move back to equilibrium after a large trade, while the breadth corresponds to the

[48] Op.cit.
[49] Ibikunle, G., Gregoriou, A., & Pandit, N. R. (2013). Price discovery and trading after hours: new evidence from the world's largest carbon exchange. International Journal of the Economics of Business, 20(3), 421-445.

[50] Op.cit.

number of market participants who do not wield significant power. These two dimensions are also captured by the bid-ask spread measures, but to a lesser extent than tightness, depth, and immediacy dimensions. The spread is thus defined as a non-zero cost born by traders that includes inventory holding cost, order processing cost, and adverse selection cost (Ibikunle, 2023). Ibikunle (2023) recommended four proxies based on the bid-ask spreads, namely the relative quoted spread, relative traded spread, effective spread, and realised spread (please see below for details on these proxies).

- Low frequency liquidity measure (Amihud[51] (2002) price impact ratio) that accounts for the possible trades that can be a source of significant price shocks. This measure is usually considered to fully capture the resilience dimension of the liquidity, meaning the time it takes for prices to move back to equilibrium after a large trade (Ibikunle, 2023)[52].

Thus, the set of liquidity measures considered in the secondary market data analysis report (Annex 4) captures all the five dimensions of liquidity mentioned above. A brief overview of the liquidity proxies considered in the analysis is presented below, along with a discussion of their limitations. For a more in-depth description of these liquidity proxies, please refer to Annex 4.

Relative quoted spread

The relative quoted spread is defined as the difference between the best bid and the best ask prices observed over a short trading interval, divided by the midpoint price (the average of these two prices). Thus, this measure of liquidity can be interpreted as the round-trip cost of a regular transaction, measured as a percentage of the prevailing midpoint. The relative quoted spread is a widely used measure of round-trip cost of the transactions because of its simplicity in both calculation and interpretation.

However, it has a few limitations. As noted by Huang and Stoll (1996)[53], “bid and ask quotes are not necessarily the prices at which trades take place, since it is possible to trade inside the quotes, especially if the spread is wide… “. In addition, in markets with relatively low trading activity, there may be no trades during the time interval for which the spread is calculated. In this case, the relative quoted spread is not a measure of the true cost of the round-trip transaction, as there are no transactions at this cost. Ibikunle (2023)[54] also notes that the relative quoted spread could overstate or understate the execution cost for liquidity demanding traders when orders execute within or beyond prevailing bid and ask quotes/prices.

Relative traded spread

Another spread measure which is very similar to the quoted spread is a traded spread. Relative traded spread is calculated in a similar way as the relative quoted spread. The main difference is that the bid and ask prices are replaced by the prices of the buyer-initiated trades

[51] Op.cit.
[52] Op.cit.
[53] Huang, R. D., & Stoll, H. R. (1996). Dealer versus auction markets: A paired comparison of execution costs on NASDAQ and the NYSE. Journal of Financial economics, 41(3), 313-357.
[54] Op.cit.

and seller-initiated trades. Thus, while having characteristics of relative quoted spread, relative traded spread is based on transaction prices only.

The limitation of this measure in the context of this evaluation is that it requires data on the direction of trade (whether each trade is buyer-initiated or seller-initiated). Data sourced from ICE Connect portal does not include trade direction indicators. This limitation can, however, be overcome by classifying trades as buyer-initiated or seller-initiated using specific procedures such as tick testing (Lee and Ready, 1993)[55]. Although these procedures have a rather high level of classification accuracy, some classification errors are still possible. These classification errors can thus reduce the accuracy of relative traded spread estimates.

Effective spread

Unlike the relative quoted spread and the relative traded spread that rely on one type of data, the effective spread is based on both data on bid and ask prices as well as data on transaction prices. The effective spread is defined as double the difference between the transaction price and the quote midpoint at the time of transaction.

Effective spread (in £) has the same interpretation as the relative quoted spread and relative traded spread. Specifically, higher spread values correspond to the higher cost of the round-trip transaction for market participants. The main limitation of the effective spread is that it overstates the liquidity provider profits and the trade's true execution cost when trades have positive price impact.

Realised spread

The realised spread represents the part of the effective spread related to the spread realised by the liquidity provider. Thus, it accounts for the limitation of the effective spread mentioned above. This spread measure considers the possible price impact of the trade, as it reflects the revenue earned by the dealer after the trade. The limitation of this spread measure is that it does not account for the adverse selection cost component of the spread. The adverse selection component reflects the cost to the 'liquidity traders' for taking the risk of trading with 'informed traders', meaning information risk (Ibikunle, 2023)[56]. Liquidity traders trade for reasons not linked to profit making (for example, an industrial producer trading in emission permits to offset its carbon footprint in accordance with the law). Informed traders are those who trade to exploit private information (value traders, technical traders, dealers, and arbitrageurs).

The main part of the secondary market data analysis report (Annex 4) focusses on only two out of the four spread measures discussed above: the effective spread and the relative traded spread. These two measures were selected based on the similarities observed between the relative quoted spread and relative traded spread, as well as between the effective spread and realised spread. The relative traded spread is, however, preferred to the relative quoted spread because it is based on transaction prices and more accurately measures liquidity in cases of

[55] Lee, C. M., & Ready, M. J. (1991). Inferring trade direction from intraday data. r, 46(2), 733-746.

[56] Op.cit.

relatively low trading activity. On the other hand, the effective spread is preferred to the realised spread due to its comprehensive nature, encompassing both the realised spread and the associated adverse selection costs, resulting in a more thorough measurement of liquidity.

Amihud (2002) price impact ratio

All the spread measures described above do not account for block (large) trades, which can be a source of significant price shocks (Ibikunle, 2023)[57]. To account for the possibility of block trades, we use an additional low-frequency measure of liquidity, which is Amihud (2002)[58] price impact ratio. It is calculated as an average ratio of the daily absolute return to the trading volume on that day. This measure is volume -based; thus, it reflects the price impact of the transactions.

The Amihud (2002) price impact ratio is usually considered a poor substitute for the high-frequency measures such as spreads. However, as noted by Ibikunle (2023), “it intuitively captures the resilience dimension of liquidity since in less liquid markets any given level of trading volume will induce a large price impact corresponding to its illiquidity state”. Thus, despite the limitations of the Amihud (2002) price impact ratio, it may be useful to consider this measure combined with spread to capture more dimensions of liquidity.

Findings from the secondary market data analysis, together with a more in-depth description of these market quality proxies, can be found in Annex 4 (presented in a separate volume).

Phase 1 synthesis process

As noted in the phase 1 scoping section above, the phase 1 scoping process identified the role of different workstreams and the contribution that they were expected to make to assessment of the phase 1 evaluation questions, and the preliminary assessment of the ToC against competing causal hypotheses.

Throughout phase 1, weekly catch-up calls were held with the department and relevant workstream leads. These calls not only discussed progress but also discussed emerging findings and issues that had arisen during the research, including apparent linkages and tensions between findings from different workstreams.

The literature review on secondary market data was completed by May 2023, to allow its findings to inform secondary market data analysis in the second half of the research period. ‘Emerging findings’ from the qualitative research and quantitative survey were shared with the department in early August 2023, with emerging findings from the secondary market data analysis and network analysis being shared in early September 2023. Emerging findings from all the workstreams were synthesised against the high level evaluation questions and presented to the Joint Working Group for the UK ETS, for sense-checking.

[57] Op.cit.
[58] Op.cit.

The early preparation of 'emerging findings' papers allowed early sight of how findings fitted together, and identification of opportunities for one workstream to answer questions raised by findings from other workstreams. The network analysis and secondary market data analysis workstreams were undertaken slightly later than the other workstreams, allowing network analysis to explore trading typologies identified in qualitative research and allowing the secondary market data analysis to implement metrics identified via the literature survey.

Draft working papers were then prepared for each workstream, allowing opportunity for other members of the evaluation team and the department to review and interrogate findings. Final working papers will be published as Annexes to the main report, in separate volumes.

Two synthesis workshops were held to review findings against the high level evaluation questions, attended by representatives from all workstreams (excluding the literature review) and by the evaluation manager from the department. These provided an opportunity to interrogate the findings from different workstreams and explore how they fitted together:

- The first workshop was held in early August 2023. While this focused primarily on qualitative research and quantitative survey findings, it provided an opportunity to share contextual findings from these workstreams with the teams undertaking network analysis and secondary market data analysis.
- The second synthesis workshop was held when draft working papers had been prepared. A whiteboard was used to collate evidence from all the workstreams against the high level evaluation questions and to present a preliminary assessment of the contribution analysis (testing the ToC hypothesis against competing hypotheses for different high level sectors).

Assessment of some topics, such as carbon leakage, were only informed by one workstream (in this case, qualitative research), while assessment of GHG abatement outcomes was informed by both qualitative research and quantitative research. Coverage of evaluation questions C1-C3 (overall impacts) was more limited than evaluation questions A1-A3 (outcomes) and B1-B3 (outcomes). Assessment of trading behaviour (EQ B1) and market outcomes (EQ B2) was informed by all the workstreams, as shown in the table below.

Table 16: Mapping of workstreams against high and mid level evaluation questions

Process and outcomes evaluation	Qualitative research	Quantitative survey	Network analysis	Secondary market - literature review and data analysis
A1. Has the introduction of the UK ETS ensured a smooth continuation of	√√	√√		

emissions trading for UK emitters previously in the EU ETS scheme?				
A2. How has the operation of the UK ETS influenced the delivery of a functioning carbon market?	√√	√√	√√	√
A3. Has the UK ETS delivery ensured that the scheme is administered efficiently and effectively (for compliance operators in the main scheme as well as participants in the two opt-out schemes; hospitals and small emitters, and ultra small emitters)?	√√	√√		
B1. What has been the behaviour of market participants and what have been the implications of observed behaviour (for example for ETS market functioning or for firms' decarbonisation prospects)? How has this varied across different types of firms and sectors?	√√	√√	√√	
B2. Has the UK ETS delivered a carbon market, which is sufficiently accessible to participants and sufficiently liquid to enable its policy objectives to be achieved?	√√	√	√	√√
B3. What are the risks to the effective functioning of the carbon market and how can these be mitigated?	√√		√√	√√
C1. What has been the impact of the UK ETS on emissions and emissions intensity in the traded sector and how has this varied across sites, firms, sectors and UK regions?	√√	√√		

C2. What has been the impact of the UK ETS on carbon leakage, investment leakage or carbon leakage risk in the traded sector? To what extent and how has carbon leakage, investment leakage and carbon leakage risk in the traded sector been influenced by carbon leakage mitigation policies, such as free allocation?	√√			
C3. Have there been any unanticipated consequences of UK ETS in the traded or non-traded sectors, and how have they varied across different types of firm or sector or UK region?	√√			

Key:

√√	Major source of evidence for this evaluation question during phase 1 of the evaluation
√	Minor source of evidence for this evaluation question during phase 1 of the evaluation

Both before and after the second synthesis workshop, additional analysis was undertaken to improve the relevance of charts and statistics, to clarify interpretations of findings, triangulate findings between workstreams and explore reasons for apparent differences.

Using the evidence base assembled through the draft working papers and whiteboard, a detailed review of the ToC was undertaken. Each of the assumptions in the ToC was assessed against evidence assembled from all the workstreams. Further internal meetings were held to refine this preliminary assessment of the assumptions in the ToC. While this assessment involved detailed consideration of the available evidence, this was only a preliminary 'interim' assessment because fuller evidence will become available during phase 2 of the evaluation. Many of the assumptions were defined as 'unproven' because of lack of evidence at this stage. The interim assessment of ToC assumptions is presented in Appendix 3.

Further contribution analysis was undertaken following the workshop, as far as was possible based on phase 1 data. Evidence from all the workstreams was reviewed for four high level sectors (namely aviation, power generation, commodity producers and other industry). Commodity producers were defined as industries producing internationally traded commodities, where the price was set internationally. The types of evidence collated for each sector were:

- Evidence about observed outcomes for carbon abatement and carbon leakage risks, from the evaluation and other published sources.
- Evidence about the contribution of the UK ETS and other factors to these outcomes.

This corresponded to the final step in the contribution analysis process as defined by John Mayne[59]: 'revise and, where additional evidence permits, strengthen the contribution story'. A further iteration of contribution analysis will be undertaken during phase 2 of the evaluation, when more robust, objective evidence is available on these topics.

This synthesis report presents the findings from this overall process. The next step in the evaluation process will be reviewing lessons from phase 1 to inform the proposed methodology for phase 2.

[59] Mayne, J. (2008), Contribution analysis: An approach to exploring cause and effect, May 2016, ILAC Brief 16.

Appendix 5: UK ETS process diagrams – installation and aircraft operators

Figure 25: Process diagram for UK ETS main scheme - installation operators

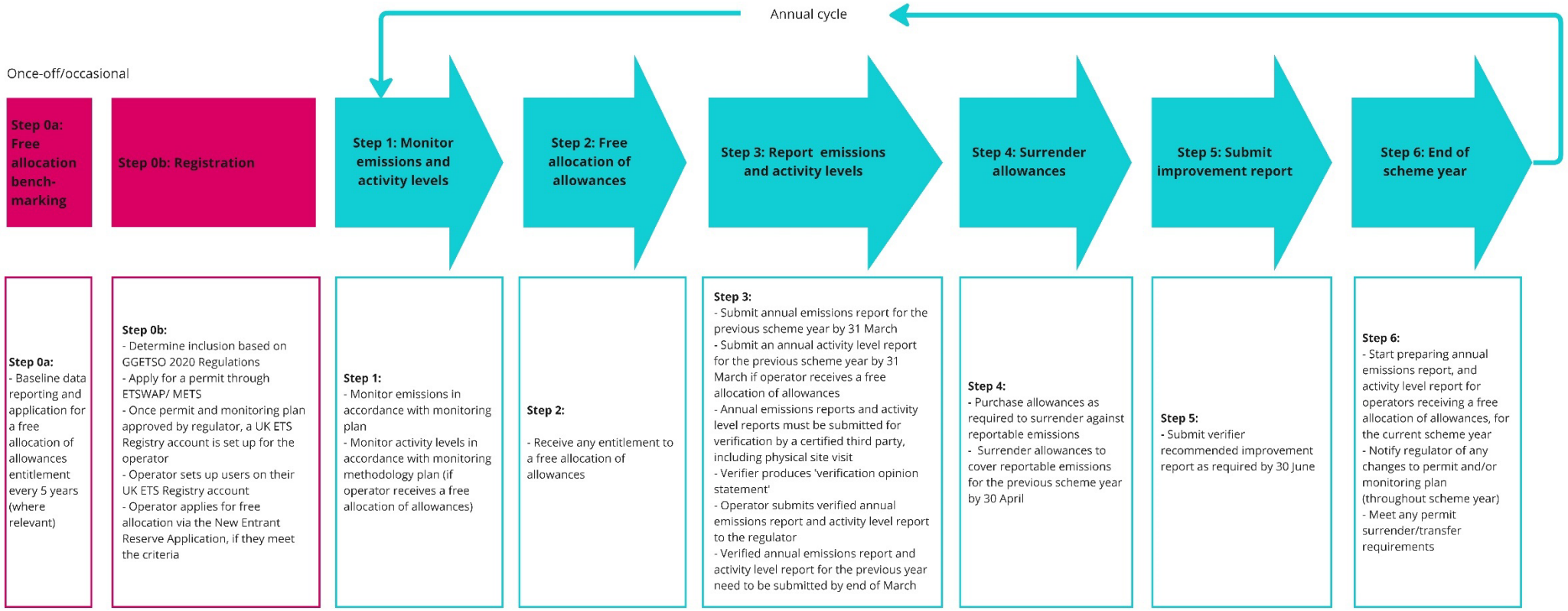


Figure 26: Process diagram for UK ETS main scheme - aircraft operators