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Understanding the impacts of emission trading systems and carbon border adjustment mechanisms on Scottish business

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Executive summary

Emissions trading systems (ETSs)[1] have been at the core of climate policy in the EU and the UK for more than 15 years. Operating under a 'cap-and-trade' principle, they are designed to enable decarbonisation to take place in industries where it is most cost-effective. However, there is a risk that these systems push carbon-intensive industrial processes to other territories with less stringent carbon pricing, regulations or emissions standards. This can result in a subsequent overall increase in greenhouse gas emissions or 'carbon leakage'.

To lower the carbon leakage risk, the Fit for 55 Package[2], published by the European Commission in July 2021, included a proposal for the introduction of the Carbon Border Adjustment Mechanism (CBAM). This EU CBAM will put a carbon price on imports of a targeted selection of products, calculated depending on product carbon intensity and the price of EU ETS allowances.

There is the potential for such carbon pricing policies – which are evolving at pace within the UK, Europe and around the world – to affect the competitiveness of Scottish business and industry. At present, there is no established approach to assess the potential impact on the Scottish economy of UK and international ETS and CBAM schemes, and the likely changes to them in the coming years.

The study underpinning this report was conducted between July 2021 and March 2022.

[1] For an explanation of how emissions trading systems work see https://www.lse.ac.uk/granthaminstitute/explainers/how-do-emissions-trading-systems-work/.

An FAQ on the EU CBAM proposal can be found here Carbon Border Adjustment Mechanism (europa.eu).

[2] This initiative aims to reduce cut greenhouse gas emissions by 55% by 2030 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0550

In this report, we have developed an approach to assess the impacts of ETS and CBAM on Scottish business which draws on a number of datasets and existing methodologies. The structure is as follows:

- First, we identify Scotland's main economic sectors currently participating in the UK ETS and outline the characteristics of those with most relevance to carbon pricing mechanisms.
- Second, we assess these sectors' exposure to trade and identify potential carbon leakage risks.
- Third, we assess the impacts of ETS by exploring a number of scenarios.
- Finally, we examine the implications of the proposed EU CBAM and identify preliminary areas of potential competitive advantage for Scottish exporters.

Findings

Scottish ETS installations face considerable uncertainty in relation to their future exposure to carbon liabilities due to the changeable policy landscape. Our ETS allocation and CBAM modelling have provided an initial estimate of the potential magnitude of impact in various sectors.

The project findings are formulated around the following key research questions:

1. **What are Scotland's main economic sectors currently participating in the UK ETS, or potentially affected by CBAMs?**

Our economic analysis ranked 138 installations. Of these, 71 are offshore installations in the oil and gas sector and 67 are onshore sites.

Based on estimates of Gross Value Added (GVA), employment, exports and GVA multipliers, the following sectors, listed in alphabetical order, were identified as the main economic sectors among ETS-covered operators:

- Chemicals, dyes and pigments
- Electricity, steam and air conditioning[3]
- Extraction of oil and gas, and natural gas distribution
- Food products
- Oil refining
- Pharmaceuticals
- Spirits
- Veneer sheets and wood-based panels.

In addition to the ETS covered sites, some Scottish fertiliser manufacturers and metal transformation companies could potentially be affected by the EU CBAM.

2. **What are the main products and costs of Scottish sectors**

The main product groups within ETS sectors include primary energy and electricity, petrochemicals, metallic and non-metallic products as well as outputs of the pharmaceuticals, food and drink, wood-based and paper product industries.

Energy costs by far exceed other purchased intermediary products for the selected sectors, with the exception of food production.

3. **What is the exposure of sectors to markets inside and outside the EU?**

As well as the Scottish domestic market, the main ETS sectors primarily compete with producers in the rest of the UK. The key ETS exporting sectors mainly compete with producers in the EU and the wider European Economic Area, followed by the US. Along

[3] This sector will also be covered by the proposed EU CBAM. Other Scottish ETS sectors to be covered by CBAM are aluminium, iron and steel and cement.

with China, these countries also represent the main sources of imports within the key ETS sectors.

4. Which of the Scottish sectors are most vulnerable to carbon leakage?

Our mapping suggests that sectors such as paper, metal forging, glass fibres, and non-metallic minerals may be particularly vulnerable to international competitiveness impacts. However, many of these sectors trade primarily with the EU, where carbon pricing is comparable. Many other sectors display "medium" risks; including glass, oil refining and chemicals. Some metal products and chemicals have a relatively high trade intensity with countries that do not currently implement stringent carbon pricing policies.

5. How could the risk of carbon leakage affect trade if the EU draft CBAM was implemented?

If the EU draft CBAM was implemented, the aluminium and iron and steel ETS sectors in Scotland would be affected. In addition, non-ETS sectors such as fertiliser production, may also see an impact, but further data collection is needed to fully quantify the impact. The effects of the implementation of the CBAM is unlikely to affect the cement and electricity sectors in Scotland due to lack of exports to the EU and is likely to have limited influence on the iron and steel sector due to low levels of EU exports. For ETS installations, the trade that is affected is likely to incur limited additional costs as ETS costs incurred in the UK will lead to a proportional reduction in the EU CBAM charge.

There may be an aspect of competitive advantage for Scottish exporters to the EU, in cases where their GHG intensity is below that of non-EU competitors. This will depend on whether the EU CBAM covers only direct emissions or also embodied emissions. It is possible that chemicals may also be covered by the EU CBAM in which case there will be a potential competitive advantage, the scale of which will depend on the exact chemicals product mix covered by CBAM. Domestic CBAM policy has also been explored by other countries outside the EU. However, among Scotland's key trading partners outside the European Economic Area, only Canada (a relatively minor trade partner) is beginning to explore the implementation of a CBAM. Therefore, the EU policy developments remain the main focus in relation to Scotland's exporters.

6. What would be the impact on Scottish sectors of a UK ETS system which deviates from the EU ETS system in terms of price or free allocation?

Our calculations suggest that the ETS installations considered in our study incurred an ETS cost of around £230 million in 2019. Under assumptions of unchanged activity levels and emission intensity rates and under the current UK allocation trajectory, the costs of the ETS to these installations would amount to £740 million by 2030, equivalent to a fifth of their current estimated GVA. This assumes an allowance price of £54/tCO_2.[4] Alternatively, using the allocation method in the Fit for 55 proposals would increase the £740 million figure by about £75 million. The projected increase in carbon liability provides a strong incentive for operators to invest in emissions abatement and therefore avoid the full scale of the potential ETS costs.

Low and high UK allowance price scenarios were also modelled. Compared with the £54/tCO_2 central case, these are -20% (i.e. £43.20) and +20% (£64.80)[5]. The base added cost of £740 million decreases to £592 million and increases to £888 million in

[4] This is based on the MIX-CP scenario of the European Commission equal to €$_{2015}$60 / €$_{2020}$63, which was above the carbon price level in the EU and the UK at the time of scenario development, however was superseded at report writing. The price estimate is not intended to reflect current ETS prices.
[5] All the carbon price projections considered are well below the carbon values recommended by the UK Government for policy appraisal: Valuation of greenhouse gas emissions: for policy appraisal and evaluation - GOV.UK (www.gov.uk).

response to these low and high carbon price assumptions respectively. Carbon price scenarios were selected during the early fall of 2021 and were superseded at report writing.

The cost of CBAM certificates for exports from Scotland to the EU, for those sectors affected, would be considerably less than the costs associated with the allocation scenarios described above. This is because the Scottish exporters would only need to pay for the cost difference between the carbon costs paid domestically and the CBAM certificate costs.

Current policy context for this research

ETS and CBAM policy are rapidly changing and as such there have been developments which it was not possible to include in the analysis here. For example, our scenarios were developed before the UK ETS consultation[6] was finalised and as such there will not necessarily be alignment. Furthermore, energy prices, and UK and EU ETS prices, have varied since the analysis was completed and may not be encompassed by the range of scenarios used. Nevertheless, the methodology developed here could be applied in future to an alternative range of ETS prices.

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

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Glossary

Term	Definition
Carbon Border Adjustment Mechanism (CBAM)	A climate policy measure that aims to prevent the risk of carbon leakage by imposing a levy on imports of specific products
Carbon leakage	A situation that may occur where businesses transfer production, and therefore emissions, to other countries with less stringent emission constraints. This may ultimately lead to an increase in overall emissions, for reasons of costs related to climate policies.
CO_2e	Carbon dioxide equivalent; a way of expressing emissions of different greenhouse gases in a common unit
Compensation (of employees)	Compensation describes the cash rewards paid to employees in exchange for the services they provide. It may include base salary, wages, incentives and/or commission. Total compensation includes cash rewards as well as any other company benefits.
Climate Change Agreements (CCAs)	Voluntary agreements made between UK industry and the Environment Agency to reduce energy use and carbon dioxide (CO2) emissions. In return, operators receive a discount on the Climate Change Levy (CCL)
Climate Change Levy (CCL)	An environmental tax on the energy supplied to companies and fuels used by power generators. It is levied on supplies of gas, electricity, oil and any other taxable fuels
Cross Sectoral Correction Factor (CSCF)	A mechanism for controlling emissions trading allowances. It ensures that the total of freely allocated emissions allowances for non-electricity generators does not exceed the maximum free allowance
Emissions Trading System (ETS)	A 'cap and trade' type market instrument that creates incentives to reduce emissions where these are most cost-effective
Greenhouse gas (GHG) emissions	Gases that absorb and emit radiation and contribute to rising global temperature. Includes carbon dioxide (CO_2) and nitrous oxide (N_2O)
Gross Value Added (GVA)	An economic productivity metric that measures the contribution of a corporate entity to the economy
Gross Operating Surplus (GOS)	The balance of the trading account for productive units. Equal to value added minus payroll and other taxes on production, plus operating grants
Installation	Reporting unit under the ETS. According to Article 3(e) of the EU ETS Directive, an installation is a stationary technical unit where one or more activities under the scope of the EU ETS and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution. Similarly, in Schedule 2.2 of the UK Greenhouse Gas Emissions Trading Scheme Order 2020, an installation is defined as a stationary technical unit or units where one or more regulated activities are carried out.
Input-Output (IO)	Input-Output (IO) is a generic term used to refer to a class of statistical tables which detail the flows of goods and services in an economy
Supply chain effect multipliers	Multipliers derived from Input-Output Tables provide a framework for estimating economic impacts and changes to an economy. They reflect how economic performance scales as a result of increased final use of an industry output. If there is an increase in final use for a particular industry output, we can assume that there will be an increase in the output of that industry, the direct effect. As these producers increase their output, there will also be an increase in use on their suppliers and so on down the supply chain; this is the indirect effect. As a result of the direct and indirect effects the level of household income throughout the economy will increase as a result of increased employment. A proportion of this increased income will be re-spent on final products, this is the induced effect. Type I multipliers sum together direct and indirect effects while Type II multipliers also include induced effects.

1 Introduction

Emissions trading systems have been at the core of climate policy in the EU and the UK for more than 15 years. The aim of these systems is to enable cost-effective decarbonisation. However, given asymmetry in international climate policy, there is a risk that these systems lead to relocation of production to jurisdictions with less stringent carbon pricing, regulations or emissions standards. This can result in a subsequent increase in greenhouse gas emissions in those countries; so-called 'carbon leakage'.

Carbon leakage is a key topic in the development of national and international climate change policy. The Fit for 55 Package[7], published by the European Commission in July 2021, included a proposal for the introduction of the Carbon Border Adjustment Mechanism (CBAM). This EU CBAM will put a carbon price on imports of a targeted selection of products, calculated depending on the price of EU ETS allowances.

In the UK, the UK ETS began operating on 1 January 2021 following the UK's withdrawal from the EU. The UK government is still developing the UK ETS, with consultation on proposed amendments ongoing and further changes to important design elements expected in the coming years.[8] Furthermore, the UK Parliament's Environmental Audit Select Committee (EAC) has recently announced an inquiry into the role a UK CBAM could play in preventing carbon leakage and helping the UK meet its environmental objectives, after recommending a UK CBAM should be considered.[9]

As carbon pricing policies evolve at pace, both within the UK and around the world, there is the potential for this to affect the competitiveness of Scottish businesses and industries. There is a need to understand the impact on the economy, employment and trade of relevant sectors and sites, in particular those within the scope and design of an ETS and/or CBAM, and which contribute most to the Scottish economy.

2 Report aims

ClimateXChange, on behalf of the Scottish Government, commissioned Ricardo Energy and Environment to research the potential competitiveness impacts on Scottish businesses and industries of changes in UK and EU carbon pricing policy. In particular, the study focuses on Emission Trading Schemes (ETS) and Carbon Border Adjustment Mechanisms (CBAM).

The research is divided into two stages and this report covers the results of Stage 1, undertaken between August and October 2021, with the results from Stage 2 to be reported by February 2022. The scope of Stage 1 is to answer the following questions:

1. What are Scotland's main economic sectors currently participating in the UK ETS, or potentially affected by CBAMs?

2. What are the main products, costs, markets and primary competitors of selected Scottish ETS and CBAM sectors?

3. What is the relationship of these sectors with markets inside and outside the EU?

4. Which of the Scottish sectors are most vulnerable to carbon leakage, and how could this affect trade in a scenario where the EU draft CBAM were implemented?

5. What would be the impact on Scottish sectors of a UK ETS system which deviates from the EU ETS system in terms of price or free allocation?

[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0550
[8] https://www.gov.uk/government/consultations/uk-emissions-trading-scheme-proposed-amendments
[9] https://committees.parliament.uk/committee/62/environmental-audit-committee/news/157728/eac-launches-new-inquiry-weighing-up-carbon-border-tax-measures/

The analysis presented below is based on published data and sector-specific inputs received with thanks from the Scottish Government, HMRC (Her Majesty's Revenues and Customs) and SEPA (the Scottish Environment Protection Agency).

3 Scotland's main economic sectors currently participating in the UK ETS

What are Scotland's main economic sectors currently participating in the UK ETS, or potentially affected by CBAM?

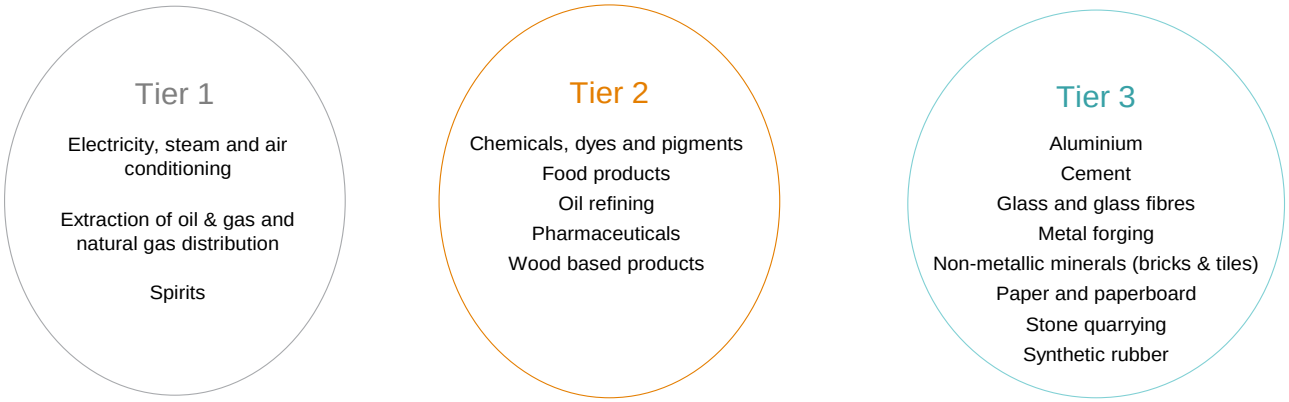
This section uses the following economic indicators to rank Scottish ETS sites and sectors: Gross Value Added (GVA), exports, employment, and supply chain multipliers.

3.1 Key findings

ETS sites were assigned to 16 economic sectors. These were then grouped into tiers on the basis of an economic ranking analysis with Tier 1 representing the highest economic contribution on basis of the selected indicators for an individual ETS sector and Tier 3 representing lower economic contribution[10]. The higher tier groupings show higher average values across all economic metrics considered.

Three sectors fall into Tier 1, five into Tier 2 and eight into Tier 3, as shown in Figure 1 below.

Figure 1. ETS sector classification by economic contribution tier



3.1.1 Selection of Scottish ETS installations

To form the economic tiers, we first developed a list of Scottish installations covered by the UK ETS.

The UK ETS has applied since January 2021, before which participating Scottish installations were covered by the EU ETS. The scope of the UK ETS currently mirrors the EU ETS and covers combustion installations rated at >20MW thermal capacity and selected energy-intensive industries[11].

[10] The economic contribution is based on the restricted range of metrics. Other sectors provide jobs, essential services and other important contributions not captured in our analysis.

[11] The EU ETS covers carbon dioxide (CO_2) from electricity and heat, energy intensive industry and commercial aviation. It covers nitrous oxide (N_2O) from the production of nitric, adipic and glyoxylic acids and glyoxal and perfluorocarbons (PFCs) from production of aluminium. See EU Emissions Trading System (EU ETS) (europa.eu)

The UK ETS includes a voluntary 'Small Emitter and Hospital Opt-Out' for installations with emissions lower than 25,000 tCO_2e per annum and a net-rated thermal capacity below 35MW.

Several installation categories were removed from the analysis. These include:

- New installations without reported emissions data
- Small emitters across several sectors marked as "excluded" in the EU Transaction Log, the source for the reference verified emissions data in the reference period 2017-2019
- Installations in sectors where goods are not or cannot be traded internationally such as health, education and Ministry of Defence buildings, as well as data centres serving UK-based banks.[12]

Electricity is not exported internationally from Scotland. However, electricity exports to Northern Ireland through the Moyle Interconnector are treated in the same way as exports to the EU according to the Northern Ireland Protocol associated with the UK exit from the EU. Therefore, electricity and steam installations were included in our analysis.

The above filtering resulted in 138 installations that were included in the economic ranking analysis. Of these, 71 are offshore installations in the oil and gas sector and 67 are onshore sites, see Appendix 1.

3.1.2 **Sectoral classification**

The 138 ETS installations were classified by sector to enable a more general analysis of impact from variations in ETS and CBAM design.

The attribution of most installations to economic activity sectors is based on an analysis undertaken by the European Commission during 2013/14 in relation to carbon leakage risks[13]. This was supplemented and adjusted by individual installation research.

The number of installations included in each sector is provided in the table below. Some sectors, for example basic pharmaceutical products and pharmaceutical preparations, are grouped for key findings reporting into one main sector.

[12] All gas compressors were included due to the trade associated with these installations, for example in dealing with imports from Norway. Similarly, all electricity producers were included due to the trade dimension with Northern Ireland.

[13] https://ec.europa.eu/clima/sites/clima/files/installation_nace_rev2_matching_en.xls

Table 1. ETS installations by economic sector

SIC Code and Sector Title		Aggregated sector category for key findings reporting	Number of installations
6100	Extraction of crude petroleum	Extraction of oil & gas and natural gas distribution	1
6200	Extraction of natural gas		6
O&G	Combined Oil and Gas extraction		2
35220	Distribution of gaseous fuels through mains		6
6100	Extraction of crude petroleum (offshore)	Offshore extraction of oil & gas and natural gas distribution	55
6200	Extraction of natural gas (offshore)		1
O&G	Combined Oil and Gas extraction (offshore)		15
8110	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	Stone quarrying	2
10410	Manufacture of oils and fats	Food products	1
10512	Butter and cheese production		1
10890	Manufacture of other food products (not elsewhere classified)		2
11010	Distilling, rectifying and blending of spirits	Spirits	11
16210	Manufacture of veneer sheets and wood-based panels	Wood based products	3
17120	Manufacture of paper and paperboard	Paper and paperboard	3
19201	Mineral oil refining	Oil refining	1
20120	Manufacture of dyes and pigments	Chemicals, dyes and pigments	1
20140	Manufacture of other organic basic chemicals		3
20170	Manufacture of synthetic rubber in primary forms	Synthetic rubber	1
21100	Manufacture of basic pharmaceutical products	Pharmaceuticals	1
21200	Manufacture of pharmaceutical preparations		1
23130	Manufacture of hollow glass	Glass and glass fibres	2
23140	Manufacture of glass fibres		1
23320	Manufacture of bricks, tiles and construction products, in baked clay	Non-metallic minerals (bricks & tiles)	1
23990	Manufacture of other non-metallic mineral products n.e.c.		2
24420	Aluminium production	Aluminium	1
23510	Manufacture of cement	Cement	1
25500	Metal forging	Metal forging	3
35110	Production of electricity	Electricity, steam and air conditioning	6
35300	Steam and air conditioning		4

As well as the SIC code shown in Table 1, a number of other descriptors are used to identify these sectors within various data sources used in our research. This mapping of descriptors is presented in Appendix 2.

3.1.3 Metrics for economic contribution

Next, four economic variables were selected in discussion with the project steering group to measure the economic contribution of Scottish ETS participants. The economic variables were as follows:

Gross value added (GVA): GVA indicators are a measure of the value of goods and services produced by a given sector. In this study, the GVA calculation for ETS sectoral groupings is based on average emission intensities on basis of the emissions information of individual installations and the sectoral emission intensity data published by the Scottish Government.

Employment: The number of people employed in each sector, calculated on basis of the GVA estimates and the employment to GVA ratio derived from the Scottish Government statistics.

Export: The value of exports from each sector, calculated using GVA figures.

Supply chain effect multipliers: Multipliers for each sector were also included in the analysis[14]. These figures represent the changes in the supply chain associated with a change in output in a given sector; direct and indirect effects as well as induced effects linked to increased consumption spending.

3.1.4 Economic contribution ranking process

In order to provide a ranking of sectors in terms of economic contribution, an analysis was undertaken on the basis of the four indicators listed above. For a given metric, sectoral values were represented as a ratio to the maximum score across all sectors. In other words, they were normalised, allowing cross-comparability across the four indicators considered.

Based on the normalised scores for each economic metric, an “average normalised score” was calculated. This was used to determine the overall ranking and split the sectors into three tiers based on their economic contribution.

The results of this exercise are presented in Table 2.

Table 2. Economic contribution ranking of ETS sectors in Scotland. Scores are normalised and adjusted as described in the text

Aggregated sectors	GVA Score	Employment Score	Export Score	Multiplier Score	Tier
Spirits (drinks)	0.55	1.00	1.00	0.53	Tier 1
Electricity, steam and air conditioning	1.00	0.61	0.12	0.75	
Extraction of oil and gas and natural gas distribution	0.92	0.56	0.11	0.66	
Chemicals, dyes and pigments	0.12	0.23	0.35	0.63	Tier 2
Food products	0.06	0.12	0.12	1.00	
Pharmaceuticals	0.14	0.26	0.39	0.48	

[14] Type II multipliers were used in the analysis.

Oil refining	0.10	0.19	0.28	0.68	
Veneer sheets and wood-based panels	0.08	0.21	0.03	0.83	
Cement	0.01	0.02	0.03	0.82	Tier 3
Paper and paperboard	0.03	0.07	0.01	0.76	
Glass and glass fibres	0.04	0.07	0.10	0.67	
Metal forging	0.03	0.07	0.04	0.66	
Quarrying of ornamental and building stone	0.00	0.00	0.00	0.71	
Aluminium	0.01	0.02	0.01	0.63	
Bricks and tiles and non-metallic minerals	0.00	0.00	0.00	0.67	
Synthetic rubber	0.00	0.01	0.01	0.58	

The individual sector scores are highly uncertain due to the significant data limitations outlined below and should not be used for sequential ranking outside of this study. However, the method used has provided high level insight into variations in sector economic contribution.

The variations across sectors can be described by three tiers. The higher tiers are clearly distinguished from lower tiers in terms of GVA and employment. In addition, there is also distinction on exports between tiers 2 and 3.

Our findings suggest that 'Spirits (drinks)', 'Electricity, steam and air conditioning' and 'Extraction of oil and gas and natural gas distribution' sectors contribute the most to the Scottish economy, in terms of the metrics assessed here.

The results show that the hierarchy of the sectors would remain unchanged when switching from the GVA to the employment metric. However, this changes when switching to exports and GVA multipliers.

3.2 Detailed data and interpretation considerations

3.2.1 Data sources

The list of ETS installations used in this section draws on three main sources:

- Onshore installation list received from SEPA in August 2021
- Offshore installation list received from the Scottish Government in September 2021
- Publicly available EU Transaction Log[15] containing verified emission and allocation data for 2008-2020 and small emitters excluded from the ETS.

[15] https://ec.europa.eu/clima/ets/

The economic variables considered in the ranking were based on information from the following sources:

- **Gross value added:** GVA indicators are based on data from the Scottish Government satellite accounts[16], multiplied by the average 2017-2019 verified emissions for the ETS installations falling within a sectoral classification obtained from the European Transaction Log (EUTL)[17].
- **Employment**: Rankings were based on Scottish Annual Business Survey (SABS) data.[18] The employment within each sector was estimated by dividing GVA averages for 2017-2018 by the GVA per head values in the SABS data.
- **Export**: Rankings were calculated from "*Export statistics Scotland: 2018*"[19], based on averages of "Total International Exports Grouped by Industry Sector" in 2017 and 2018. This metric is based on GVA figures.
- **Supply chain effect multipliers**: Type II multipliers were used in the analysis, obtained from Scottish government data[20]. These range from 1.25 for the pharmaceutical sector to 3.58 for the food production sector.

3.2.2 Analysis limitations

Due to data gaps, the analysis does not account for relevant factors such as the geographic distribution of compensation for labour or capital inputs, or tax contributions.

The GVA calculation for ETS sectoral groupings is based on average emission intensities. In this study, since sector-wide statistics cannot be used due to partial sectoral coverage by the ETS, GVA is calculated by multiplying average emission intensity by ETS emissions data, for a given sector. The sectoral classifications under which emissions intensity data is reported are relatively broad, for example the same metric applies for synthetic rubber, oil refining, chemicals, dyes and pigments. However, the installations within these sectors are likely to display a wide range of emissions per unit of Gross Value Added. This limitation contributes to weak GVA estimates for the ETS sub-group, which further limits the differentiation of ETS sub-groups with regard to employment and export estimates (which use the GVA estimate).

To mitigate the uncertainty of the estimate, the GVA indicators were compared to grouped Scottish Annual Business Statistics (SABS) GVA data for individual subsectors[21] and adjusted where the totals for the ETS sectors exceeded SABS totals, therefore reducing over-estimated GVA figures by the proportion of the exceedance for the SABS sector group.

The analysis does not include a ranking of operators potentially affected by the proposed CBAM and not covered by the UK ETS. Around 670 Scottish operators not covered by the UK ETS are reported by SABS as making products covered by the CBAM proposals. These operators make secondary iron and steel products (664 units) or fertilisers (eight units). The study team did not have sufficient information on the relevance of the CBAM proposals to this large number of registered economic entities.

Following discussion with the Project Steering Group, only one sector, synthetic rubber, was filtered out of the subsequent analysis stages due to the lower economic ranking and limited emission levels.

[16] Provided to Ricardo by the Scottish Government
[17] https://ec.europa.eu/clima/ets/napInstallationInformation
[18] https://www.gov.scot/publications/scottish-annual-business-statistics-2018/
[19] https://www.gov.scot/publications/export-stats-scotland-2018/
[20] https://www.gov.scot/publications/input-output-latest/
[21] SABS data was presented to the consultants in sector clusters to avoid disclosure and could only be used to a limited degree.

4 Characteristics of ETS sectors

What are the main products, costs, markets of Scottish ETS sectors and sites?

Following on from the assessment of the economic contribution of Scottish ETS installations in Section 3, it is important to identify the characteristics of these sites and sectors. This will enable greater detail of the exposure of these sites and sectors to markets inside and outside the EU.

4.1 Key findings

We find that for all sectors, apart from food production, energy costs exceed the costs of all other intermediate inputs to their production processes. A high energy intensity is often associated with higher direct and indirect climate policy costs, e.g. as linked to renewable electricity. The high proportion of energy costs of sectors here highlights the risk of additional ETS costs being passed on to overall product cost, as compared to less energy intensive products.

Primary competitors and important markets were also investigated. We find that, for both imports and exports, EU Member States plus Norway and Switzerland constitute the most frequently reported trading partners, followed by the USA. For imports, China also plays an important role. Therefore, given the level of industrialisation of the countries where a large proportion of the key international competitors are located, these are likely to have a comparable high level cost structure, and in the case of the EU, a comparable carbon pricing context.

Further detail of the products, costs, and markets/competitors are provided below.

4.1.1 Products

The main products of the focus ETS installations are shown in the table below.

Table 3. Main products of “focus” Scottish ETS installations

Products	Tier
Electricity, steam and air conditioning	1
Crude petroleum	1
Natural gas	1
Whisky, gin, other spirits	1
Ethylene, polyethylene, propylene, polypropylene, ethanol, dyes and pigments	2
Refined petroleum	2
Basic pharmaceuticals, antibiotics	2
Cheese	2
Oils and fats, supplements	2
Asphalt, bricks and ceramics	2
Wood panels	2
Aluminium	3
Glass bottles	3

Cement	3
Paper and paperboard	3
Metal structures	3
Building stone	3
Synthetic rubber	3
Total: 18 product groups, 7 on Tier 3, 7 in Tier 2 and 4 in Tier 1	

Source: Individual installation websites, SEPA environmental permit data, email responses from selected sites.

These products were identified by performing individual website and SEPA environmental permit searches as well as from one stakeholder response.

Some uncertainty remains with regards to the exact nature of metal structures produced by the ETS installations and with regards to the full list of food products. However, the above list provides a strong indication of the main products that are necessary to consider when assessing Scotland's economic performance and competitiveness.

4.1.2 Costs

In this study, we use energy costs as a metric of industry sensitivity to changes in carbon prices. Energy costs, rather than GHG emissions, are commonly used for this purpose because GHG emissions are often not well reported internationally, and energy costs provide a correlated, though admittedly weak, proxy. For sectors with high emissions from non-energy aspects of the production process, such as chemical reactions in the cement sector, the correlation between combustion and total GHG emissions is least strong.

Most Scottish installations are energy intensive, with primary energy and electricity constituting a significant proportion of total costs. Therefore, an increase in the cost of carbon allowances is likely to affect a large proportion of the costs for these installations.

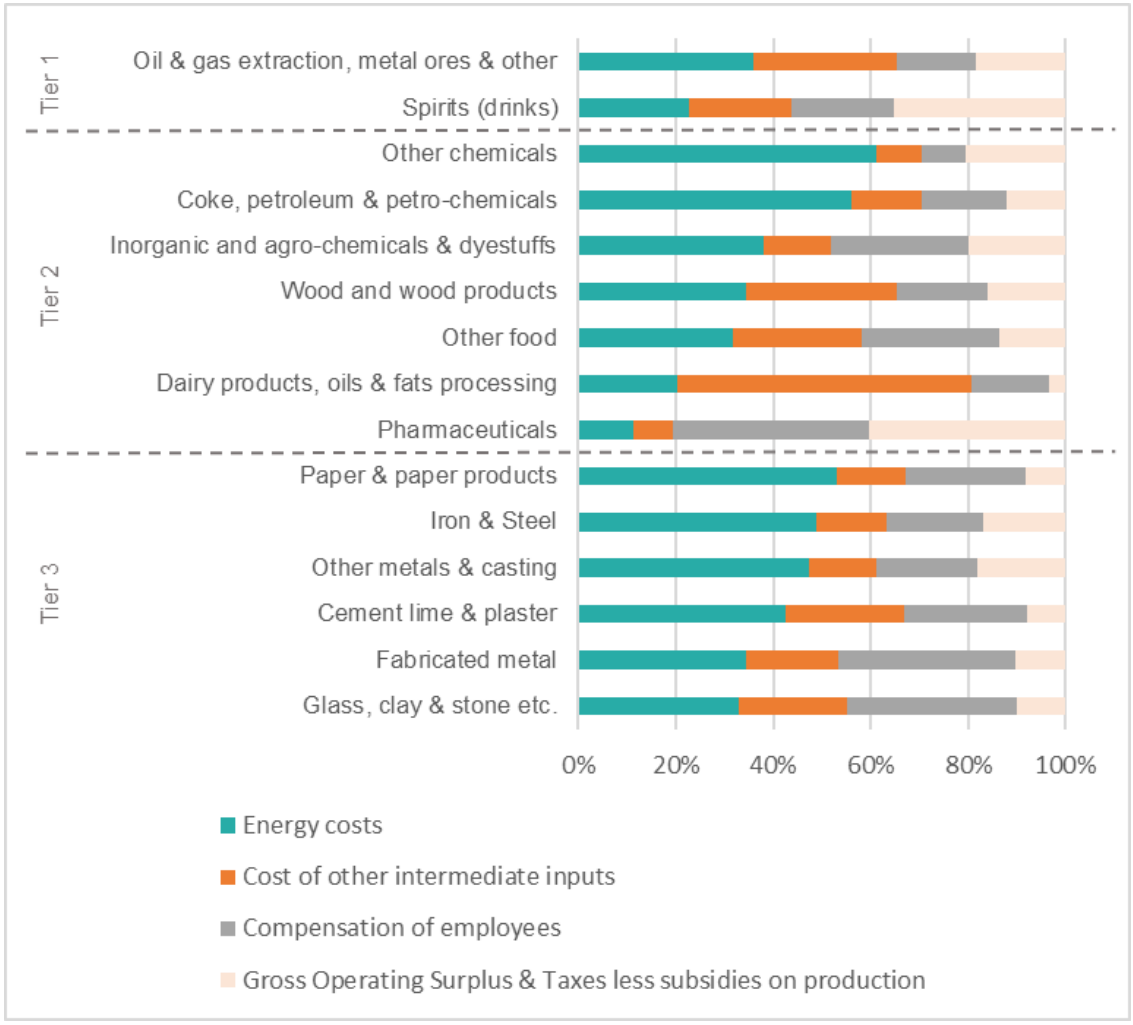
Figure 2 below represents a breakdown of the following parameters as a proportion of the total value of output for each sector as a snapshot for the year 2017[22].

- Energy costs
- Costs of other intermediate inputs, e.g. materials
- Costs of employee compensation[23]
- A remainder, which is the sum of Gross Operating Surplus and Taxes less subsidies on product.

Figure 2. Cost breakdown of economic sectors to which ETS installations belong, ordered by economic contribution ranking tier and energy costs as a proportion of total costs

[22] The latest available data at time of analysis.

[23] Compensation describes the cash rewards paid to employees in exchange for the services they provide. It may include base salary, wages, incentives and/or commission. Total compensation includes cash rewards as well as any other company benefits.



Source: Scottish IO Tables for 2017; for sector mapping to ETS sectors, see Appendix 2.

The above data shows that, except for food production, the energy costs of all sectors exceed the costs of all other intermediate inputs to their production processes. For all sectors except pharmaceuticals, food production and spirits energy costs represent between 32% and 61% of output value for the sector.

The figure above suggests that sectors such as petro-chemicals are more sensitive to added carbon costs, in the context of cost structure comparisons. The ETS installations in the petro-chemicals sector constitute a larger proportion of the Scottish economy than other installations with high energy costs. For example, paper and paper products or iron and steel are both tier 3 and constitute a smaller proportion of the Scottish economy.

4.1.3 Primary competitors and markets

To identify possible dimensions of carbon leakage risk, we now identify key competitors within Scotland, the rest of the UK[24], the European Union and the rest of the world.

Depending on the use of the product, competition can arise from similar products produced by other companies (discussed in the section below) or from substitute products. We discuss these in turn.

- **Competition with different products**

Substitution effects of one product with another are not quantified as part of this study. However, examples of product substitution that may need to be considered in future work are:

[24] Including imports to the UK, as this is relevant to a UK CBAM scenario.

- Container glass competes with plastic and cardboard packaging in the food and drink sector
- Cement, wood and metals can be substituted to some extent in the construction sector
- Fuel switching such as changes in the amount of time different types of power stations operate, with a gradual decrease in coal fired electricity generation, is an example of intermediate input substitution in the electricity sector.

This study has also not considered broader trends in demand for final products, for example as linked to the reduction in food packaging and other products or feedstocks made by the Scottish ETS sectors.

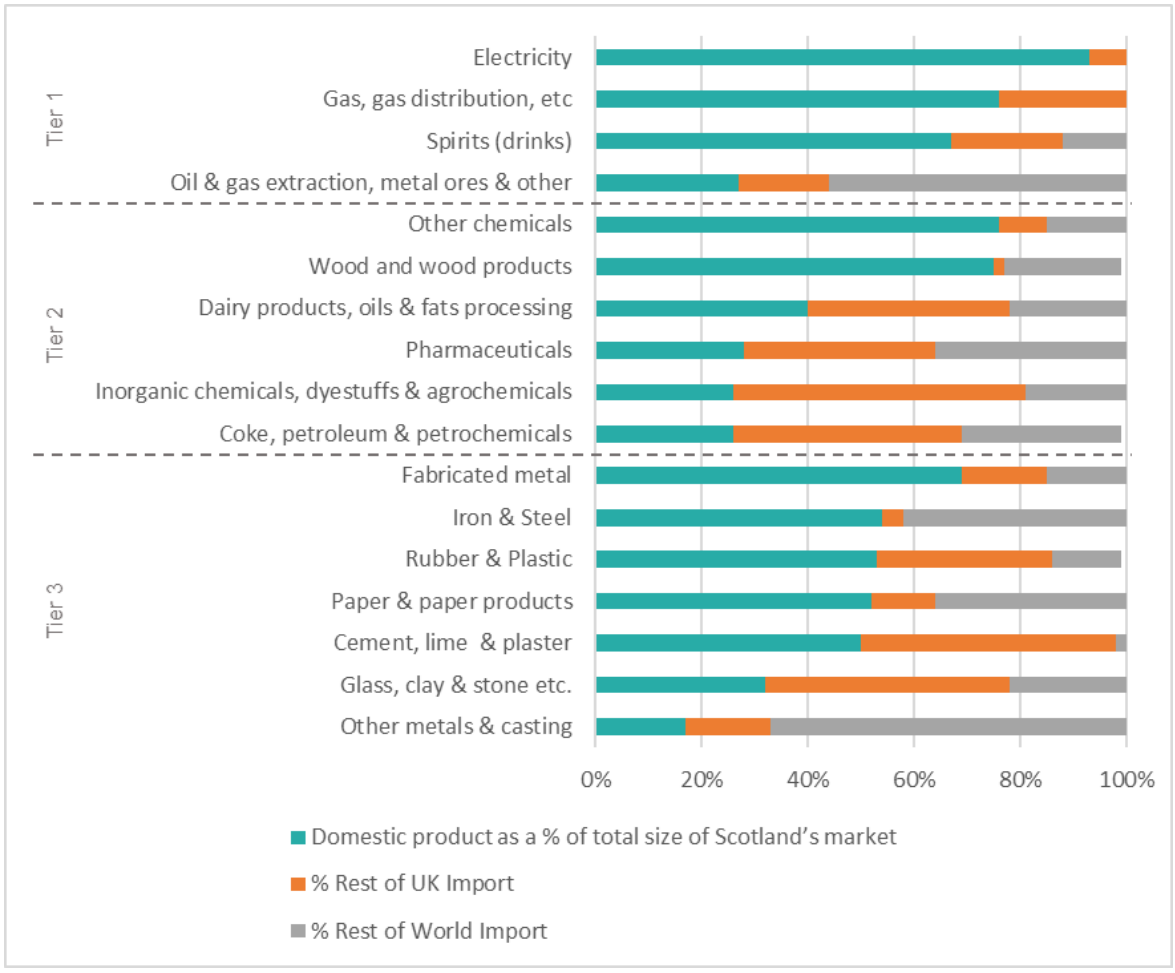
- **Competition within the same product category**

Competition within the same product category is more easily determined from available data.

1. Competition in the Scottish and UK markets

A large proportion of the products made by Scottish installations that fall within ETS sectors are supplied to the domestic Scottish market, see Figure 3 below. This market is further supplied by rest of the UK producers who are expected under the assumptions of this study to face similar carbon costs to Scottish installations.

Figure 3. Competition to ETS installations in the Scottish market, ordered by economic contribution ranking tier and percentage of domestic use



Source: Scottish Supply and Use Tables for 2017.

In the Scottish market, competition from international suppliers, as indicated in grey, is highest in the extractive industry, metal forging (as captured by the Iron and Steel sector in the Scottish Supply and Use Tables and the figure above), pharmaceuticals and paper and paper product sectors.

The analysis of the information that was made available suggests that a large proportion of the output of Scottish ETS installations is used within the UK market, with varying degrees of international export levels.

2. Competition in the UK and international markets

Analysis of trade data for the individual product categories identified in Section 2 enabled identification of the **key international trading partners** for Scottish ETS installations.

Major international export destinations and sources of imports for these products are listed in the tables below. The information in the table includes countries that passed statistical disclosure rules, this means that countries listed first are among the top three export destinations or import sources but may not be the top first.

Table 4. Export destinations of sectors that include ETS sites, grouped by economic contribution of sector ranking tiers

Tier	Product categories	Top export destinations for which data is available		
Tier 1	Extraction of natural gas	Ireland*	Netherlands	France
	Extraction of crude petroleum	Gibraltar		
	Distilling, rectifying and blending of spirits	United States	France	Singapore
Tier 2	Butter and cheese production	Ireland	Spain	Hong Kong
	Other food products	Ireland	UAE	Netherlands
	Pharmaceutical preparations	United States	France	Netherlands
	Antibiotics	Germany	Ireland	
	Dyes and pigments	Germany	United States	Netherlands
	Other organic basic chemicals	United States		
	Veneer sheets and wood-based panels	Ireland	France	Belgium
Tier 3	Metal structures and parts of structures	Ireland	United States	Australia
	Tubes, pipes and hollow profiles, of cast iron	United States		
	Stone quarrying	Netherlands	Belgium	Ireland
	Cement	Ireland		
	Bricks, tiles and construction products, in baked clay	Ireland	Germany	United States
	Other non-metallic mineral products	Norway	Belgium	Gibraltar
	Glass fibres	Germany	UAE	Canada
	Hollow glass	United States	Netherlands	Italy
	Paper and paperboard	France	Germany	Ireland

Source: Data received from HMRC in September 2021 and *complemented by ONS UK-wide trade partner data (denoted by dark grey shading).

Table 5. Major sources of import of sectors that include ETS sites, grouped by economic contribution of sector ranking tiers

Tier	Product categories	Top import sources for which data is available		
Tier 1	Extraction of natural gas	Norway*	Qatar	United States
	Extraction of crude petroleum	Norway		
	Distilling, rectifying and blending of spirits	France	United States	Ireland
Tier 2	Butter and cheese production	Germany	Italy	Netherlands
	Other food products	Switzerland	France	Germany
	Pharmaceutical preparations	Germany	United States	Belgium
	Antibiotics	Netherlands	Germany	Belgium
	Dyes and pigments	Germany	Netherlands	Belgium
	Other organic basic chemicals	United States	India	Netherlands
	Veneer sheets and wood-based panels	China	Poland	Germany
Tier 3	Metal structures and parts of structures	China	Germany	Poland
	Tubes, pipes and hollow profiles, of cast iron	United States		
	Stone quarrying	Ireland	Norway	Germany
	Cement	Ireland	Germany	Netherlands
	Bricks, tiles and construction products, in baked clay	China	Germany	Italy
	Other non-metallic mineral products	United States	Russia	Trinidad & Tobago
	Glass fibres	United States	China	France
	Hollow glass	France	Germany	Italy
	Paper and paperboard	China	Germany	France

Source: Data received from HMRC in September 2021 and *complemented by ONS UK-wide trade partner data (denoted by dark grey shading).

These tables show that, for both imports and exports, the EU Member States plus Norway and Switzerland constitute the most frequently reported trading partners, followed by the USA. For imports, China also plays an important role. Therefore, decisions on carbon price in those markets could affect Scottish competitiveness.

The main competitors of Scottish products within export markets are local producers in those jurisdictions, that is European and US producers. Furthermore, exporters to those markets from the rest of the world constitute competition to Scottish industry.

Outside these main trading partners, export destinations include Gibraltar, Singapore, the United Arab Emirates, Canada and Hong Kong. Rest of the world import sources include India, Qatar and Trinidad and Tobago.

Information on international trade values for the main products of the focus ETS installations is incomplete but available evidence is presented in Appendix 5.

4.2 Detailed data and interpretation considerations

4.2.1 Data sources and analysis limitations

The source of the data laid out in Section 4.2 was Scottish Input-Output (IO) Tables for 2017[25], which provide an overview of the flows of goods and services within the Scottish economy.

International trade data used in this section was obtained from Scottish Government statisticians and HMRC in September 2021. The subsector export data does not allow a calculation of the percentage of exports compared to total production value due to the gaps generated by the statistical processing required to avoid disclosure of commercially confidential data.

HMRC data also provides information on the main export destinations and import sources for the product categories produced by Scottish ETS installations. HMRC report the top three export destinations by export value, however, the accuracy of the reported rank is affected by the suppression of some data points due to statistical processing. Where the HMRC information is fully suppressed for a sector, this was supplemented by in-house research[26] and UK-wide data based on ONS statistics[27].

As indicated in the figures above, information on international trade values were only available for a restricted number of sectors for the year 2020, an unrepresentative year.

4.2.2 Relevance to later study analysis

The information collated in this section provides an overview of the main characteristics of the covered Scottish ETS sectors and will form the basis for establishing the Scottish sector's trade exposure and exposure to international carbon pricing mechanisms, in Section 5

5 Trade exposure of Scottish sites and sectors

What is the exposure of the Scottish ETS sites and sectors to markets inside and outside the EU?

Sectors that exhibit high trade exposure, in conjunction with high emissions intensity, are most likely to be at risk of carbon leakage.

[25] https://www.gov.scot/publications/about-supply-use-input-output-tables/pages/environmental-input-output/

[26] This applies to aluminium production and electricity.

[27] This applies to natural gas and refined petroleum as well as wood-based panels.

After outlining the key characteristics of the Scottish installations, we now aim to build a deeper understanding of Scottish business exposure to domestic and international markets. This will be achieved by first establishing the nature of competition that exists, before ranking sectors and installations in terms of trade exposure risk.

5.1 Key findings

Our findings suggest that the majority of Scottish ETS sectors are exposed to high or medium competitiveness impact risks. Manufacturing of paper and paperboard, glass fibres, bricks, tiles and, to some extent cement were found to be at greatest risk in terms of trade exposure. Sectors such as extraction of natural gas, production of sprits and pharmaceuticals face limited international competitiveness risks, at least in the short term.

5.1.1 Nature of competition

ETS installations make a range of products that compete on price, quality, or both.

A large increase in added costs that is passed on to final consumers can lead to competition from jurisdictions where such an added cost does not apply, especially for products with a low transport cost to product value ratio that compete on price, such as aluminium.

Products that compete on quality are expected to be able to pass on additional cost more easily to their final consumers. This is because competing on quality means that a product has distinct characteristics in addition to those of competitors, which increases consumers' willingness to pay more.

The figure below shows the categorisation of most ETS products into Price, Quality and Intermediate archetypes, following the approach quoted in a 2020 BEIS paper on competitiveness and carbon pricing[28].

Figure 4. ETS products categorised according to BEIS archetypes, colour coded by economic contribution ranking tier

Price	Quality	Intermediate
Organic chemicals	Distilling, rectifying and blending of spirits	Mineral oil refining
Veneer sheets and wood panels	Pharmaceutical products	"Other food products"
Metal forging	Manufacture of dyes and pigments	
Hollow glass	Cheese	
Cement		
Aluminium		
Paper and paperboard		
Glass fibres		
Quarrying of stone		
Other non-metallic minerals		
Bricks, tiles and construction products, in baked clay		

Key: = Tier 1 = Tier 2 = Tier 3

NB: The order of the products is not associated with any ranking.

[28] UK Business Competitiveness and the Role of Carbon Pricing

A general feature of the results is that, apart from chemicals and wood products, it is primarily tier 3 products that fall into the solely price competitive products. These products make up a smaller proportion of the Scottish economy according to our analysis in Section 1.

Electricity, natural gas and petroleum are not included in the table above. They are generally considered to be pure commodities that compete on price within a market, to the extent that they can be transported easily to that market. Scottish domestic producers of these energy sources have the advantage of the significant infrastructure that allows the transportation of these key products to their UK customers. This applies in particular to electricity and natural gas. Therefore, they are less affected by external competition in the UK market.

5.1.2 Competitiveness Risk Ranking

A Competitiveness Risk Ranking metric has been developed to measure the exposure of installations and sectors to international competition, in relation to the eventuality of additional carbon costs.

The metric includes proxies for profitability, energy and labour cost differentials with key trading partners, as well as a gradation depending on whether the sector's output is a commodity competing on price or a more specialised product.

The four proxies are profitability, difference in energy costs, labour costs and product archetype. These are discussed in turn below.

5.1.3 Profitability

This metric is included with the expectation that a lower level of profitability allows less scope for absorbing added costs that cannot be passed on to final consumers. See Figure 5 for data on the profitability of the Scottish sectors that encompass ETS installations with traded products.

Figure 5. Gross Operating Surplus for Scottish sectors that include ETS installations, 2017

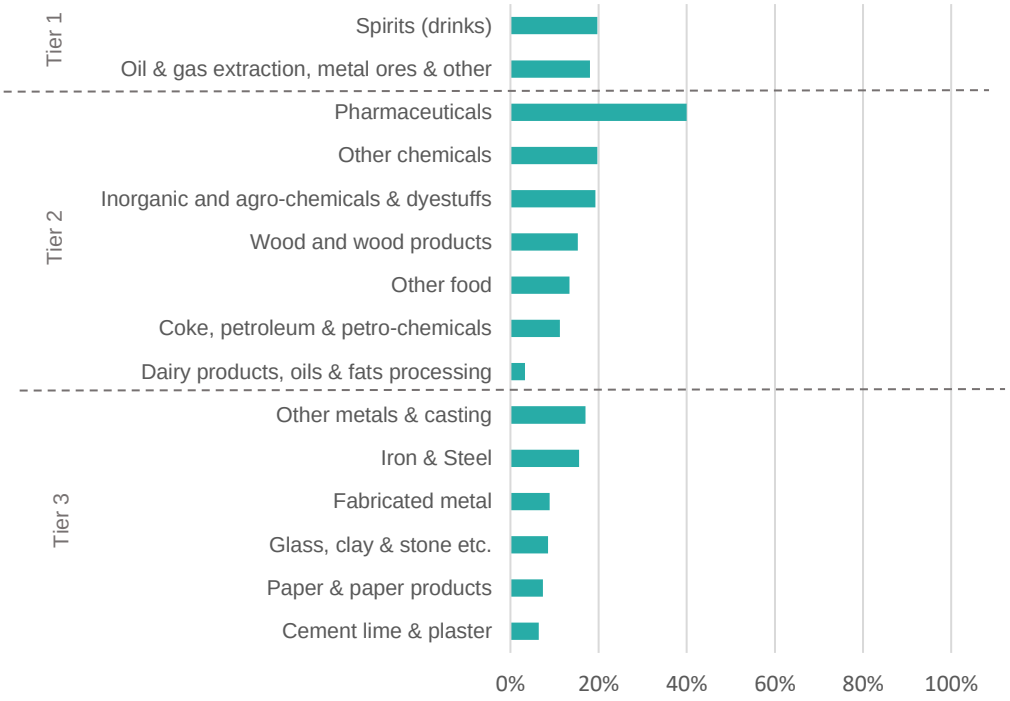


Figure 5 shows that most of the products in sectors making up a larger proportion of the Scottish economy (Tiers 1 and 2), generally have profits of around 10-20%. A clear

exception are dairy products which have a low gross operating surplus, and therefore it may be challenging for this sector to internalise any additional costs[29].

5.1.4 Difference in energy costs

This metric is the ratio of energy costs to output value. It represents a proxy of the likely level of exposure to carbon liabilities for fossil fuels or extra costs for renewable energy sources by domestic producers as compared to their international counterparts[30]. This metric has the benefit of capturing the effects of energy subsidies or carbon tax levies.

5.1.5 Labour costs

This metric is the average difference in labour costs as a proportion of output value. The metric is selected due to the frequent reference to labour cost differentials in the manufacturing relocation literature and the longer-term risks of investment "leakage".

5.1.6 Product archetype

The higher international trade risks associated with product archetypes such as standardised commodities, as compared to specialised products, is also taken into consideration.

5.1.7 Aggregated findings

An aggregate competitiveness risk categorisation was developed on basis of the four metrics above. The resultant risk rankings are shown in

[29] The datasets for the other three metrics are more complex and do not lend themselves to an illustration. See Appendix 4 for more detail on energy cost comparisons.

[30] Here, EU Members State costs are considered individually and not on basis of an EU average, given heterogeneity across individual EU countries.

Table 6.

Table 6. Competitiveness Risk Categorisation Ranking results for international competitiveness risks of ETS sectors

Sector	Risk ranking	Level of trade: comments
Manufacture of paper and paperboard	High	High: large absolute value exports and high imports
Manufacture of glass fibres	High	Medium
Manufacture of bricks, tiles and construction products, in baked clay	High	
Manufacture of cement	Medium	Low: only 2% "rest of the world" imports and notoriously high international transport costs
Manufacture of hollow glass	Medium	
Manufacture of other non-metallic mineral products n.e.c.	Medium	
Extraction of crude petroleum	Medium	
Forging, pressing, stamping and roll-forming of metal; powder metallurgy	Medium	Relatively high import values are associated with this product group.
Manufacture of other food products n.e.c.	Medium	
Production of electricity	Medium	Small volume of international trade
Mineral oil refining	Medium	
Manufacture of other organic basic chemicals	Medium	
Manufacture of veneer sheets and wood-based panels	Medium	
Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	Medium	
Aluminium production	Medium	
Cheese production	Medium	
Extraction of natural gas	Low	
Distilling, rectifying and blending of spirits	Low	
Manufacture of dyes and pigments	Low	Medium
Manufacture of basic pharmaceutical products	Low	
Manufacture of pharmaceutical preparations	Low	

These results suggest that the majority of ETS sectors are exposed to high or medium competitiveness impact risks. Sectors such as extraction of natural gas, production of sprits and pharmaceuticals face limited international competitiveness risks, at least in the short term. In the longer term, the introduction of considerable added costs can lead to a change in fixed structures that underlie competitive aspects, such as the building of additional liquefied natural gas facilities or pharmaceutical plants in other countries. This is a form of "investment carbon leakage", as discussed further in Section 6.

5.2 Detailed data and interpretation considerations

5.2.1 Data sources and assumptions

This analysis uses data from Scottish IO tables, and standardised OECD IO tables containing data for the UK[31] as well as a large proportion of trading partners of Scottish ETS installations[32].

The metric includes the four proxies for profitability, energy and labour cost differentials with key trading partners, as well as a gradation depending on whether the sector's output is a commodity competing on price or a more specialised product.

The data used to produce these proxies is discussed below, with Appendix 7 providing a detailed breakdown of the ranking methodology.

- The proxy for **profitability** used for the analysis is the level of Gross Operating Surplus (GOS) based on the Scottish IO Tables for 2017. Sectors with a GOS of 10% and below are categorised as "high" risk and those with a GOS of 20% and higher are categorised as "low" risk.
- The **difference in energy costs** metric is based on average costs to UK producers and the average for the top three export destinations and top three import source countries if these are known and the data are available. The threshold selected for "low" risk is a 5 percent difference in the proportion of energy costs compared to the value of output between UK producers and the average for key trading partners. A "high" risk threshold for this difference is 50% and higher, for example if the proportion of energy costs for UK operators were 30% of total output value, whereas those of international counterparts constituted 15% or less of their total output value. See Appendix 4 for a detailed breakdown of the cost differentials that were used in this analysis.
- The higher international trade risks associated with **product archetypes** such as standardised commodities as compared to specialised products are described in the "Nature of competition" section above. Competition on quality is linked to "low" risk, whereas competition on price is associated with a "high" risk metric.

The Competitiveness Risk Rankings were developed on the basis of the metrics discussed above. Given that the vast majority of international trade for Scottish ETS installations is likely to be linked to competing operators in the European Economic Area and the USA, the importance of labour cost differentials is expected to be limited as the issue of relocation on basis of labour cost differentials is usually mentioned in the literature in relation to risks linked to industry moving to developing countries. Therefore, the weight assigned to this factor is only 10%.

The remaining three factors are assigned an equal weight of 30%[33].

5.2.2 Analysis limitations

The weighting factors applied in this ranking are subjective. Furthermore, categorisation into risk category is linked to the distribution of the values present in the data and is sensitive to the selection of countries for which data is available.

[31] The ranking is based on the simplifying assumption that the cost structure of UK and Scottish installations is similar and relies on UK-wide averages per sector as proxies.
[32] The OECD standardised tables do not provide information for Qatar, the United Arab Emirates, Hong Kong and Singapore.
[33] The aggregation of the initial low-medium-high qualitative metric using the 10%-30%-30%-30% weighting relies on assigning linear quantitative values to the low-medium-high metrics and applying the weighting to these values to derive an aggregated quantitative range that was then re-converted into a low-medium-high ranking.

In addition to these limitations, the aggregate metric is bounded by the non-inclusion of parameters such as transport costs and existing trade levels, due to the lack of comprehensive data for each ETS subsector. Therefore, the results are presented within the context of trade information, where this is available.

5.2.3 Relevance to later study analysis

The Competitiveness Risk Rankings produced in this section are used as a reference for the Carbon Leakage risk factor applied by the European Commission to determine free allocation to ETS installations[34]. It is also used to contextualise the added costs from a UK ETS system which may deviate from the current EU ETS system and Fit for 55 proposals, including in relation to the introduction of a Carbon Border Adjustment Mechanism.

6 Carbon leakage risks

Which of the Scottish ETS sectors are most vulnerable to the risk of carbon leakage?

The risk of carbon leakage arises when manufacturers must pay a carbon cost associated with the products they make and sell, yet they compete with overseas producers who are subject to lower or zero corresponding carbon costs. The resultant economic disadvantage felt by the carbon constrained producers could impact their profitability, market share and ability to finance investment.

Two forms of carbon leakage are linked to emissions trading systems: production leakage and investment leakage. Production leakage is observed in the short to medium term, with production changing location as a result of carbon policies. Investment leakage is observed as less investment for production in a location. It occurs over the longer term due to typically long lifetimes of equipment in ETS installations. Investment leakage affects *production capacity*.

Carbon leakage risks are intensified or moderated by the standing of the industry compared to its competition, see Section 5.

6.1 Key findings

To assess the competitiveness exposure of Scottish ETS sectors we discuss the current UK ETS allowance prices compared to the current and expected carbon prices in third party jurisdictions that compete with Scottish producers. Most Scottish exports and imports are with European Economic Area countries and therefore with operators with carbon costs that are similar to those incurred in the UK.

The next most important trade partner is the US and the only carbon pricing policy for industry in the US applies in California. The Californian Cap and Trade programme saw a carbon price of around £12.5/tCO2e in 2020; this increased to around £20/t CO2e in early 2022, although carbon leakage-related compensation is provided to all industrial sectors. Data on international trade of Scottish installations specifically with California was not available to the study team[35]. However, given the low/no carbon price in the US, we can conclude that all ETS installation trade with the US is exposed to a risk of carbon leakage.

Outside the EU and the US, there are small pockets of carbon regulation of industrial emitters, for example in Canada with limited coverage in other jurisdictions (see

[34] The UK ETS free allocation is based on the EU's Carbon Leakage list at the time of writing.
[35] The US as a whole features as an important trading partner for the spirits sector, chemicals, natural gas, pharmaceuticals, metal forging and glass sectors.

Appendix 6 for a detailed carbon policy description). Canada, with two regional and one federal carbon pricing system, has recent carbon price levels of £9 and £14 per tCO2e. According to trade data, Canada is an important trade destination for the Scottish glass fibres sector.

Table 7 summarises the findings of Section 5, competitiveness risk ranking and the assessment of carbon pricing policies among key trading partners. Furthermore, it indicates whether the sector is included on the EU carbon leakage list, which currently determines the level of free allocation to Scottish ETS installations, within the transition process from the EU to the UK ETS.

The EU established a carbon leakage list to define the most exposed sectors and it updates it periodically. The same list is currently used in the UK and determines the level of free allocation received by Scottish ETS installations. Sectors and subsectors are deemed at significant risk of carbon leakage if they exceed thresholds for carbon cost intensity and trade exposure, so called carbon leakage indicators. These are calculated as EU-wide averages. The calculation formulae for these indicators are described in Appendix 3.

Table 7. Competitiveness risk ranking, comparable carbon policy and Carbon Leakage Indicators used for the determining of Scottish ETS installation allocation

Aggregated sector	SIC Sub-sector Title	Competitiveness Impact Risk (from Table 5)	Fraction of main trade partners with similar carbon policy***, and risk in parenthesis	Deemed at risk of carbon leakage by the EU for the period 2021 to 2030
Glass and glass fibres	Manufacture of glass fibres	High	2-3/6 (Medium)	✓
	Manufacture of hollow glass	Medium	5/6 (Low)	✓
Paper and paperboard	Manufacture of paper and paperboard	High	5/6 (Low)	✓
Non-metallic minerals (bricks & tiles)	Manufacture of bricks, tiles and construction products, in baked clay	High	5/6 (Low)	✓
	Manufacture of other non-metallic mineral products n.e.c.	Medium	3/6 (Medium)	✓
Cement	Manufacture of cement	High-Medium	4/4 (Low)	✓
Chemicals, dyes and pigments	Manufacture of other organic basic chemicals	Medium	1/4 (High)	✓
	Manufacture of dyes and pigments	Low	5/6 (Low)	✓
Metal forging	Forging, pressing, stamping and roll-forming of metal, powder metallurgy	Medium	3/8* (Medium-High)	(✓)**
Aluminium	Aluminium production	Medium	N/A	✓
Oil refining	Mineral oil refining	Medium	4/6 (Low-Medium)	✓
Food products	Manufacture of oils and fats	Medium	N/A	✓
	Butter and cheese production	Medium	5/6 (Low)	✗
	Manufacture of other food products n.e.c.	Medium	5/6 (Low)	✗
Wood based products	Manufacture of veneer sheets and wood-based panels	Medium	5/6 (Low)	✓
	Extraction of crude petroleum	Medium	2/2 (Low)	✓

Extraction of oil & gas and natural gas distribution	Extraction of natural gas	Low	3/6 (Medium)	✗
	Distribution of gaseous fuels through mains	Low	N/A	✗
Stone quarrying	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	Medium	6/6 (Low)	✗
Electricity, steam and air conditioning	Production of electricity	Medium	1/1 (Low)	✗

Aggregated sector	SIC Sub-sector Title	Competitiveness Impact Risk (from Table 5)	Fraction of main trade partners with similar carbon policy***, and risk in parenthesis	Deemed at risk of carbon leakage by the EU for the period 2021 to 2030
Pharmaceuticals	Manufacture of basic pharmaceutical products	Low	4/6 (Low-Medium)	✓
	Manufacture of pharmaceutical preparations	Low	5/5 (Low)	✗
Spirits	Distilling, rectifying and blending of spirits	Low	3/6 (Medium)	✗

*Includes two sub-sectors.

**This represents the count of EU or European Economic Area countries among the top three export destinations or import sources, glass fibres is listed as 2-3 to include carbon policies in Canada.

***some sub-sectors in this category are included in the carbon leakage list and others are not.

The summary analysis suggests that in the high competitiveness risk category, all sectors except for glass fibre, trade with counterparts facing similar carbon pricing policies. This largely counteracts the risk of carbon leakage.

Among the sectors with a medium competitiveness risk, “other organic and basic chemicals” trade with several jurisdictions lacking comparable carbon pricing policies for industrial installations. The consistency of these two considerations highlights the medium level of carbon leakage risk faced by this sector.

All the sectors assigned to the high competitiveness risk category as part of this study are included in the EU carbon leakage list. That is despite the differing methodology approaches and geographic focus to the study here. Whilst some sectors not on the EU list have medium risk in one of the other factors, there are none with a medium risk in relation to both factors. Therefore, while our findings add more detail in terms of what distinguishes sectors, **the EU carbon leakage list broadly captures the risk of Scottish sectors**.

6.2 Detailed data and interpretation considerations

The findings in this section are based on analysis undertaken as part of Section 5, which contains a discussion on data sources and limitations.

The analysis of carbon policies in Scotland’s key trade partners is based on established datasets such as the International Carbon Pricing Partnership. Appendix 6 outlines the data quality for recent pricing information as well as projections to 2030.

The EU carbon leakage indicators allow a feasible calculation using well understood and established data sources such as import and export volumes, gross value added and GHG emissions. However, the following limitations apply:

- It does not capture a range of indicators such as carbon costs in third party jurisdictions, proportion of carbon costs as compared to costs of intermediate products, product archetype differentiation and industry structure parameters
- It is assumed that the values for indicators at EU-level are applicable for Scotland (expected to be reasonable for carbon cost intensity since variations in average carbon intensity are likely relatively small but trade intensities could vary significantly to the EU).

The EU Carbon Leakage indicators are complemented with the additional assessments in Table 7.

7 Implications of deviations in UK and EU Emissions Trading Systems

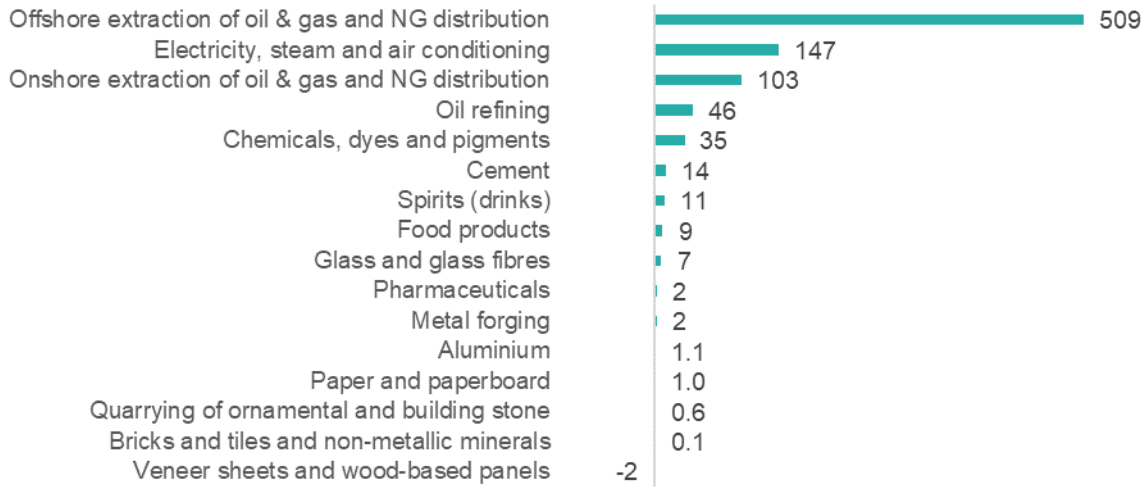
What would be the impact on Scottish sectors/sites of a UK ETS system which deviates from the EU ETS system in terms of price or free allocation?

The UK ETS has recently been established with a similar ruleset to the EU ETS. Scottish sectors are required to surrender UK allowances to match their eligible greenhouse gas emissions. The system also adopts the same approach of using free allocation to mitigate carbon leakage risk. The UK allowance allocation rules are currently the same as those in the EU but in future the systems could deviate, if for example a more stringent overall cap were to be adopted. Meanwhile, changes in the EU Fit for 55 proposals are expected to lead to a divergence in the rules applied to EU installations. Such differences would lead to relative cost impacts for Scottish manufacturers compared with those in the EU.

7.1 Key findings

Figure 6 below shows the added cost from the ETS scheme to Scottish sectors under a continuation of current UK ETS policy and the central assumed carbon price of £54/tCO2e in 2030.

Figure 6. Estimated ETS costs by sector in 2030, in £ million: Reference Scenario



Under this scenario, total added ETS costs are highest in the extraction and distribution of oil and gas, followed by the electricity sector, oil refining, chemicals, cements, spirits, food and glass production. The wood-based product sector incurs a benefit of around £2

million due to the benchmarked allocation exceeding the sector's emissions, meaning that these installations can sell excess allowances on the market. Other sectors incur considerably lower costs in absolute terms, due to a large extent to the lower emission and economic activity levels. Overall, added costs are highest in the sectors that have the highest levels of total GHGs covered by the ETS and receive the lowest level of free allocation.

Divergence from the current UK ETS approach of free allocation and projected prices are modelled. We consider indicative variations in allocation price of ±20% and a faster rate of decrease in free allocation, i.e. benchmark improvement rate (2.5% per year[36], up from 1.6% per year in the reference scenario). Allowance price differentials could be caused by a wide range of factors including a divergence in the overall system cap stringency or external factors such as fuel prices, subsidies for emissions abatement technologies, underlying cost of abatement opportunities, etc.

The minimum and maximum added costs, linked to carbon price assumptions of £43.2 and £64.8 per tonne CO_2e are presented in Table 8 below. Full results for all scenarios are shown in Appendix 9. The minimum added costs result from the scenario with a reduction in allocation price. The maximum added costs result from the scenario with increased allocation price and higher benchmark improvement rate.

In the presence of output data by the ETS installations, total added ETS costs would be divided by total output to obtain data that is comparable across sectors. However, with the absence of such output data, scale effects are addressed through a division by average emissions in 2017-2019.

Table 8. Minimum and maximum ETS added costs determined from scenario modelling

Aggregated sector	SIC Sector description	Reference Scenario		Lowest added cost scenario		Highest added cost scenario	
		£ m	£/tCO2e	£ m	£/tCO2e	£ m	£/tCO2e
Extraction of oil and gas and natural gas distribution[37]	Extraction of crude petroleum	354	40	283	32	459	52
	Extraction of natural gas	49	54	39	43	59	65
	Combined oil and gas extraction	76	40	61	32	100	52
	Natural gas distribution	31	54	25	43	37	65
Electricity, steam and air conditioning	Electricity	85	54	68	43	101	65
	Steam and air conditioning	38	54	31	43	46	65
Oil refining	Oil refining	38	25	30	20	59	38
Chemicals, dyes and pigments	Chemicals	29	16	24	13	56	30
Cement	Cement	11	20	9	16	19	34
Spirits (drinks)	Spirits (drinks)	10	54	8	43	11	65
Food products	Other food products	7	54	6	43	8	65
	Cheese	0.5	54	0.4	43	0.7	65
Glass	Hollow glass	6	29	5	23	9	42
Pharmaceuticals	Pharmaceutical preparations	2	54	2	43	2	65
Metal forging	Metal forging	1.5	54	1.2	43	2	65
Synthetic rubber	Synthetic rubber	1.5	26	1.2	21	2	39

[36] The annual rate is calculated on basis of timeframes based on iterative EU ETS regulation updating and includes some retrospective updates with the reference year of 2008. The benchmarking updating rate is not applied de facto through a linear annual reduction.

[37] Offshore extraction of oil and gas and gas and natural gas distribution ranges from lowest added cost scenario of £509 million to highest added cost scenario of £549 million.

Aluminium	Aluminium	0.9	12	0.7	9	2	27
Paper and paperboard	Paper and paperboard	0.9	11	0.7	9	2	26
Quarrying of stone	Quarrying of stone	0.5	54	0.4	43	0.6	65
Bricks and tiles & non-metallic minerals	Other non-metallic minerals	0.1	19	0.1	15	0.1	33
Veneer sheets & wood-based panels	Veneer sheets & wood-based panels	-2[38]	-16	-1.4	-12	0.2	2

As emissions data is a limited proxy for output, we recommend that the two sets of results, absolute costs and "per unit" costs are considered together. This is particularly important for sectors such as oil refining, oil and gas extraction, and chemicals. Whereas total costs for these sectors considerably exceed those of smaller emitting sectors, unit costs are lower than those in the food and drink, pharmaceutical and other sectors. This is because the former group of sectors are on the carbon leakage list and therefore receive a higher level of free allocation (see Appendices 8 and 9 for further detail).

Changing from the 1.6%/year to the 2.5%/year benchmark improvement rate scenario leads to a 9% reduction in total 2030 allocation across all Scottish ETS installations considered. The benchmark improvement rate only affects installations that receive free allocation due to inclusion on the carbon leakage list. All industrial sectors receive some free allocation in the period to 2030, but from 2030 this only applies to sectors on the EU Carbon Leakage List.

By 2030, free allocation is reduced to zero for the natural gas sector (extraction and distribution), spirits, food production, metal forging, quarrying and pharmaceuticals. Therefore, the variation in benchmarking improvement rate does not affect these sectors in 2030. For the remaining industrial sectors (extraction of crude petroleum, chemicals, paper and paperboard, cement, oil refining, synthetic rubber, other non-metallic minerals, wood-based products and aluminium production), the transition from the current benchmark improvement trajectory to the one proposed in the EU Fit for 55 package leads to a decrease in free allocation and a proportionate increase in added costs of 25%.

7.2 Detailed data and interpretation considerations

Six policy scenarios are developed and shown in Table 9. They represent a feasible range of cost drivers to which Scottish sectors could be exposed as a result of UK and EU carbon trading policy. These scenarios are subsequently used to calculate the added cost impacts for 2030. The key drivers varying across scenarios are the allowance price (i.e. carbon price) and benchmark improvement rate, described below. Further details are provided in Appendix 8.

7.2.1 Terminology

Added costs – these are the costs of purchasing deficit allowances, that is the difference between projected emissions and the free allocation.

Allowance price – this is the price of traded allowances in either the UK or the EU ETS.

Benchmark improvement rate - at present, the level of free allocation to industrial installations is based on emissions intensity benchmarks for each product covered by the ETS. The same set of benchmark values are applied in the UK and EU for every year in the period 2021-2025 inclusive. For the period 2026-2030, the EU benchmarks are to be updated based on an annual average improvement rate (i.e. reduction in the free allocation) for the corresponding sectors and subsectors. That improvement rate is currently capped at 1.6% per year but under the EU's Fit for 55 proposals the maximum improvement rate will increase to 2.5% per year.

[38] Negative figures represent benefits from the sale of excess allowances.

7.2.2 Scenarios

As noted above, the added carbon cost incurred for Scottish sectors is a result of the following elements, which in turn depend on the EU and UK Carbon prices:

- The cost of allowances to cover their emissions less any free allowance
- Changes in free allowance as a result of the benchmark improvement rate

Table 9. Carbon price and free allocation divergence scenarios

Scenario	UK ETS allowance price (£/allowance)	UK ETS benchmark improvement rate (%/yr)
Scenario A	54	1.6
Scenario B	54	2.5
Scenario C	43.2	1.6
Scenario D	43.2	2.5
Scenario E	64.8	1.6
Scenario F	64.8	2.5

In addition, there are a set of common assumptions for all scenarios:

- Scottish installation emissions in 2030 remain at the average of 2017-2019
- The 2030 EU allowance price is £54
- The EU benchmark improvement rate is 2.5%/year
- Carbon leakage exposed sectors receive allocation at 100% of the benchmark level, whereas other industrial sectors receive an allocation that declines from 30% in 2026 to zero in 2030.
- No Cross-Sectoral Correction factor (a mechanism to ensure the economy-wide cap on allowances is not exceeded, see Appendix 8) is applied either in the UK or EU.

7.2.3 Modelling approach

We model the concept of "added ETS compliance costs." These are used in conjunction with qualitative or semi-qualitative analysis on carbon leakage and competitiveness impacts trade risks to derive answers to research questions, see Appendix 8 for detail on the modelling methodology.

7.2.4 Added costs

The added costs are given by:

$$Added\ ETS\ costs = (projected\ emissions - free\ allocation) * ETS\ allowance\ price$$

Where both the free allocation and the ETS allowance price apply the UK rules as shown in the scenarios table in Section 6.2. The projected emissions are kept constant at average 2017-2019 levels.

Total costs for each sector were divided by the level of emissions to determine the added cost per tonne CO_2e. For 2030 the population of Scottish ETS sectors falls into two categories:

- Sectors that receive no free allocation have an added cost of £54/tonne – i.e. the full carbon price assumed in Scenario A.

- Sectors on the carbon leakage list, who will receive 100% of their benchmark allocation, vary in their added costs per tonne of CO2e

7.2.5 Analysis limitations

The added ETS compliance costs are based on the difference between assumed continuation of current emission levels for each installation and scenarios of free allocation levels, multiplied by variations of allowance prices. Our modelling exercise is not aimed at generating accurate projections of overall emissions or cost figures across sectors. It relies on a simplified approach to quantitative modelling and does not consider abatement potential costs of Scottish ETS installations or likely changes in activity levels.

Each benchmark has an improvement rate of up to the maximum indicated but could be lower. For the period 2021 to 2025 these improvement rates are known. However, the analysis is done by projecting installation-level allocations, which in some cases will be the aggregate result of more than one benchmark applying at the installation. We do not know which benchmarks were applied to each installation, so cannot project allocations forward precisely. Instead, we assume that allocations will reduce at the maximum possible improvement rate.

The scope of the project covers variation in carbon prices and the level of free allocation between the EU and the UK ETS. The modelling of carbon prices and levels of free allocation is an illustration of potential areas of divergence between the design of the UK and EU ETS. A wider range of factors may affect the level of added ETS costs, outside GHG abatement. These include:

- Further changes to the UK benchmarking approach, for example a shift from the Fit for 55 Scenario (Scenario 2) 2.5% annual update factor for benchmarks to 4% leads to a change in added costs (from £812 million to £950 million) that is close to that of the 20% carbon price increase from £812 million to £975 million).
- The approach to activity level change free allocation updating, this is currently set at 15%, that is if annual production levels increase or decrease by this percentage, a change in the amount of free allocation is triggered for the installation.
- Changes to the market stability reserve, a mechanism of the EU ETS to address the accumulation of surplus allowances during Phase III and to improve the resilience of the ETS to major external shocks to the system.
- Aspects linked to the auction design and price limits.

The scenarios don't cover the case of any future linking between the UK and the EU ETS.

8 Impact of EU CBAM proposals on Scottish installations

How will the introduction of the EU draft CBAM affect trade for Scottish installations, given carbon leakage risks?

The Fit for 55 package includes a Carbon Border Adjustment Mechanism (CBAM) proposal for aluminium, cement, electricity, fertilisers, and iron & steel. CBAM will affect Scottish exporters to the EU in these sectors by requiring one-off registration costs, minor recurring administrative costs and ongoing CBAM certificate costs, should the carbon price Scottish producers face be lower compared to that faced by EU installations. In this section we quantify the potential cost of CBAM certificates.

8.1 Key findings

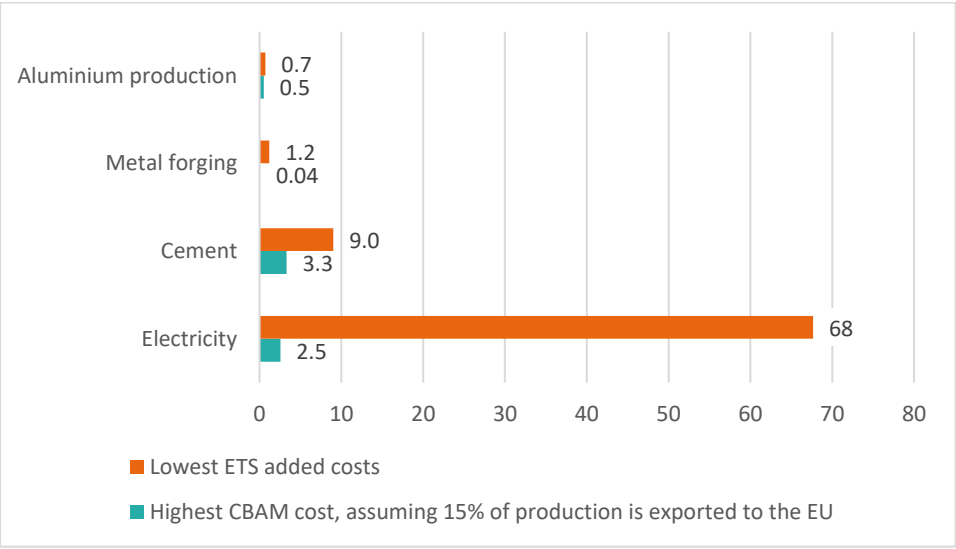
8.1.1 EU CBAM impacts on Scottish ETS operators: illustrative scenario

Since data is unavailable to define the level of export to the EU we have assumed 15% across all CBAM sectors as a conservative estimate for an illustrative scenario. We expect the level of export, and therefore CBAM costs, to generally be lower than found here because the few sectors for which we have information export less than 2% of production to the EU.

Under current EU CBAM proposals, Scottish installations are expected to receive a rebate for the ETS costs incurred in the UK. Therefore, given the limited proportion of exports and the expected rebate, the marginal added costs of the EU CBAM are expected to the limited.

We have developed an extension of the modelling in Section 7 that estimates the added ETS costs compared CBAM certificate costs. Figure 7 shows the combination of the lowest added ETS costs and the highest CBAM certificate costs (for the scenarios we've considered) to show that CBAM certificate costs are still often much lower than the ETS added costs. For all other ETS scenarios the added cost is higher and the CBAM certificate costs are lower.

Figure 7. CBAM certificate costs, assuming 15% of total relevant ETS production is exported to the EU: illustrative scenario, in £million per year



Given the uncertainty with regards to the level of exports for the CBAM-relevant sectors, the figures above are illustrative. The added ETS costs for electricity are relatively high

to other sectors due to the lack of free allocation to this sector - see Appendix 11 for detail.

8.1.2 EU CBAM impacts on Scottish non-ETS operators

Around 670 Scottish operators not covered by the UK ETS are reported by SABS as making products covered by the CBAM proposals. These operators make secondary iron and steel products (664 units) or fertilisers (eight units).

A considerable proportion of the CBAM certificate liability is likely to be associated with carbon embodied in feedstocks, such as the iron used by the metal-forming sector and chemical feedstocks used by fertiliser producers.

Iron and steel: Product-specific export data for the year 2020 provided by HMRC does not disclose export volumes for three of the eight relevant iron and steel product categories. The total value of exports for the product categories reported was around £25 million. The main export destinations[39] are EU countries such as Germany, France, Ireland as well as Norway (where the same ETS and CBAM rules are expected to apply as for the EU), followed by the US and Canada.

Fertiliser production: Export levels of fertilisers and key destinations have not been disclosed to the study team.

8.1.3 Indirect impacts through effects on EU producers

A gradual reduction in free allocation to installations covered by CBAM is proposed. As a result, EU producers will face a domestic market where carbon liability is associated with carbon intensity for all players in that market, domestic producers and exporters to the EU. However, they will face a disadvantage in outside markets given the added costs to their products.

The reduced competitiveness of EU companies may allow Scottish producers to capture a larger share of the domestic market and is expected to apply in particular to iron and steel products which show a large proportion of imports in meeting domestic demand and importance of imports from Germany and Poland. This may also apply to the cement sector, depending on available capacity. In other Scottish ETS sectors, this effect is expected to be very limited as the reported imports stem mainly from countries outside the EU, e.g. the US and China.

The table below lists the competitiveness impacts and carbon leakage list inclusion for the ETS sectors covered by the EU CBAM proposals.

[39] See limitations linked to the top export destinations in Section 4.1 Key findings

Table 10. Summary carbon leakage indicators for Scottish ETS sectors covered by EU CBAM proposals

Aggregated sector	SIC Sub-sector Title	Competitiveness Impact Risk (from Table 5)	Fraction of main trade partners with similar carbon policy***, and risk in parenthesis	Deemed at risk of carbon leakage by the EU for the period 2021 to 2030
Cement	Manufacture of cement	High-Medium	4/4 (Low)	✓
Metal forging	Forging, pressing, stamping and roll-forming of metal, powder metallurgy	Medium	3/8* (Medium-High)	(✓)**
Aluminium	Aluminium production	Medium	N/A	✓
Electricity, steam and air conditioning	Production of electricity	Medium	1/1 (Low)	✗

The cost comparison risk is high for cement and medium for the other three sectors. However, once the carbon policy of competitors is considered the picture is more nuanced. For instance, the cement sector has a low risk from competitors since they are regulated by comparable carbon policies. The introduction of the EU CBAM proposals is likely to be associated with a mix of gains and added costs.

A further indirect effect is likely to be associated with the rest of the world exporters to the EU that have a high embodied carbon content and a limited domestic carbon price. These exporters may choose to reorient to the UK market, should a CBAM not be implemented by the UK. Therefore, Scottish producers may face additional pressure from competitors in countries such as the US, China and other major exporters of manufacturing products to the EU.

8.2 Detailed data and interpretation considerations

8.2.1 Approach to CBAM certificate cost modelling for ETS installations

Under the European Commission's (EC) CBAM proposals, exporters to the EU will be liable for CBAM certificate costs. These costs will be linked to the level of GHGs embodied in the covered exported products, calculated on basis of a default factor unless the exporter provides proof of lower GHG intensity. This embodied carbon will be multiplied by the EU carbon allowance price but is then reduced to account for the carbon costs incurred by the exporter outside the EU[40]. For Scottish sectors this means a CBAM deduction equal to the UK ETS added costs: i.e. their UK ETS carbon liability minus the value of their free UK ETS allocation, both associated with the exported goods. The relevant formulas are shown in Appendix 10.

8.2.2 Data, parameters and assumptions

The EC CBAM proposal suggests that default emission factors will be equal to the average emission intensity in the exporting country. In the absence of data on export volumes and values to the EU for each ETS product and on basis of export values for 2020, a cross-sectoral assumption of 15% exports to the EU is used as an illustrative scenario, see text box below. The default emission factor is the average for each Scottish ETS sector.

[40] EU CBAM proposal: https://ec.europa.eu/info/sites/default/files/carbon_border_adjustment_mechanism_0.pdf

Text Box 1. Trade data and qualitative information for the ETS CBAM sectors

Aluminium: no trade data available from the HMRC. Current owner website for Lochaber smelter indicates that the smelter serves both national and international market with semi-finished aluminium. New expansion plant will serve domestic market.
Electricity: no trade data available from the HMRC. Electricity is exported from Scotland to Northern Ireland through the Moyle interconnector, export capacity has been restricted; this is expected to increase further to changes in commercial arrangements. Electricity exports to Northern Ireland are treated in the same way as exports to the EU according to the Northern Ireland Protocol associated with the UK exit from the EU.
Cement: main export destination reported by the HMRC is Ireland, however, export values are likely to be below 1-2% on basis of the SABS production value and HMRC export value data.

Iron products: main export destination reported by the HMRC is the United States.

More detail on the calculations together with sensitivity analysis scenarios are presented in Appendix 10.

8.2.3 Analysis limitations

The conclusion regarding the ratio of CBAM and UK ETS added costs is based on the conservative approach of the combining the highest modelled CBAM costs with the lowest added ETS cost estimate, including a UK ETS allowance price 20% lower than the EU ETS allowance price. However, the calculations use assumptions linked to the following data gaps:

- The conclusions are sensitive to the level of exports assumed. Should the full level of production be exported to the EU, CBAM costs would exceed ETS costs in some scenarios, see Appendix 10.
- Scottish exporters will be able to apply for reduced CBAM costs if there is proof of lower GHG intensity of the exported product than the default factor.
- EU and UK ETS allowance price assumptions influence the outcome of calculations.
- The analysis is based on the EC CBAM proposals which are subject to change further to tripartite negotiations. Appendix 10 includes information on two additional sectors considered in the EC CBAM Impact Assessment and not included in the policy proposal – pulp and paper and chemicals.
- The allocation to EU counterpart producers, and therefore the likely rebate applied in relation to this CBAM calculation aspect, is based on limited information.

With regards to non-ETS sectors potentially covered by CBAM, information with regards to:

- the number of exporting companies to the EU and their size
- the feedstock used by Scottish exporters and how this compares to the likely default factors used by the European authorities

would be required in order to perform a more in-depth analysis of the effects of the CBAM proposals on these operators.

9 Competitive advantages to Scottish exporters to the EU

Is there an advantage to Scottish exporters to the EU, in cases where their GHG intensity is below that of other non-EU competitors in the EU market, in the context of the EU CBAM?

Imports into the EU27 countries from 200 trade partners were analysed for the precise list of sub-products covered by the EC's Fit for 55 Proposals[41] which fall within three of the five sectors covered by the EC's CBAM proposals:

- Aluminium
- Iron and steel
- Fertilisers.

Cement and electricity were not included due to limited or no exports to EU countries currently undertaken by Scottish businesses in these sectors.

Key competitor GHG intensity was compared to the UK average, where data allowed.

The assumption is that Scottish aluminium, iron and steel and fertiliser outputs are of comparable GHG intensity with UK average products, or are less GHG intensive, for example due to renewable energy used for aluminium production.

Exporters to the EU will either use their own emissions factors, upon proof of verified GHG intensity, or default factors developed by the European Commission. It is expected that default factors will be generally unfavourable to exporters of CBAM products to the EU and therefore considering actual GHG intensity differentials may underestimate Scotland's advantage against competitors that use default factors.

In addition to the three sectors above, this section includes a comparison for the chemicals sector, which was a strong candidate for inclusion in the EU CBAM at the time of writing.

9.1 Key findings

The level of competitive advantage of Scottish producers is highly dependent on the boundary of the analysis for emissions intensity, that is, whether only direct emissions from the exporting installations are subject to CBAM charges or whether a wider scope of embodied emissions is included, e.g. from purchased electricity or emissions embodied in the production of intermediate products. The EC CBAM proposal clearly differentiates between "simple" and "complex" products in the embodied emission methodology presented in Annex III[42] and Article 35 (2) (c) requires exporters of CBAM products to report embodied electricity emissions during the transition phase. The EC FAQ on CBAM[43] stipulates that "the CBAM will apply to direct emissions of greenhouse gases emitted during the production process of the products covered. By the end of the transition period, the Commission will evaluate how the CBAM is working and whether to extend its scope to more products and services - including down the value chain, and whether to cover so-called 'indirect' emissions (i.e. carbon emissions from the electricity used to produce the good)." The EU Parliament Rapporteur Report responding to the European Commission's proposals[44] suggests changes to the accounting of upstream and downstream emissions, and specifically the inclusion of embodied electricity.

[41] See Appendix 12 for the list of products in the EC's CBAM proposal. Trade data was extracted the Eurostat COMEXT. Database - International trade in goods - Eurostat (europa.eu)
[42] EUR-Lex - 52021PC0564 - EN - EUR-Lex (europa.eu), Document 2.
[43] Carbon Border Adjustment Mechanism (europa.eu)
[44] https://www.euractiv.com/wp-content/uploads/sites/2/2022/01/CBAM-Informal-draft.pdf.

The transition phase is expected to take place between 2023 and 2025 and the types of products covered is expected to be known by 2023, whereas the determination of the rules around system boundaries and emission factors will continue being developed after the beginning of 2023.

Should only direct emissions from an installation be included under the EU CBAM, the main competitive advantage identified in relation to Scottish producers is related to aluminium exports, compared to imports into the EU from China and the UAE.

The coverage of the electricity embodied in CBAM products would entail an expansion of the competitive advantage for Scottish aluminium production, as compared to a wide range of jurisdictions including China and UAE as well as others such as Russia and Turkey, all significant aluminium exporters to the EU. In addition, data used for analysis in Sections 9 and 10 precede recent sanctions on Russia, which could modify its competitiveness.

Iron & steel production in Scotland only includes the finalisation of intermediate products, e.g. through forging. The sector is likely to hold a competitive advantage compared to Ukrainian and Serbian iron and steel, on the basis of IEA GHG intensity data, depending on the sourcing of intermediate products by Scottish producers.

The situation with regards to the emission intensity of Scottish fertiliser production is not clear as we anticipate that this relies on intermediate products, provided that fertiliser producers are not covered by the UK ETS Information on fertiliser exports from Scotland to the EU is not available due to commercial confidentiality concerns. The main exports of nitrogenous fertiliser to the EU are from Russia, Egypt, Algeria and Morocco, according to the EU COMEXT database.

Should chemicals be covered by CBAM, as mentioned in the EU Parliament Rapporteur Report, further competitive advantage is likely. While there is considerable uncertainty at the time of writing and the amendments in the Rapporteur Report include references to “chemicals”, “organic chemicals” and “organic basic chemicals”, the list of products suggested in the amended annex includes the following Common Nomenclature codes and products:

1. CN 29 - organic chemicals
2. CN 2804 10 000 - hydrogen
3. CN 2814 10 000 - anhydrous ammonia
4. CN 2814 20 00 - ammonia in aqueous solution
5. CN 39 - plastics and articles thereof.

The UK production is, on average less carbon intensive than that of the majority of non-EU countries we have information on. This is an indicator of a potential competitive advantage, depending on the exact chemicals product mix covered by CBAM.

9.1.1 Key competing exporters to the EU and their comparative carbon intensity

The main countries exporting aluminium, iron and steel and fertiliser products to the EU are presented in the figures below.

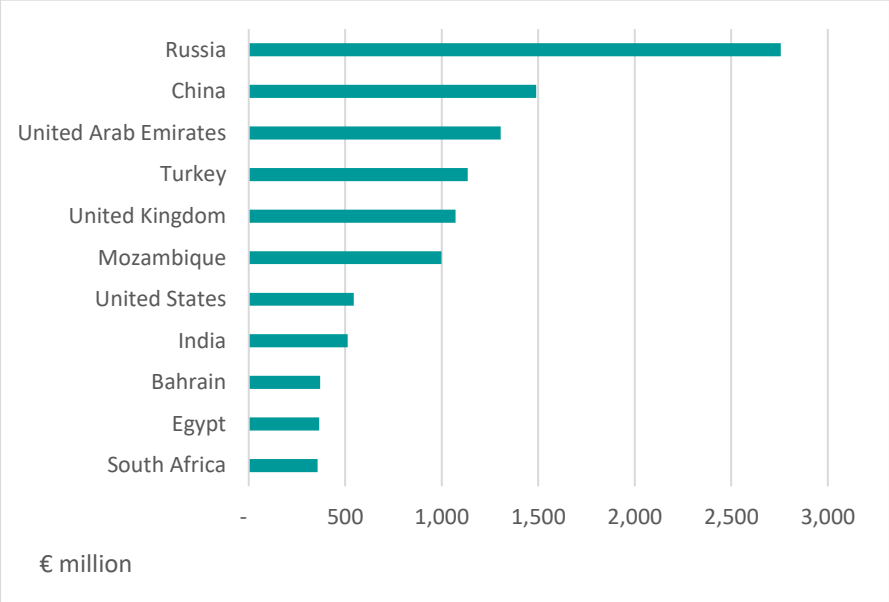
Aluminium

Scotland has significant aluminium production. Progress towards investment in new facilities next to the existing Lochaber smelter was confirmed during the study[45], although no information on export volumes could be made available due to commercial confidentiality. The current competition with regards to exports to the EU stems from

[45] ALVANCE begins consultation on recently announced £94m Lochaber smelter expansion to make GREENALUMINIUM | ALVANCE Aluminium Group, Lochaber aluminium recycling plant approved - BBC News.

plants based in Russia, China, the United Arab Emirates, Turkey and Mozambique (see Figure 8 below).

Figure 8. Key exporting countries to the EU of aluminium products covered by the European Commission CBAM proposals, on basis of average trade values for the years 2017-2019



The production of primary aluminium is highly energy intensive, with a high reliance on electricity, responsible for around 70% of emissions attributable to aluminium production at a global level[46]. Within the electricity related emissions linked to aluminium production, the majority of emissions are associated with coal fired electricity generation. On average, coal-fired generation supplies electricity for 59% of global aluminium production, hydro-generation 26% and gas fired generation 11%.

Final products vary in their energy intensity depending on whether scrap aluminium is recycled, which leads to a lower energy requirement. Scotland's existing smelter reduces alumina to aluminium metal, using a "primary" production process. The proposed new plant will use scrap metal.

A large proportion of electricity for aluminium production in Asia is self-generated, e.g. 65% in China[47], and 95% in the rest of Asia, which includes the UAE, a large exporter to the EU. Most electricity is purchased from external operators in Europe, Africa and Oceania. Therefore, should only direct emissions apply to CBAM charges, the largest competitive advantage is in relation to products imported from China, the rest of Asia and UAE. An expansion of the scope of emissions to cover electricity production imported to sites would likely extend this competitive advantage over other exporters to the EU, such as Russia and Turkey.

Iron and steel

In 2020 Scotland exported ferrous metal products relevant to the EC CBAM proposal with a value around £25 million, some of which were exported to the Netherlands, Germany, France and Ireland[48].

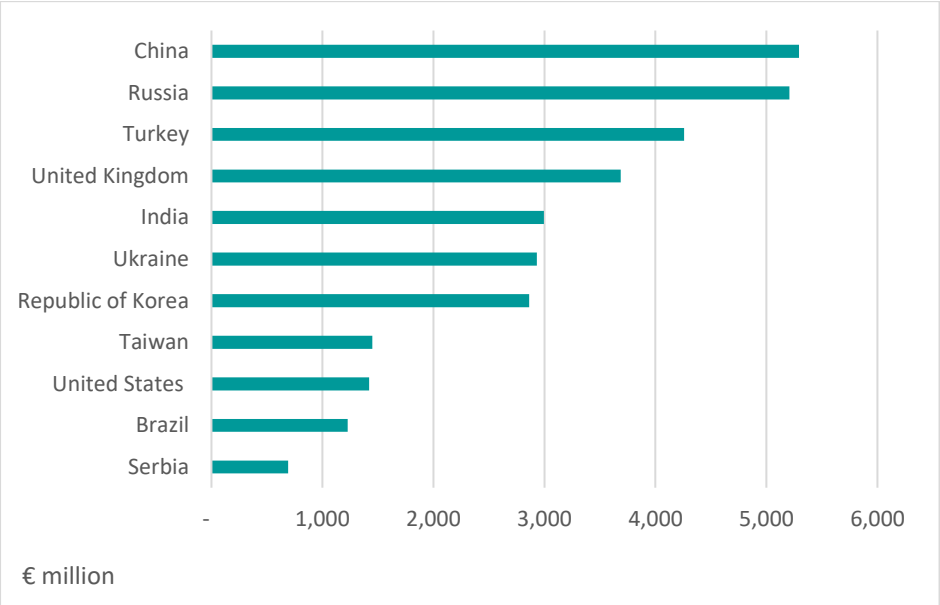
Other key exporters of metal products to the EU include China, Russia, Turkey, India, the Ukraine and the Republic of Korea - see **Error! Reference source not found.** b elow.

[46] Aluminium – Analysis - IEA

[47] In China, coal is used in relation to 90% of aluminium production.

[48] Precise data on exports to the EU is not available.

Figure 9. Key exporting countries to the EU of iron and steel products covered by the European Commission CBAM proposals, on basis of average trade values for the years 2017-2019



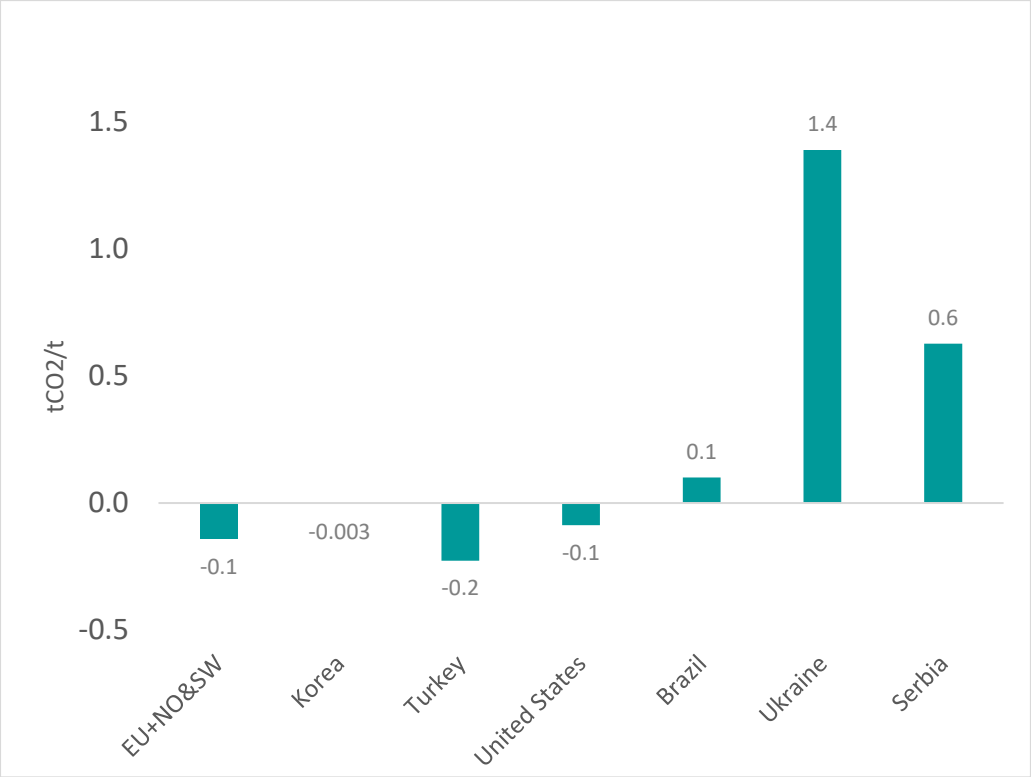
The direct GHG intensity of Scottish metals producers is limited because no primary iron and steel production takes place in Scotland. Scottish producers use intermediate iron and steel inputs made outside Scotland in their production. We do not have information on the source of these intermediate products, and if the GHG embodied in intermediate products are liable for EU CBAM charges, Scottish exporters will be incentivised to source the least GHG intensive intermediate products while also accounting for transport costs and other supply chain considerations. The inclusion of the full embodied carbon, including that from intermediate inputs in the EU CBAM will make a difference to both costs to exporters and the level of competitive advantage, depending on the source and GHG intensity of intermediate products used.

Information on the GHG intensity of the ferrous metals sector is available in the IEA Energy Efficiency Indicators Database[49]. The figure below shows the difference between the UK GHG intensity of the sector and that of competing countries. Scottish iron and steel production constitutes only a very small fraction of the UK production and therefore the proxy used in this analysis is very uncertain. Should Scottish producers use UK-based feedstock, and should upstream products be included in CBAM accounting, the competitive advantage emerging from the IEA comparison is of relevance. This suggests that as Ukraine and Serbia both show higher carbon intensity than UK production[50], this may be indicative of a potential competitive advantage to Scottish producers.

Figure 10. Carbon intensity of iron and steel sectors in key exporters to the EU, as compared to the UK, on average for 2017-2019.

[49] Energy Efficiency Indicators - Data product - IEA

[50] Comparative carbon intensity of iron and steel sectors depend on the use of electric arc furnace versus blast furnace (more energy intensity) and the use of scrap metal in production.



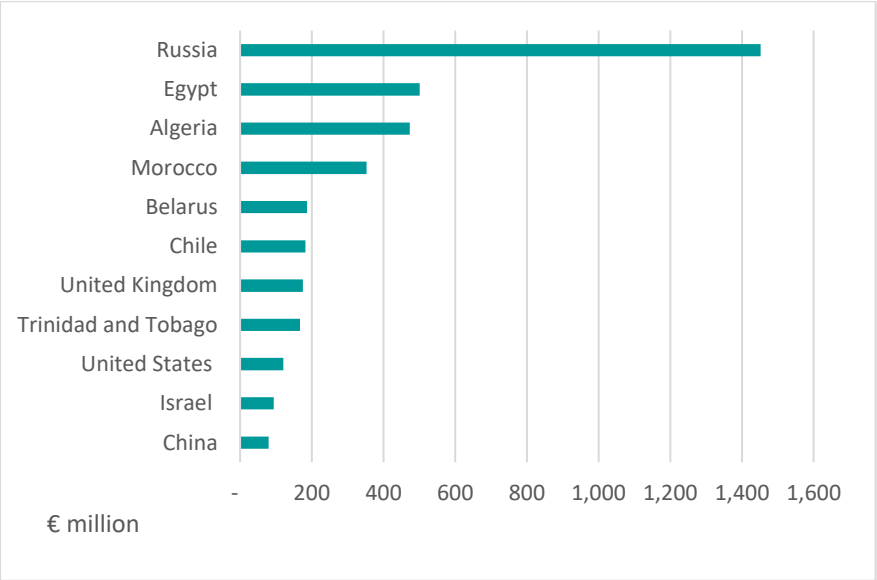
Note: A negative figure indicates that average UK production is more carbon intensive; a positive figure indicates that average UK production is less carbon intensive.

Fertiliser

While some nitrogenous fertiliser is exported from Scotland and £6 million in gross value added was generated in nitrogenous product facilities in Scotland in 2018, no information on the volume of exports is available due to commercial confidentiality.

If fertilisers are exported from Scotland to the EU, the main competition stems from Russia, Egypt, Algeria and Morocco - see Figure 12 below.

Figure 11. Key exporting countries to the EU of fertiliser products covered by the European Commission CBAM proposals, on basis of average trade values for the years 2017-2019



The UK ETS covers the production of ammonia among its activities. As none of the Scottish fertiliser producers are covered by the ETS, we expect that these producers use ammonia made at other sites and convert it to other nitrogenous fertilisers, e.g. ammonium nitrate and urea.

When ammonia is produced, nitrogen from the air is mixed with hydrogen from natural gas at high temperature and pressure. Approximately 60% of the natural gas is used as raw material, with the remainder employed to power the synthesis process. Emissions intensity data for nitrogenous fertilisers is not available across competing exporters to the EU. However, the level of domestic energy subsidies and lack of carbon pricing policies in Russia, Egypt and Algeria are likely to be associated with higher energy, and higher GHG intensities, both in relation to CO_2 and N_2O than those encountered in the UK.

9.1.2 Additional sectors of interest

The EU Parliament Rapporteur Report mentions the inclusion of the chemicals sector and hydrogen within CBAM.

Chemical products

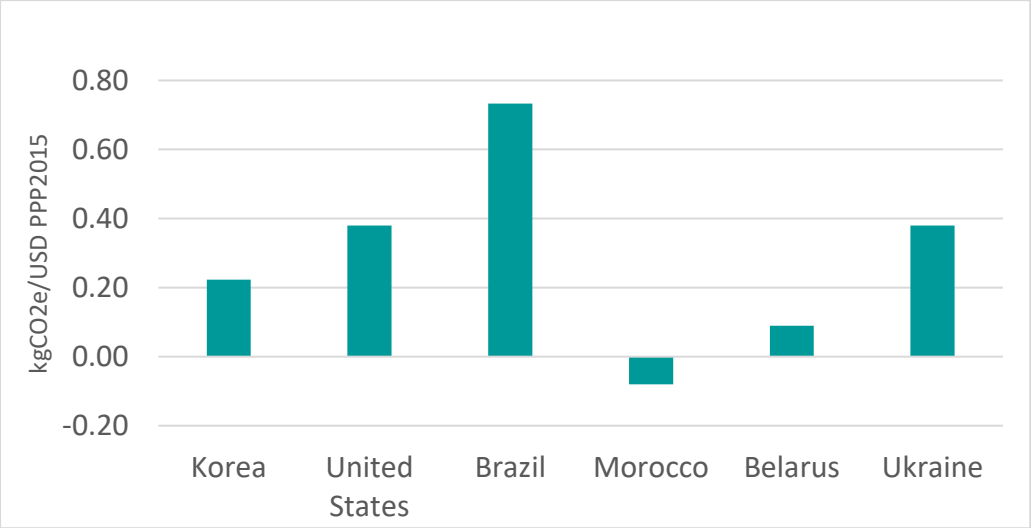
Adding chemicals and plastics to the list of CBAM products would change the total impact of the EU CBAM on Scottish businesses considerably. Current Scottish exports of chemical products are around £240 million to a range of countries, including members of the EU.

The information available in the IEA Energy Efficiency Indicators Database[51] suggests that the UK's chemical sector[52], emits on average less than its counterparts in Brazil, the US, the Ukraine, South Korea and Belarus. Among the non-EU countries for which information is available, only Morocco shows a lower energy intensity.

Figure 12. GHG Intensity of selected countries, compared to UK GHG intensity: Chemicals sector, average for 2017-2019

[51] Energy Efficiency Indicators - Data product - IEA

[52] Scotland's chemical production in the sectors coke, petroleum and petrochemicals, paints varnishes and inks, cleaning and toilet preparations and other chemicals (SIC 19, 20B, 20.3, 20.4 and 20.5) contributed 19% of the total UK GVA in these sectors – figure derived on basis of 2017 Scottish IO tables and UK GDP and GVA dataset for 2017.



Note: A negative figure indicates that average UK production is more carbon intensive; a positive figure indicates that average UK production is less carbon intensive.

An EU CBAM that expands to cover chemicals is likely to lead to a competitive advantage, depending on the exact products covered.

9.2 Analysis limitations

The above analysis is using the best publicly available data to our knowledge, from which precise conclusions cannot be drawn due to the lack of granularity of this data, specifically:

- information on exports of sub-products from Scotland has gaps due to commercial confidentiality
- quantitative comparative data on GHG intensities is limited to a reduced number of countries, often missing precision for large global players such as China and Russia
- the level of sectoral aggregation is too wide to allow comparisons against sectors such as fertiliser production and chemicals.

10 Overview of CBAM domestic considerations among key international players

What are the domestic CBAM plans among Scotland's key international trade partners and competitors?

10.1 Introduction

Whether trade partners introduce a CBAM is important for Scottish business with regards to countries Scotland imports from as well as those it exports to:

Export destination CBAM – This could lead to administrative export arrangements, export costs and potential competitiveness advantages arising from differences in GHG intensities of Scottish exporters and other exporters to these destinations.

Import source CBAM – The need for a domestic CBAM arises from the implementation of a domestic carbon pricing system, such as an ETS or carbon

taxation. A CBAM helps ensure that carbon costs for importers into a country and for domestic producers are the same. Domestic carbon pricing policies could affect the final costs of carbon-intensive imported products to Scotland, due to the added costs of carbon.

Countries that export to the EU have a CBAM-driven incentive to introduce a domestic carbon pricing scheme. This is because carbon costs incurred domestically will be subject to a rebate at the EU border, through the EU CBAM. Therefore, exporting countries with a carbon pricing scheme can avoid the accumulation of this tax revenue with the EU instead of with the domestic government. However, the level of the carbon price, and therefore the EU CBAM rebate, will depend on a range of factors such as tolerance for increased domestic prices for GHG intensive goods and the ability of exporters to pass through or internalise additional costs for countries without a CBAM.

Domestic pricing levels and CBAMs will affect international competitiveness through differentiated costs of carbon, in addition to the primary effects of the differences in GHG intensity among industries in different countries.

10.2 Key findings

Among Scotland's key trading partners outside the European Economic Area, only Canada is exploring implementing a CBAM. Therefore, the EU policy developments remain the main focus in relation to Scotland's exporters.

Key players in the international markets such as the USA, China and Russia have expressed reservations with regards to the EU CBAM proposals due to trade barrier concerns. This contributes to policy uncertainty with regards to the implementation of the EU CBAM.

10.2.1 Scotland's key international trade partners in sectors that may be affected by CBAMs

For both imports and exports, the EU Member States plus Norway and Switzerland constitute the most frequently reported trading partners, followed by the USA. For imports, China also plays an important role. Outside these main trading partners, export destinations include Singapore, the United Arab Emirates, Canada and Hong Kong. Rest of the world import sources include India, Qatar and Trinidad and Tobago.

Among Scotland's key trading partners outside the European Economic Area, only Canada is exploring implementing a CBAM. The Canadian Government ran consultation with regards to border carbon adjustment mechanisms, more specifically on:

- Environmental outcomes: how a border carbon adjustment mechanism can deliver better environmental outcomes for Canada
- Economic impacts: including distribution of impacts across sectors, regions and customers
- International engagement and trade relations

The consultation closed in February 2022[53] and the Department of Finance is now in the process of reviewing findings.

A number of Scotland's trading partners are considering the implementation of domestic emissions trading systems.

10.2.2 CBAM considerations among Scotland's key export competitors to the EU

Russia, China, and the USA have been openly critical of the EU's plans for a CBAM and have shown concern with regards to barriers to trade. However, this does not mean that

[53] Consultation on Border Carbon Adjustments - Canada.ca

they will not implement a CBAM in the future[54]. The latest developments in these countries include:

- In the USA: the implementation of a carbon border tax was included as part of President Joe Biden's presidential campaign. However, the lack of a federal carbon price in the USA could indicate minimal considerations for a CBAM at this time.
- In China:
    - Chinese president, Xi Jinping, was critical of the EU CBAM plans at a virtual climate summit on April 16, 2021, due to trade implications. According to the ERCST, it is not clear whether China will initiate a WTO dispute in relation to EU CBAM proposals.
    - According to the chairman of the carbon exchange in Shanghai, China is looking to bring steel into its national emissions trading scheme imminently. If implemented, this may lead to higher import prices for Chinese steel products in Scotland, if Chinese producers choose to pass through the additional costs to their consumers.
- In Russia[55]:
    - Estimates of the potential impact of the EU CBAM on Russia vary from $3-$6.6 billion per year[56]. Russia has opposed the EU's proposed CBAM as the country likely to be most negatively affected.
    - Russia initiated the development of a domestic carbon taxation system that will be internationally recognised and could be credited towards the CBAM. This means that production falling under the tax and exported to the EU could be partially or fully exempt from CBAM. This will most likely be in the form of carbon quotas, with a lower price than the EU.[57] If implemented, this may lead to higher import prices for Russian products in Scotland.

Among other competitors to Scotland in the EU CBAM product markets:

- The longer term position for the Ukraine is very uncertain and the only useful indications are activities prior to the start of the war: Ukraine launched a working group to negotiate with the European Commission on the implementation of CBAM[58] and was planning to launch its own carbon market mirroring the EU ETS from 2025.

Turkey's response to the EU CBAM is to prepare a domestic carbon market. Turkey has adopted legislation with regards to a pilot ETS at the end of 2020 and, as candidate to EU accession and thereby aims to complete the environmental obligations of the EU accession (including the EU ETS directive)59.

[54] A state level CBAM is already in place in California.
[55] The analysis for this section was undertaken before the start of the war in Ukraine and the introduction of economic sanctions on Russia and Russia's retaliatory ban on selected exports.
[56] ERCST, 2021.
[57] Bloomberg, 2021.
[58] The analysis in this section was undertaken before the start of the war in Ukraine.
[59]https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=66

11 Conclusions and recommendations

11.1 Summary answers to the research questions

Conclusions are formulated around the project research questions and are presented in sequence.

1. What are Scotland's main economic sectors currently participating in the UK ETS, or potentially affected by CBAMs?

Based on estimates of GVA, employment, exports and GVA multiplier the following sectors, listed in alphabetical order, were identified as having the highest economic contribution among ETS-covered operators:

- Chemicals, dyes and pigments
- Electricity, steam and air conditioning
- Extraction of oil and gas and natural gas distribution
- Food products
- Oil refining
- Pharmaceuticals
- Spirits
- Veneer sheets and wood-based panels

Through lack of explicit GVA data for each ETS installation, it was necessary to estimate this by proxy (See Section 1 for more details). As such there is significant uncertainty in the findings which means that the details of individual sectors cannot be compared. Nevertheless, confidence in the data is sufficient to broadly group the sectors in high, medium and low economic contribution tiers. The sectors of the top two tiers are listed above.

2. What are the main products, costs and markets of Scottish ETS sectors and sites?

The main product groups made by ETS sectors include primary energy and electricity, petrochemicals, metallic and non-metallic products as well as outputs of the food and drink, wood-based and paper product industries. See table below.

Table 11. Key products of the most economically important Scottish ETS operators

Sector	Products
Electricity	Electricity
Steam and air conditioning	Steam and air conditioning
Extraction of crude petroleum	Crude petroleum
Extraction of natural gas	Natural gas
Spirits (drinks)	Whisky, gin, other spirits
Chemicals	Ethylene, polyethylene, propylene, polypropylene, ethanol, dyes and pigments
Oil refining	Refined petroleum
Pharmaceutical preparations	Basic pharmaceuticals, antibiotics

Cheese production	Cheese
Other food products	Oils and fats, supplements
Other non-metallic minerals	Asphalt, bricks and ceramics
Veneer sheets and wood-based panels	Wood panels

Energy costs by far exceed other purchased intermediary products for the most important sectors, with the exception of food production.

In the domestic market, the main ETS sectors compete with producers in the rest of the UK, the EU, the US and China.

3. What is the exposure of the ETS sites/sectors to markets inside and outside the EU?

The primary competitors of the key ETS exporting sectors are producers in the EU and the wider European Economic Area followed by the US. Along with China, these countries also represent the main sources of imports in the key ETS sectors.

4. Which of the Scottish sectors and sites are most vulnerable to carbon leakage?

The following metrics were mapped against modelling results of added ETS costs in the absence of in-house GHG abatement:

- Comparison of cost structures of Scottish ETS producers and their key competitors
- Ranking of profitability levels and risk related to product archetypes.

This mapping suggests that sectors such as paper, metal forging, quarrying and some food products may be particularly exposed to carbon leakage. Many other sectors display “medium” risks; these include cement, glass, oil refining and chemicals.

5. How could the risk of carbon leakage affect trade if the EU draft CBAM were implemented?

The effects of the implementation of the CBAM are likely to affect a small proportion of trade, given

a) The limited exports to the EU by the cement, iron and steel, aluminium and electricity sectors in Scotland, and

b) Since UK ETS installations will receive a CBAM rebate for the carbon price already paid in the UK, under current EU CBAM proposals.

However, this is based on quantification of costs to ETS installations that would be covered by the CBAM. It has not been possible to quantify the impact on sectors which are not part of the UK ETS, such as fertiliser production. Additional data collection will be required to quantify the potential impact.

There may be an aspect of competitive advantage for Scottish exporters to the EU, in cases where their GHG intensity is below that of non-EU competitors. This will depend on whether the EU CBAM covers only direct emissions or also embodied emissions. It is possible that chemicals may also be covered by the EU CBAM in which case there will be a potential competitive advantage, the scale of which will depend on the exact chemicals product mix covered by CBAM. Domestic CBAM policy has also been explored by other countries outside the EU. However, among Scotland’s key trading

partners outside the European Economic Area, only Canada (a relatively minor trade partner) is beginning to explore the implementation of a CBAM. Therefore, the EU policy developments remain the main focus in relation to Scotland's exporters.

6. What would be the impact on Scottish sectors/sites of a UK ETS system which deviates from the EU ETS system in terms of price or free allocation?

Two free allocation scenarios to Scottish ETS installations were modelled: free allocation on basis of the current UK ETS trajectory[60] and a free allocation scenario using the EU ETS Fit for 55 approach. The latest EU approach entails a steeper decline in the level of free allocation as associated with product GHG intensity benchmarking.

The added ETS costs to Scottish installations would amount to £740 million under the current UK allocation trajectory and an assumed reference allowance price of £54/tCO_2[61]. Using the allocation method in the Fit for 55 proposals would increase these total costs by about £75 million.

Low and high UK allowance price scenarios were also modelled. Compared with the £54/tCO_2 central case, these are -20% (i.e. £43.2) and +20% (£64.80). The base added cost of £740 million decreases to £592 million and increases to £888 million in response to changing carbon price assumptions.

An attempt to match the EU ETS Fit for 55 allocation, compared to the current UK allocation trajectory, would lead to considerably higher added ETS costs to CBAM installations than the cost of the CBAM certificates. This is because the Scottish exporters would only need to pay for the cost differential between the carbon costs paid domestically and the CBAM certificate costs. Given that EU exports only constitute a small proportion of the Scottish ETS installations' markets, the importance of aligning free allocation levels in relation to CBAM are outweighed by wider added costs associated with ETS allowances.

11.2 Additional conclusions

Scottish ETS installations face considerable uncertainty in relation to their future exposure to carbon liabilities. Our ETS allocation modelling and changes associated with the current UK allocation trajectory and the EU Fit for 55 proposals, demonstrate the magnitude of this uncertainty.

Considering carbon price uncertainty ranges of ±20% leads to a range of total added ETS costs of £592 million to £978 million for the ETS installations included in the analysis. This constitutes between 18 - 30% of estimated Gross Value Added for the installations covered in the study, where Gross Value Added is the difference between the value of the goods produced and the cost of raw materials and other intermediate inputs. This figure is based on a continuation of current emissions for each installation and is therefore an upper bound of total added costs since it would be hoped that the GHG intensity of Scottish ETS installations will reduce over time.

The modelling does not account for several potential changes in the UK ETS design other than the update to benchmarking levels, which could cause the level of added costs to either decrease or increase. However, the scenarios explored here have

[60] The current UK ETS trajectory used for this analysis was determined prior finalisation of the UK ETS consultation https://www.gov.uk/government/consultations/developing-the-uk-emissions-trading-scheme-uk-ets

[61] This is based on the MIX-CP scenario of the European Commission[61] equal to €$_{2015}$60 / €$_{2020}$63[61]

focused on the dominant aspects of the ETS design in terms of the effect on added costs.

Some of the unambiguous conclusions relate to large added costs to the sectors with the highest current levels of emissions such as the extractive industries, fossil-fuel based electricity producers and petrochemicals.

However, some significant impacts, in proportion to the size and number of installations covered, are likely for sectors such as metal forming, food and paper production. We recommend that further analysis is undertaken in relation to such sectors, to establish further detail with regard to product range, supply chain structure and abatement potential such that their risk exposure is managed optimally. Assessing the need for support requires more detailed sectoral and ETS-specific data on:

- Production volumes
- Output values
- Export destinations
- Export volumes and values

The introduction of CBAM policies in Europe is likely to be associated with considerable administrative costs for Scottish exporters with an embodied carbon rating below the default factors used by the EU. Government could consider supporting Scottish CBAM exporters to Europe to certify actual carbon content of exports, once the final CBAM rules are approved (further to tripartite negotiations between the European Commission, the European Parliament, and the Council).

11.3 Data gaps

Undertaking the analysis has revealed several data gaps including:

- The economic impact analysis would strongly benefit from information on list of products, value of output, GVA and exports specifically linked to ETS installations.
- Information on the make-up of sectors that may be affected by the EU CBAM and not covered by the EU ETS, as well as the supply chain aspects that would affect their CBAM export costs is very limited.
- Future analysis of competitiveness impacts would benefit from exact information on trading partners of ETS installations, including quantified exports of products and their respective destinations. This more detailed export data would allow a calculation of the percentage of exports compared to total production value, although we recognise the need to avoid disclosure of commercially confidential data.

Current policy context for this research

ETS and CBAM policy are rapidly changing and as such there have been developments which it was not possible to include in the analysis here. For example, our scenarios were developed before the UK ETS consultation[62] was finalised and as such there will not necessarily be alignment. Furthermore, energy prices, and UK and EU ETS prices, have varied since the analysis was completed and may not be encompassed by the

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

range of scenarios used. Nevertheless, the methodology developed here could be applied in future to an alternative range of ETS prices.

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Appendix 1. Sectors and ETS installations included in the analysis of economic importance ranking

Sector	Verified emissions, in thousand tCO2e average 2017-2019	Number of installations included
Glass and glass fibres	232	3
Extraction of oil and gas and natural gas distribution, inc. compressors	13,182, including 10,410 associated with offshore installations	15 onshore, 72 offshore
Spirits (drinks)	228	11
Chemicals, dyes and pigments	1,809	4
Food products	136	4
Electricity, steam and air conditioning	2,535	10
Paper and paperboard	96	3
Cement	570	1
Oil refining	1,491	1
Pharmaceuticals	44	2
Bricks and tiles and non-metallic minerals	13	3
Synthetic rubber	59	1
Metal forging	27	3
Veneer sheets and wood-based panels	109	3
Quarrying of ornamental and building stone	9	2
Aluminium	71	1
Total	20,609 of which 10,199 are associated with onshore installations	139

Appendix 2. Sector mapping

SIC Code	SIC Label	Common Nomenclature (CN) Code	CN Label	OECD sector aggregation	Scottish Gov't Statistics code	Scottish Gov't Statistics grouping sector name
6100	Extraction of crude petroleum	2709	Extraction of crude petroleum	D05T06: Mining and extraction of energy producing products	5-8	Mining and quarrying, excluding support activities
35110	Production of electricity	271600	Production of electricity	D35T39: Electricity, gas, water supply, sewerage, waste and remediation services	35	Electricity, gas, steam and air conditioning supply
20140	Manufacture of other organic basic chemicals	2942	Manufacture of other organic basic chemicals	D20T21: Chemicals and pharmaceutical products	19-20	Manufacture of coke, refined petroleum and chemicals
23510	Manufacture of cement	2523	Manufacture of cement	D23: Other non-metallic mineral products	23	Manufacture of other non-metallic mineral products
19201	Mineral oil refining	2709	Mineral oil refining	D19: Coke and refined petroleum products	19-20	Manufacture of coke, refined petroleum and chemicals
6200	Extraction of natural gas	271121	Extraction of natural gas	D05T06: Mining and extraction of energy producing products	5-8	Mining and quarrying, excluding support activities
11010	Distilling, rectifying and blending of spirits	2208	Distilling, rectifying and blending of spirits	D10T12: Food products, beverages and tobacco	11-12	Manufacture of beverages and tobacco products
25500	Forging, pressing, stamping and roll-forming of metal; powder metallurgy	7308	Structures (excluding prefabricated buildings of heading 9406) and parts of structures* of iron or steel; plates, rods, angles, shapes, sections, tubes and the like, prepared for use in structures, of iron or steel	D25: Fabricated metal products	25	Manufacture of fabricated metal products
25500	Forging, pressing, stamping and roll-forming of metal; powder metallurgy	7303	Tubes, pipes and hollow profiles, of cast iron	D25: Fabricated metal products	25 - A weak match with 25500	Manufacture of fabricated metal products
23130	Manufacture of hollow glass	7010	Manufacture of hollow glass	D23: Other non-metallic mineral products	23	Manufacture of other non-metallic mineral products
16210	Manufacture of veneer sheets and wood-based panels	4408	Manufacture of veneer sheets and wood-based panels	D16: Wood and products of wood and cork	16	Manufacture of wood products, except furniture

21100	Manufacture of basic pharmaceutical products	30	Manufacture of pharmaceutical preparations	D20T21: Chemicals and pharmaceutical products	21	Manufacture of pharmaceutical products
21200	Manufacture of pharmaceutical preparations	2941	Antibiotics	D20T21: Chemicals and pharmaceutical products	None corresponding but likely matched to pharmaceutical	
24420	Aluminium production	7601	Aluminium production	D24: Basic metals	24	Manufacture of basic metals
17120	Manufacture of paper and paperboard	48	Manufacture of paper and paperboard	D17T18: Paper products and printing	17	Manufacture of paper products
20170	Manufacture of synthetic rubber in primary forms	4002	Manufacture of synthetic rubber in primary forms	D22: Rubber and plastic products	19-20	Manufacture of coke, refined petroleum and chemicals
23140	Manufacture of glass fibres	7019	Manufacture of glass fibres	D23: Other non-metallic mineral products	23	Manufacture of other non-metallic mineral products
10890	Manufacture of other food products n.e.c.	2106	Manufacture of other food products n.e.c.	D10T12: Food products, beverages and tobacco	10	Manufacture of food products
8110	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	25	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	D07T08: Mining and quarrying of non-energy producing products	5-8	Mining and quarrying, excluding support activities
23990	Manufacture of other non-metallic mineral products n.e.c.	27	Manufacture of other non-metallic mineral products n.e.c.	D23: Other non-metallic mineral products	23	Manufacture of other non-metallic mineral products
23320	Manufacture of bricks, tiles and construction products, in baked clay	6904	Manufacture of bricks, tiles and construction products, in baked clay	D23: Other non-metallic mineral products	23	Manufacture of other non-metallic mineral products
20120	Manufacture of dyes and pigments	32	Manufacture of dyes and pigments	D20T21: Chemicals and pharmaceutical products	19-20	Manufacture of coke, refined petroleum and chemicals
10512	Cheese	0406	Butter and cheese production	D10T12: Food products, beverages and tobacco	10	Manufacture of food products

*for example, bridges and bridge-sections, lock- gates, towers, lattice masts, roofs, roofing frameworks, doors and windows and their frames and thresholds for doors, shutters, balustrades, pillars and columns.

Appendix 3. EU ETS Carbon Leakage formula

The **Carbon Leakage Indicator (CLI)** is based on EU-wide metrics for each sub-sector, derived as follows[63]:

$$CLI = Trade\ Intensity\ (TI)\ x\ Emissions\ Intensity\ (EI)$$

The **Trade Intensity (TI)** is determined as follows:

$$TI = \frac{Imports + Exports}{Production\ value\ (Turnover) + Imports}$$

The **Emission Intensity (EI)** is the sum of the Direct Emissions Intensity (DEI) and the Indirect Emissions Intensity (IEI). Both are determined by dividing the Direct or Indirect Emissions by the sub-sector divided by the Gross Value Added (GVA) of the sub-sector. The Indirect Emissions are the product of the net electricity consumption by the sector and the Emission Factor. Therefore, the EI is determined as follows:

$$EI = \frac{Direct\ Emissions}{Gross\ Value\ Added} + \frac{Net\ electricity\ consumption * Emission\ Factor}{Gross\ Value\ Added}$$

The threshold value for the carbon leakage indicator is 0.2 and sectors falling above that threshold receive 100% free allocation up to the sectoral benchmark set at the level of the 10% least GHG intensive installations.

[63] https://ec.europa.eu/clima/sites/clima/files/events/docs/0127/3b_quantitative_assessment_en.pdf

Appendix 4. Energy cost comparison

The table below shows the proportion of energy costs as a percentage of total output value as presented in the OECD Input Output tables.[64]

Name	Country	Indicator for trading partner	UK Indicator
Extraction of crude petroleum	Norway	1%	9%
Production of electricity	Ireland	22%	46%
Manufacture of other organic basic chemicals	United States	8%	6%
	India	12%	6%
	Netherlands	12%	6%
Manufacture of cement	Ireland	7%	14%
Manufacture of cement	Germany	7%	14%
Manufacture of cement	Netherlands	6%	14%
Extraction of natural gas	Ireland	12%	9%
Extraction of natural gas	Netherlands	9%	9%
Extraction of natural gas	France	3%	9%
Extraction of natural gas	Norway	1%	9%
Extraction of natural gas	United States	8%	9%
Distilling, rectifying and blending of spirits	United States	2%	3%
Distilling, rectifying and blending of spirits	France	2%	3%
Distilling, rectifying and blending of spirits	Ireland	2%	3%
Metal structures	Ireland	2%	4%
Structures (excluding prefabricated buildings of heading 9406) and parts of structures (for example, bridges and bridge-sections, lock- gates, towers, lattice masts, roofs, roofing frameworks, doors and windows and their frames and thresholds for doors, shutters, balustrades, pillars and columns), of iron or steel; plates, rods, angles, shapes, sections, tubes and the like, prepared for use in structures, of iron or steel	United States	1%	4%
Structures (excluding prefabricated buildings of heading 9406) and parts of structures (for example, bridges and bridge-sections, lock- gates, towers, lattice masts, roofs, roofing frameworks, doors and windows and their frames and thresholds for doors, shutters, balustrades, pillars and columns), of iron or steel; plates, rods, angles, shapes, sections, tubes and the like, prepared for use in structures, of iron or steel	Australia	3%	4%
Structures (excluding prefabricated buildings of heading 9406) and parts of structures (for example, bridges and bridge-sections, lock- gates, towers, lattice masts, roofs, roofing frameworks, doors and windows and their frames and thresholds for doors, shutters, balustrades, pillars and columns), of iron or steel; plates, rods, angles, shapes, sections, tubes and the like, prepared for use in structures, of iron or steel	China	3%	4%

[64] Input-Output Tables (IOTs) 2018 ed. (oecd.org)

Structures (excluding prefabricated buildings of heading 9406) and parts of structures (for example, bridges and bridge-sections, lock- gates, towers, lattice masts, roofs, roofing frameworks, doors and windows and their frames and thresholds for doors, shutters, balustrades, pillars and columns), of iron or steel; plates, rods, angles, shapes, sections, tubes and the like, prepared for use in structures, of iron or steel	Germany	2%	4%
Structures (excluding prefabricated buildings of heading 9406) and parts of structures (for example, bridges and bridge-sections, lock- gates, towers, lattice masts, roofs, roofing frameworks, doors and windows and their frames and thresholds for doors, shutters, balustrades, pillars and columns), of iron or steel; plates, rods, angles, shapes, sections, tubes and the like, prepared for use in structures, of iron or steel	Poland	3%	4%
Tubes, pipes and hollow profiles, of cast iron	United States	1%	4%
Manufacture of hollow glass	United States	4%	14%
Manufacture of hollow glass	Netherlands	6%	14%
Manufacture of hollow glass	Italy	11%	14%
Manufacture of hollow glass	France	9%	14%
Manufacture of hollow glass	Germany	7%	14%
Manufacture of veneer sheets and wood-based panels	Ireland	3%	3%
Manufacture of veneer sheets and wood-based panels	France	4%	3%
Manufacture of veneer sheets and wood-based panels	Belgium	4%	3%
Manufacture of veneer sheets and wood-based panels	China	3%	3%
Manufacture of veneer sheets and wood-based panels	Poland	4%	3%
Manufacture of veneer sheets and wood-based panels	Germany	3%	3%
Manufacture of pharmaceutical preparations	United States	8%	6%
Manufacture of pharmaceutical preparations	France	8%	6%
Manufacture of pharmaceutical preparations	Netherlands	12%	6%
Manufacture of pharmaceutical preparations	Germany	6%	6%
Manufacture of pharmaceutical preparations	Belgium	7%	6%
Antibiotics	Germany	6%	6%
Antibiotics	Ireland	2%	6%
Antibiotics	Netherlands	12%	6%
Antibiotics	Belgium	7%	6%
Manufacture of paper and paperboard	France	7%	6%
Manufacture of paper and paperboard	Germany	5%	6%
Manufacture of paper and paperboard	Ireland	2%	6%
Manufacture of paper and paperboard	China	5%	6%
Manufacture of synthetic rubber in primary forms	Germany	3%	5%
Manufacture of synthetic rubber in primary forms	United States	2%	5%
Manufacture of synthetic rubber in primary forms	Belgium	3%	5%
Manufacture of synthetic rubber in primary forms	Netherlands	2%	5%
Manufacture of synthetic rubber in primary forms	Ireland	3%	5%

Manufacture of glass fibres	Germany	7%	14%
Manufacture of glass fibres	Canada	11%	14%
Manufacture of glass fibres	United States	4%	14%
Manufacture of glass fibres	China	12%	14%
Manufacture of glass fibres	France	9%	14%
Manufacture of other food products n.e.c.	Ireland	2%	3%
Manufacture of other food products n.e.c.	Netherlands	1%	3%
Manufacture of other food products n.e.c.	Switzerland	2%	3%
Manufacture of other food products n.e.c.	France	2%	3%
Manufacture of other food products n.e.c.	Germany	1%	3%
Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	Netherlands	15%	7%
Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	Belgium	9%	7%
Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	Ireland	10%	7%
Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	Norway	7%	7%
Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	Germany	8%	7%
Manufacture of other non-metallic mineral products n.e.c.	Norway	5%	14%
Manufacture of other non-metallic mineral products n.e.c.	Belgium	6%	14%
Manufacture of other non-metallic mineral products n.e.c.	United States	4%	14%
Manufacture of other non-metallic mineral products n.e.c.	Russia	14%	14%
Manufacture of bricks, tiles and construction products, in baked clay	Ireland	7%	14%
Manufacture of bricks, tiles and construction products, in baked clay	Germany	7%	14%
Manufacture of bricks, tiles and construction products, in baked clay	United States	4%	14%
Manufacture of bricks, tiles and construction products, in baked clay	China	12%	14%
Manufacture of bricks, tiles and construction products, in baked clay	Italy	11%	14%
Manufacture of dyes and pigments	Germany	6%	6%
Manufacture of dyes and pigments	United States	8%	6%
Manufacture of dyes and pigments	Netherlands	12%	6%
Manufacture of dyes and pigments	Belgium	7%	6%
Butter and cheese production	Ireland	2%	3%
Butter and cheese production	Spain	3%	3%
Butter and cheese production	Hong Kong	2%	3%
Butter and cheese production	Germany	1%	3%
Butter and cheese production	Italy	3%	3%
Butter and cheese production	Netherlands	1%	3%

Appendix 5. Export and import values for selected Sectors

Trade values for 2020 for selected Scottish ETS sectors were received by the study team from the HMRC in September 2021. As the data is for an unrepresentative year, 2020 and there are data gaps for a large proportion of the sectors considered, the scope for interpretation in the context of ETS implementation is limited.

Figure 13. Export values for selected products from Scotland, 2020

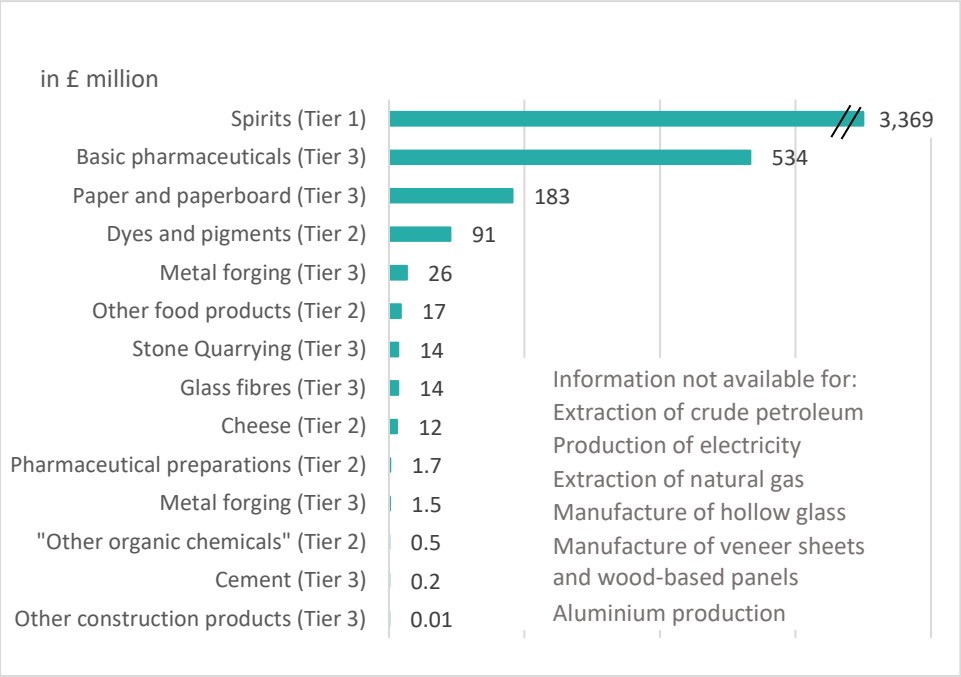
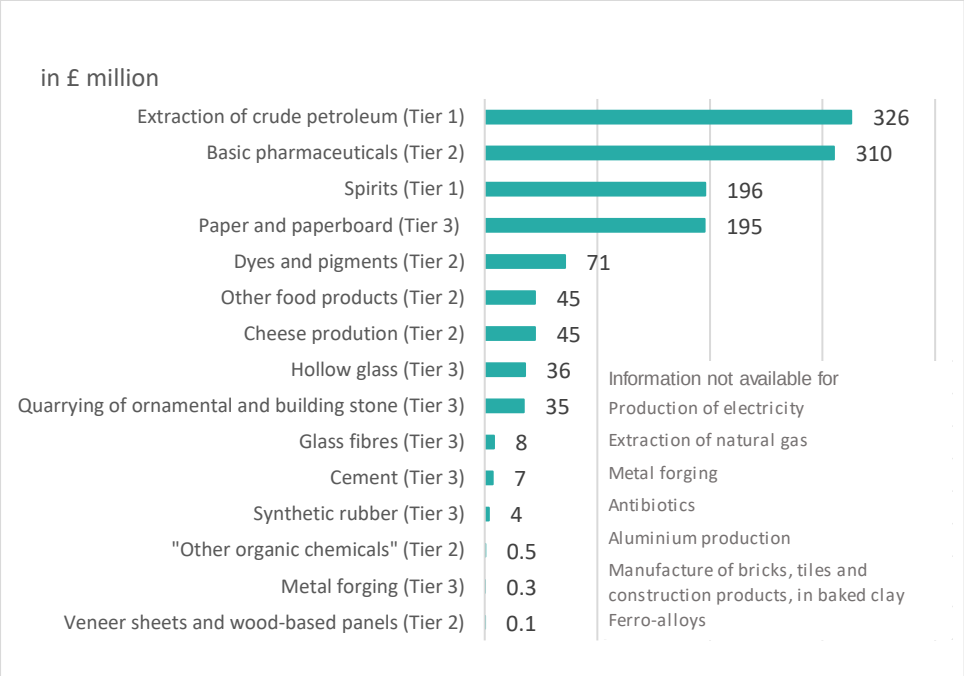


Figure 14. Import values for Scotland for selected products, 2020



*data for 2020 likely to exceed pre-pandemic levels for pharmaceuticals.

Appendix 6. Carbon pricing policies in Scotland's trading partners

Table 12. Carbon pricing in Scotland's ETS sectors main trading partners

Country	Carbon pricing policy	Sectors covered	Recent price[65] (£/tCO2e)	Expected 2030 price (£/tCO2e)	Projection robustness	Comments
US	California ETS	Industry, electricity, transport, buildings	11.4	30[66]	Consultancy estimation	
	RGGI (10 states)	Electricity	3.3	8[67]	Consultancy estimation	
	Other (e.g. Transportation and Climate Initiative ETS)[68]	N/A	N/A	N/A	N/A	Currently being developed
Canada	Federal OBPS: fuel charge/trading component	All large emitters (i.e. including industry)	11.8	99	Official policy price targets	Industries under the trading component are only exposed to a portion of carbon price as they participate in a baseline-and-trading system
	Nova Scotia ETS	Industry, electricity, transport, buildings	14.2	23	Estimation based on the governmental announcement of annual 5% carbon price increase	The increase in price is based on the estimated annual 5% increase and does not include inflation
	Quebec ETS	Industry, electricity, transport, buildings	8.8	30	Estimation based on the governmental announcement to align carbon prices with California ETS	2030 price estimated based on the Quebec´s intention to align its prices with those of California ETS[69]

[65] Typically, 2019, but in some cases includes average for 2017-2019.
[66] https://carbon-pulse.com/124384/#:~:text=deficits%20grow%20%2Danalysts-,California%20carbon%20prices%20to%20hit%20%2440,as%20annual%20deficits%20grow%20%2Danalysts&text=California%20Carbon%20Allowance%20(CCA)%20prices,US%20investment%20bank%20said%20Friday.
[67] https://rhg.com/research/rggi-expansion-road-ahead/
[68] https://openknowledge.worldbank.org/handle/10986/35620
[69] https://carbonpricingdashboard.worldbank.org/map_data

Australia	N/A	Australia doesn't have a mandatory carbon price, but has a price for carbon has been created through voluntary investment to offset carbon emissions (£7.4/tCO2e)				
Hong Kong	N/A	Hong Kong does not have a mandatory carbon price. Offsetting prices are at around £0.05/tCO2e				
Singapore	Carbon tax	All large emitters (i.e. including industry	2.9	8.5	Governmental estimation	Carbon tax rates will be updated after the 2023 review.
China	ETS	Electricity	5.8	18.1	Consultancy estimation	Power sector is the first to be covered, but other industrial sectors will be added based on the results of the initial phase

Estimates for 2030 are uncertain with regards to the US and China, given ongoing policy developments. Canadian industry is likely to face increasing carbon pricing in line with or exceeding that to Scottish ETS installations. Other countries are unlikely to introduce carbon pricing policies comparable to those in the UK and therefore competition from producers situated in those countries will constitute a risk to Scottish ETS installations, both in relation to direct trade with Scotland as well as in relation to Scotland's markets.

Appendix 7. Aggregation method for international competitiveness risk ranking

The trade impact risk ranking relies on standardised OECD IO tables for the UK[70] and a large proportion of trading partners of Scottish ETS installations. The risk ranking includes:

1. A profitability metric: Gross Operating Surplus and mixed income (this includes capital income) as a proportion of output value. The threshold selected for “high” risk is 10% and below and for “low” risk is 30% and higher.
2. The average difference in energy costs, as a proportion of output value, in the respective industry sector, as compared to the top three export destinations and top three import source countries if these are known, or fewer. The threshold selected for “low” risk is 5% and below and for “high” risk is 50% and higher.
3. As above, for the average difference in labour costs as a proportion of output value. This metric is selected due to the frequent reference to labour cost differentials in the manufacturing relocation literature.
4. Product archetype risk: this is based on whether a product is likely to compete on quality, price or both and relies on the classification presented in the BEIS paper *UK Business Competitiveness and the Role of Carbon Pricing*. Competition on quality is linked to “low” risk, competition on price to “high” risk.

Data received from the HMRC suggests that Scotland’s primary trade partners are based in the US and in the EU. Therefore, the weighting of the labour cost differential metric is at only 10% of the aggregate, with the remaining factors assigned an equal weighting of 30% each.

The risk ranking is presented in the table below:

[70] The ranking is based on the simplifying assumption that the cost structure of UK and Scottish installations is similar and relies on UK-wide averages per sector as a proxies.

Table 13. Competitiveness impacts risk ranking

	Gross Operating Surplus and mixed income as a proportion of output value	Energy costs as a proportion of output value	Labour compensation as a proportion of output value	Product Archetype
Threshold for average risk	10%	5%	5%	n/a
Threshold for low risk	20%	50%	n/a	n/a
Threshold for high risk	n/a	n/a	50%	n/a
Weighting for the Risk Ranking	30%	30%	10%	30%

SIC Code	Sector	CN Code	CN Product Category	OECD sector aggregation	Energy costs as a proportion of output value		Energy costs / output		Labour compensation / output		Product Archetype		Overall score
						low=1	medium=2	high=3					
6100	Extraction of crude petroleum	2709	Extraction of crude petroleum	D05T06: Mining and extraction of energy producing products	18%	2	90%	3	8%	2	Intermediate	2	2.3
35110	Production of electricity	271600	Production of electricity	D35T39: Electricity, gas, water supply, sewerage, waste and remediation services	23%	1	52%	3	-16%	1	Price	3	2.2
20140	Manufacture of other organic basic chemicals	2942	Manufacture of other organic basic chemicals	D20T21: Chemicals and pharmaceutical products	20%	2	-57%	1	38%	2	Price	3	2
23510	Manufacture of cement	2523	Manufacture of cement	D23: Other non-metallic mineral products	6%	3	52%	3	-2%	1	Price	3	2.8
19201	Mineral oil refining	2709	Mineral oil refining	D19: Coke and refined petroleum products	11%	2	5%	2	57%	3	Intermediate	2	2.1
6200	Extraction of natural gas	271121	Extraction of natural gas	D05T06: Mining and extraction of energy producing products	18%	2	25%	2	-124%	1	Quality-location	1	1.6
11010	Distilling, rectifying and blending of spirits	2208	Distilling, rectifying and blending of spirits	D10T12: Food products, beverages and tobacco	35%	1	46%	2	38%	2	Quality	1	1.4

25500	Forging, pressing, stamping and roll-forming of metal; powder metallurgy	7308	Structures and parts of structures of iron or steel; plates, rods, etc.	D25: Fabricated metal products	17%	2	37%	2	34%	2	Price	3	2.3
25500	Forging, pressing, stamping and roll-forming of metal; powder metallurgy	7303	Tubes, pipes and hollow profiles, of cast iron	D25: Fabricated metal products	17%	2	37%	2	34%	2	Price	3	2.3
23130	Manufacture of hollow glass	7010	Manufacture of hollow glass	D23: Other non-metallic mineral products	9%	3	43%	2	2%	1	Price	3	2.5
16210	Manufacture of veneer sheets and wood-based panels	4408	Manufacture of veneer sheets and wood-based panels	D16: Wood and products of wood and cork	15%	2	-21%	1	12%	2	Price	3	2
21100	Manufacture of basic pharmaceutical products	30	Manufacture of pharmaceutical preparations	D20T21: Chemicals and pharmaceutical products	40%	1	-28%	1	20%	2	Quality	1	1.1
21200	Manufacture of pharmaceutical preparations	2941	Antibiotics	D20T21: Chemicals and pharmaceutical products	40%	1	-5%	1	24%	2	Quality	1	1.1
24420	Aluminium production	7601	Aluminium production	D24: Basic metals	17%	2	4%	1	-27%	1	Price	3	1.9
17120	Manufacture of paper and paperboard	48	Manufacture of paper and paperboard	D17T18: Paper products and printing	7%	3	10%	2	17%	2	Price	3	2.6
20170	Manufacture of synthetic rubber in primary forms	4002	Manufacture of synthetic rubber in primary forms	D22: Rubber and plastic products		3	41%	2	25%	2	Price	3	2.6
23140	Manufacture of glass fibres	7019	Manufacture of glass fibres	D23: Other non-metallic mineral products	9%	3	38%	2	14%	2	Price	3	2.6
10890	Manufacture of other food products n.e.c.	2106	Manufacture of other food products n.e.c.	D10T12: Food products, beverages and tobacco	13%	2	53%	3	34%	2	Intermediate	2	2.3

8110	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	25	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate	D07T08: Mining and quarrying of non-energy producing products	18%	2	-35%	1	19%	2	Price	3	2
23990	Manufacture of other non-metallic mineral products n.e.c.	27	Manufacture of other non-metallic mineral products n.e.c.	D23: Other non-metallic mineral products	9%	3	47%	2	4%	1	Price	3	2.5
23320	Manufacture of bricks, tiles and construction products, in baked clay	6904	Manufacture of bricks, tiles and construction products, in baked clay	D23: Other non-metallic mineral products	9%	3	43%	2	7%	2	Price	3	2.6
20120	Manufacture of dyes and pigments	32	Manufacture of dyes and pigments	D20T21: Chemicals and pharmaceutical products	19%	2	-35%	1	21%	2	Quality	1	1.4
10512	Cheese production	0406	Butter and cheese production	D10T12: Food products, beverages and tobacco	3%	3	41%	2	34%	2	Quality	1	2

Note: cells highlighted in grey are based on consultant judgement as compared to BEIS 2020 paper.

Appendix 8. Approach to scenario modelling: EU and UK divergence and CBAM certificate cost estimation

Carbon emissions for which UK allowances must be surrendered

Operators in the UK ETS must acquire and surrender one carbon allowance for each tonne of CO_2e they emit. This obligation covers direct emissions only, arising from combustion and industrial processes. To calculate added carbon costs for 2030 it is necessary to assume a level of liable emissions for Scottish sectors in that year. This would be too complicated and uncertain to predict with any accuracy, therefore the simple assumption is made that Scottish sectors' emissions in 2030 are the same as their average annual values for the years 2017-2019 inclusive. Sector totals have been calculated by aggregating the emissions for each installation in each sector.

This single assumption has been made for all policy scenarios; the scenarios do not differ in their assumed sector emissions levels.

The clear limitation to this approach is that installations covered by the UK ETS are required in aggregate to reduce their emissions, so the assumption that they remain static is clearly not realistic. However, it is a common basis from which indicative results can be drawn across all sectors without needing to make assumptions about production levels or abatement measures undertaken. As will be explained later, uncertainties in the cost of allowance surrender are represented by different carbon price scenarios.

Free allowance allocation and CBAM

Within both the UK and EU allowances are allocated for free to more trade exposed sectors based on performance benchmarks. Sectors exposed to significant risk of carbon leakage receive 100% of the benchmark-derived allocation. Other industrial sectors receive an allocation based on a declining trajectory (it is static at 30% of the benchmark-derived allocation for the period 2021 to 2025 and then declines linearly to zero by 2030). Power sector installations receive no free allocation. These assumptions are fixed and assumed to be the same for all scenarios. The only variant related to EU allocation to CBAM sections explained later in this subsection.

There are two important aspects of the benchmarking approach that need consideration when developing carbon cost scenarios:

- When benchmarks are applied to the installations in the trading systems, the sum of this initial allocation could exceed the cap of allowances available. In that case all allocations would be reduced by what is called the Cross Sectoral Correction Factor (CSCF). The CSCF is unpopular with industry and therefore policymakers seek to ensure that the benchmarks are sufficiently stringent that it is not needed, even in later years when the cap is lower. For the scenarios in this report we assume no CSCF either in the EU or the UK[71].
- Benchmarks are updated periodically to reflect real performance improvement. This is to maintain fairness between sectors, avoid situations where some might be allocated more than they need, and as mentioned is the means to avoid needing to apply a CSCF. For the analysis it is necessary to represent different benchmark update scenarios.

[71] https://www.gov.uk/government/publications/participating-in-the-uk-ets/participating-in-the-uk-ets

At present the same set of benchmark values are applied in the UK and EU for every year in the period 2021-2025 inclusive. For the period 2026-2030, the EU benchmarks are to be updated based on an annual average improvement rate for the corresponding sectors and subsectors. That improvement rate is currently capped at 1.6% per year but under the EU's Fit for 55 proposals the maximum improvement rate will increase to 2.5%. In the UK, ETS allocation rules for 2026-2030 will be developed taking into consideration the need to further increase the ambition of the scheme to meet the UK's net zero ambition. Therefore, the scenarios cover two options for the UK benchmark trajectory after 2025:

- Downward trajectory of up to 1.6% per year, as per the current EU policy
- Downward trajectory of up to 2.5% per year, as per the EU Fit for 55 policy

The possibility of an improvement rate of 4% is also briefly considered for further work.

There is a practical point for the analysis to mention here. Each benchmark has an improvement rate of *up to* the maximum indicated but could be lower. For the period 2021 to 2025 these improvement rates are known. However, the analysis is done by projecting installation-level allocations, which in some cases will be the aggregate result of more than one benchmark applying at the installation. We do not know which benchmarks were applied to each installation, so cannot project allocations forward precisely. Instead, we assume that allocations will reduce at the maximum possible improvement rate.

A further scenario is introduced to represent the CBAM. This assumes the CBAM is phased in and free allocation to the covered sectors in the EU is phased out over the period 2026 to 2035, such that in the analysis year of 2030 free allocation is reduced to half what it would otherwise have been. Free allocation within the UK is done for benchmarks with the 1.6% annual improvement rate limit. The scenario is:

- CBAM for electricity, cement, aluminium, fertilisers and iron and steel production.

Further discussion in possible extension of CBAM is provided in Section 6.6.

Allowance prices

The central UK and EU allowance price used in the calculation is £54/allowance[72].

Given the uncertainty around the UK ETS cap and the calculation of UK allowance liability for Scottish sectors, low and high UK allowance price scenarios are used in the scenarios that examine UK benchmark improvement rates. Compared with the central case these are -20% (i.e. £43.2) and +20% (£64.8). For the CBAM scenario only one price is used: £54/allowance.

[72] Scenario description at Policy scenarios for delivering the European Green Deal | Energy (europa.eu), Fit for 55 proposal are closest to the MIX-CP scenario. Prices from page 68, Green Deal IA, adjusted for inflation. Inflation multiplier from World Economic Outlook (October 2020) - Inflation rate, average consumer prices (imf.org), Exchange rate 0.86 from www.xe.com

Appendix 9. Detailed results of scenario modelling: EU and UK divergence and CBAM certificate cost estimation

The added carbon cost incurred for Scottish sectors is a result of the following elements, which in turn depend on the EU and UK Carbon prices:

- The cost of allowances to cover their emissions less any free allowance
- Changes in free allowance as a result of the benchmark improvement rate

Table 14. Carbon price and free allocation divergence scenarios

Scenario	UK ETS allowance price (£/allowance)	UK ETS benchmark improvement rate
Scenario A	54	1.6%
Scenario B	54	2.5%
Scenario C	43.2	1.6%
Scenario D	43.2	2.5%
Scenario E	64.8	1.6%
Scenario F	64.8	2.5%

Here, analysis is done to compare the added cost position of Scottish sectors under UK ETS rules with the positions they would have experienced under EU ETS rules. It can be seen as representing the cost changes they may face as a result of the UK's own possibly divergent system as well as being a comparison of competitiveness impacts relative to EU producers in the same sectors. Two comparisons can be made, see table below:

- UK ETS benchmarks with an annual improvement rate of 1.6% after 2026 compared with an annual improvement rate of 2.5%, for the central UK ETS price (**Scenario A** vs **Scenario B**)
- UK ETS benchmarks with an annual improvement rate of 2.5% after 2026, for the low, central and high UK carbon prices (**Scenarios D, B** and **F** respectively)

Table 15. Summary ETS carbon price and free allocation deviation results

Narrow SIC codes	Simplified sector descriptions	Scenario A		Scenario B		Scenario C		Scenario D		Scenario E		Scenario F	
		£ million	£/tCO2e	£ million	£/tCO2e	£ million	£/tCO2e	£ million	£/tCO2e	£ million	£/tCO2e	£ million	£/tCO2e
23130	Hollow glass	6	29	7	35	5	23	6	28	7	34	9	42
6100	Extraction of crude petroleum	354	40	383	44	283	32	306	35	424	48	459	52
6200	Extraction of natural gas	49	54	49	54	39	43	39	43	59	65	59	65
O&G	Combined oil and gas extraction	76	40	83	43	61	32	66	35	92	48	100	52
35220	Natural gas distribution	31	54	31	54	25	43	25	43	37	65	37	65
11010	Spirits (drinks)	10	54	10	54	8	43	8	43	11	65	11	65
20140	Chemicals	29	16	47	25	24	13	37	20	35	19	56	30
10512	Cheese	1	54	1	54	0	43	0	43	1	65	1	65
35110	Electricity	85	54	85	54	68	43	68	43	101	65	101	65
17120	Paper and paperboard	1	11	2	21	1	9	1	17	1	13	2	26
10890	Other food products	7	54	7	54	6	43	6	43	8	65	8	65
23510	Cement	11	20	16	28	9	16	13	22	14	23	19	34
19201	Oil refining	38	25	49	32	30	20	39	26	46	30	59	38
20170	Synthetic rubber	1	26	2	33	1	21	2	26	2	31	2	39
25500	Metal forging	1	54	1	54	1	43	1	43	2	65	2	65
23990	Other non-metallic minerals	0	19	0	27	0	15	0	22	0	22	0	33
16210	Veneer sheets and wood-based panels	-2	-16	0	2	-1	-12	0	1	-2	-19	0	2
8110	Quarrying of ornamental and building stone	1	54	1	54	0	43	0	43	1	65	1	65
21200	Pharmaceutical preparations	2	54	2	54	2	43	2	43	2	65	2	65
24420	Aluminium	1	12	2	22	1	9	1	18	1	14	2	27
35300	Steam and air conditioning	38	54	38	54	31	43	31	43	46	65	46	65
Total costs		740		815		592		652		888		978	

The highest and lowest range information from the table is presented in the two figures below, with the extractive industries and electricity separated out to allow a better view of the different scale of costs in the remaining sectors.

Figure 15. Low and High Aggregated Added ETS Cost Scenario results for 2030 for selected sectors, in £million

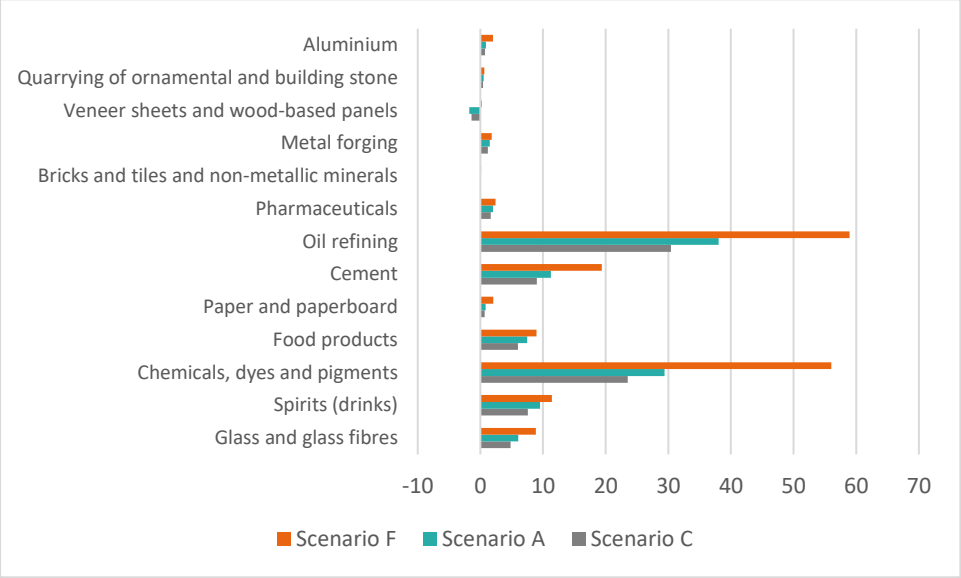
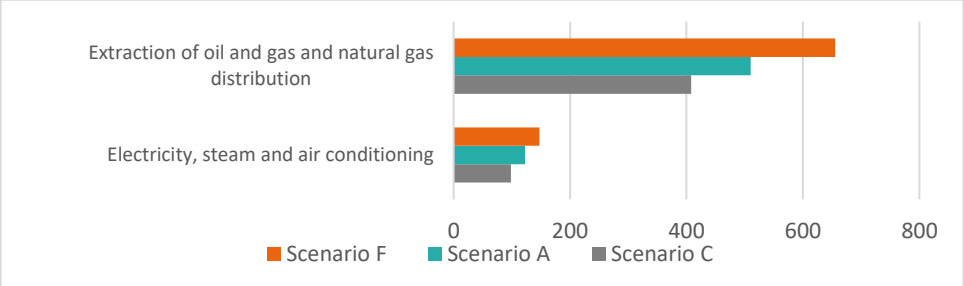


Figure 16. Low and High Aggregated Added ETS Cost Scenario results for 2030 for the extractive industries and electricity, in £million



The figures suggest that there is a considerable variation in the ETS carbon liability for several sectors, depending on the level of free allocation and carbon price, for example extractive industries, oil refining, cement and chemicals. The variation in added costs to the electricity sector, which receives no free allocation under any of the modelled scenarios is an illustration of the effect of carbon price sensitivity, taken in isolation[73].

The table below presents a summary of the analysis outcomes for the Scottish ETS sectors, including the categorisation according to GVA, employment, exports and economic multipliers, trade exposure risks and ETS allocation modelling.

[73] The modelling and figures above do not include the electricity Carbon Price Support, a tax paid by the electricity producers that use coal, oil or gas. The rate at the time of writing is £18/tCO2e.

Table 16. Summary outcomes analysis for the ETS sectors considered under analysis

SIC codes	Simplified sector descriptions	#instal-lations	tCO2 equivalent	Economic ranking cluster	EU / UK ETS Carbon Leakage List	CBAM categorisation	Lowest level of free allocation	Highest level of free allocation	Lowest added cost scenario, in £million	Highest added cost scenario, in £million	Reference Scenario, cost per tonne CO2e	Trade risk exposure	Trade volume notes
35110	Electricity	6	1,566,154		No	Fit for 55 Proposal	-	-	67.7	101.5	54	Medium	Very low
35300	Steam and air conditioning	4	706,707	1	No	-	-	-	30.5	45.8	54	N/A	
6100	Extraction of crude petroleum	48	8,753,564		Yes	-	1,663,769	2,205,226	282.9	459.4	40	Medium	
6200	Extraction of natural gas	6	909,248		No	-	-	-	39.3	58.9	54	Low	
35220	Natural gas distribution	6	577,113		No	-	-	-	24.9	37.4	54	N/A	
O&G	Combined oil and gas extraction	15	1,915,669	1	assumption: Yes	-	379,266	502,694	61.0	99.6	40	Medium / Low	
11010	Spirits (drinks)	8	175,939	1	No	-	-	-	7.6	11.4	54	Low	
20140	Chemicals	3	1,848,314	2	Yes	Fit for 55 IA	983,426	1,303,472	23.5	56.0	16	Medium	
19201	Oil refining	1	1,539,789	2	Yes	Preliminary scope	630,301	835,427	30.4	58.9	25	Medium	
21200	Pharmaceutical preparations	1	37,686	2	No	-	-	-	1.6	2.4	54	Low	
10512	Cheese production	1	10,076		No	-	-	-	0.4	0.7	54	Medium	
10890	Other food products	2	128,323	2	No	-	-	-	5.5	8.3	54	Medium	
23990	Other non-metallic minerals	1	4,144	3	Yes	Fit for 55 Proposal	2,055	2,723	0.1	0.1	19	Medium	
16210	Veneer sheets and wood-based panels	3	112,636	3	Yes	-	109,491	145,124	-1.4	0.2	-16	Medium	
24420	Aluminium	1	75,912	3	Yes	Fit for 55 Proposal	44,695	59,241	0.7	2.0	12	Medium	
23130	Hollow glass*	2	210,772	3*	Yes	Preliminary scope	74,410	98,626	4.8	8.8	29	Medium	
23510	Cement	1	575,874	3	Yes	Fit for 55 Proposal	277,063	367,230	9.0	19.4	20	High	Very low
17120	Paper and paperboard	2	79,852	3	Yes	Fit for 55 IA	48,357	64,094	0.7	2.0	11	High	High
25500	Metal forging	3	27,546	3	No*	Fit for 55 Proposal	-	-	1.2	1.8	54	Medium	High imports
8110	Quarrying of ornamental and building stone	2	9,474	3	No	-	-	-	0.4	0.6	54	Medium	
20170	Synthetic rubber	1	58,201	3	Yes	-	22,957	30,428	1.2	2.3	26	Not included	

Appendix 10. EU CBAM certificate cost for Scottish ETS installations

Under the European Commission's (EC) CBAM proposals, exporters to the EU will be liable for CBAM certificate costs. These costs will be linked to the level of GHGs embodied in the covered exported products, calculated on basis of a default factor unless the exporter provides proof of lower GHG intensity. This will be multiplied by the EU carbon allowance price and reduced on basis of the carbon costs incurred by the exporter outside the EU[74], e.g. under the UK ETS as well as on basis of the level of free allocation to EU ETS installations in the corresponding sectors:

$$\begin{aligned} &CBAM\ export\ cost \\ &\quad = (export\ volume\ \times default\ emission\ factor) \times EU\ carbon\ allowance\ price \\ &\quad - value\ of\ free\ allocation\ to\ EU\ ETS\ installations \\ &\quad - carbon\ costs\ incurred\ outside\ the\ EU \end{aligned}$$

The EC CBAM proposal suggests that default emission factors will be equal to the average emission intensity in the exporting country. In the absence of data on export volumes and values to the EU for each ETS product and on basis of export values for 2020, a cross-sectoral estimate of 15% exports to the EU is used as an illustrative scenario. The default emission factor is the average for each Scottish ETS sector. As such, the first line of the formula is equal to 15% of the *assumed continuation of current emission levels* for each sector multiplied by £54/tCO2e.

As a proxy for the level of free allocation to EU ETS installations in corresponding sectors, the difference between the selected free allocation scenario and the allocation to Scottish installations in the ETS scenario modelling is used.

Trade-off between free allocation and CBAM certificate costs

The first line of the formula above results in a gross CBAM certificate cost without the subtraction of reductions linked to free allocation to EU ETS installations and carbon costs incurred domestically. The results of this calculation are shown in the table below.

Table 17. Illustrative estimates of CBAM certificate costs for Scottish ETS sectors

	CBAM certificate charge without rebate, assuming 15% exports to EU, in £ million
Manufacture of other organic basic chemicals	15
Production of electricity	13
Manufacture of paper and paperboard	0.6
Manufacture of cement	4.7
Forging, pressing, stamping and roll-forming of metal; powder metallurgy	0.22
Aluminium production	0.03

[74] EU CBAM proposal: https://ec.europa.eu/info/sites/default/files/carbon_border_adjustment_mechanism_0.pdf

The total level of the CBAM certificate cost reduction, lines 2 and 3 of the formula, is calculated for the highest and lowest levels of added ETS costs on basis of:

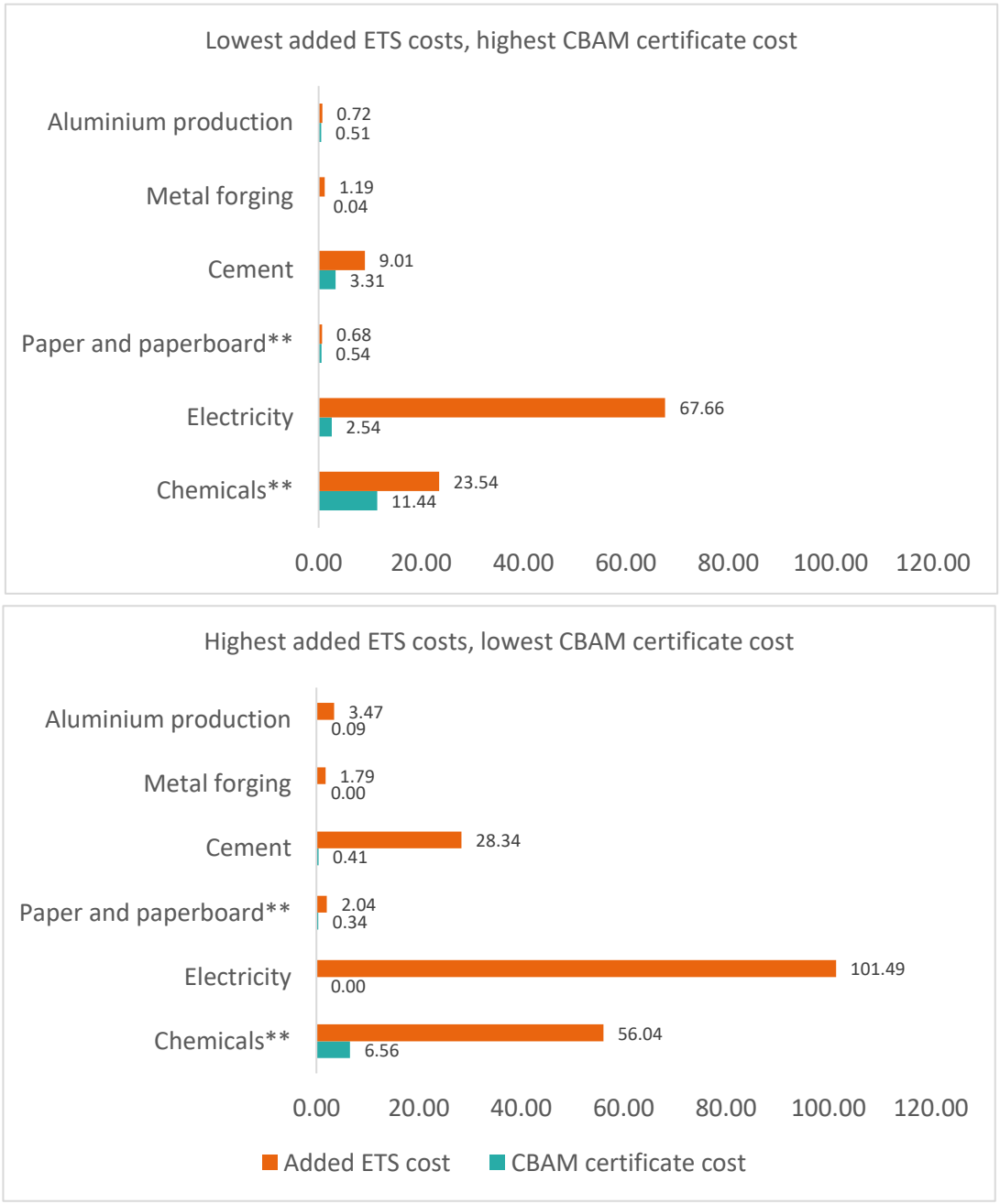
- the lowest UK carbon price, that is the reference price of £54/tCO2e – 20% and the highest level of free allocation, as represented by Scenario 1 and
- the lowest UK carbon price, that is the reference price of £54/tCO2e + 20% and the highest level of free allocation, as represented by Scenario 3.

These are adjusted to apply to the 15% "export emissions." The EU carbon price is maintained at the level of £54/tCO2e.

The difference in CBAM certificate costs, given the low level of exports is dwarfed by the difference in total added ETS costs due to the illustrative assumption that 15% of production is exported to countries affected by the EU CBAM proposals. Figure 16 (below) shows the low and high CBAM certificate cost scenarios, depending on the UK's level of free allocation and carbon prices.

Where the rebate linked to the costs per unit of embodied carbon incurred by Scottish installations in the UK exceeds the cost of CBAM certificates, this is reduced to zero and applies to all sectors but chemicals in the low CBAM certificate cost scenario.

Figure 17. High – Low-Cost Scenarios for CBAM sectors, 15% and 100% export to EEA scenario



Note: In this figure, the sectors not included in the current CBAM proposals, but considered as part the European Commission Impact Assessment are marked with asterisks. The introduction of a CBAM policy for these sectors is of relatively low likelihood.

Provided that the assumption of 15% export to countries implementing the EU CBAM is based on limited data, a further illustration assuming 100% exports is provided in the figure above.

Assuming that all production is exported to the EU, Norway, Switzerland or Iceland, a generous level of free allocation combined with a UK carbon price that is 20% below that of the EU leads to CBAM certificate costs exceeding added ETS costs for all sectors except electricity production. When UK carbon prices exceed those of the EU ETS and the level of free allocation is aligned with the Fit for 55 CBAM scenario, added ETS costs exceed the net cost of CBAM certificates for all sectors except chemicals.

Appendix 11. EU CBAM certificate cost for Scottish non-ETS producers

Additional information on Climate Change Levy

As non-ETS installations are covered by the UK Climate Change Levy, they will be able to claim back this cost against CBAM certificate cost in relation to electricity use:

> Article 9 of the CBAM proposal[75] states that "an authorised declarant may claim in its CBAM declaration a reduction in the number of CBAM certificates to be surrendered in order for the carbon price paid in the country of origin for the declared embedded emissions to be taken into account"[76]

As a type of carbon pricing mechanism, the Climate Change Levy rate from April 2021 is set at 0.775p per kWh for electricity, increasing to 0.465p per kWh for gas. Many sectors have umbrella agreements for Climate Change Agreements (CCAs) and discounts on the main rate of the CCL[77]. Exports are also eligible for exemptions from the main rate. Meaning they could pay a lower rate of a "carbon price" in the UK for this electricity and might still have to pay a certain amount towards a CBAM certificate[78]. In the chemicals sector, the CCA commits the sector to a gradual percentage reduction of energy use of 11% compared to a base year, by December 2020[79]. In the paper sector, the commitment is a percentage reduction of 7% from the base year [80]. Additionally, in the metal forming sector, this commitment is a 6% percentage reduction[81]. Agreements past this point have not been publicised, however the CCA scheme has been extended to March 2025 with new targets set up to 2022[82].

Sectoral sensitivity analysis

Possible additional sectors to be included under CBAM: The CBAM Impact Assessment included chemicals and sub-sectors such as plastic production. If composite products from the chemical sector were to be covered by CBAM, a further 300 units would be covered, with the sum of disclosed exports around £145 million in 2020. The key export destinations for these products include EU countries such as Germany and Ireland as well as the US.

[75] https://ec.europa.eu/info/sites/default/files/carbon_border_adjustment_mechanism_0.pdf
[76] https://eur-lex.europa.eu/resource.html?uri=cellar:a95a4441-e558-11eb-a1a5-01aa75ed71a1.0001.02/DOC_1&format=PDF
[77] https://www.gov.uk/government/collections/climate-change-agreements-umbrella-agreements
[78] https://www.gov.uk/guidance/exemptions-from-climate-change-levy
[79] https://www.gov.uk/government/publications/climate-change-umbrella-agreement-for-the-chemicals-sector
[80] https://www.gov.uk/government/publications/climate-change-umbrella-agreement-for-the-paper-sector
[81] https://www.gov.uk/government/publications/climate-change-umbrella-agreement-for-the-metalforming-sector
[82] https://www.gov.uk/guidance/climate-change-agreements--2#cca-scheme-extended-until-march-2025

Appendix 12. European Commission CBAM certificate cost for Scottish non-ETS producers

The tables below provide the list of products and relevant gases covered by Annex I of the EC CBAM Proposal.

CN Stands for Common Nomenclature product classification.

Cement

CN code	Greenhouse gas
2523 10 00 – Cement clinkers	Carbon dioxide
2523 21 00 – White Portland cement, whether or not artificially coloured	Carbon dioxide
2523 29 00 – Other Portland cement	Carbon dioxide
2523 90 00 – Other hydraulic cements	Carbon dioxide

Electricity

CN code	Greenhouse gas
2716 00 00 – Electrical energy	Carbon dioxide

Fertilisers

CN code	Greenhouse gas
2808 00 00 – Nitric acid; sulphonitric acids	Carbon dioxide and nitrous oxide
2814 – Ammonia, anhydrous or in aqueous solution	Carbon dioxide
2834 21 00 - Nitrates of potassium	Carbon dioxide and nitrous oxide
3102 – Mineral or chemical fertilisers, nitrogenous	Carbon dioxide and nitrous oxide
3105 – Mineral or chemical fertilisers containing two or three of the fertilising elements nitrogen, phosphorus and potassium; other fertilisers; goodsof this chapter in tablets or similar forms or in packages of a gross weight not exceeding 10 kg - Except: 3105 60 00 – Mineral or chemical fertilisers containing the two fertilising elements phosphorus and potassium	Carbon dioxide and nitrous oxide

Iron and Steel

CN code	Greenhouse gas
72 – Iron and steel Except: 7202 – Ferro-alloys 7204 – Ferrous waste and scrap; remelting scrap ingots and steel	Carbon dioxide
7301- Sheet piling of iron or steel, whether or not drilled, punched or made from assembled elements; welded angles, shapes and sections, of iron or steel	Carbon dioxide

7302 – Railway or tramway track constructionmaterial of iron or steel, the following: rails, check-rails and rack rails, switch blades, crossing frogs, point rods and other crossing pieces, sleepers (cross-ties), fish- plates, chairs, chair wedges, sole plates (base plates), rail clips,bedplates, ties and other material specialised for jointing or fixing rails	Carbon dioxide
7303 00 – Tubes, pipes and hollow profiles, of cast iron	Carbon dioxide
7304 – Tubes, pipes and hollow profiles, seamless, of iron (other than cast iron) or steel	Carbon dioxide
7305 – Other tubes and pipes (for example,welded, riveted or similarly closed), having circular cross-sections, the external diameter ofwhich exceeds 406,4 mm, of iron or steel	Carbon dioxide
7306 – Other tubes, pipes and hollow profiles (for example, open seam or welded, riveted or similarly closed), of iron or steel	Carbon dioxide
7307 – Tube or pipe fittings (for example, couplings, elbows, sleeves), of iron or steel	Carbon dioxide
7308 – Structures (excluding prefabricatedbuildings of heading 9406) and parts of structures (for example, bridges and bridge-sections, lock- gates, towers, lattice masts, roofs, roofing frameworks, doors and windows and their frames and thresholds for doors, shutters, balustrades, pillars and columns), of iron or steel; plates, rods, angles, shapes, sections, tubes and the like,prepared for use in structures, of iron or steel	Carbon dioxide
7309 – Reservoirs, tanks, vats and similar containers for any material (other than compressed or liquefied gas), of iron or steel, of a capacity exceeding 300 l, whether or not lined or heat-insulated, but not fitted with mechanical or thermal equipment	Carbon dioxide
7310 – Tanks, casks, drums, cans, boxes and similar containers, for any material (other thancompressed or liquefied gas), of iron or steel, of a capacity not exceeding 300 l, whether or not linedor heat-insulated, but not fitted with mechanical or thermal equipment	Carbon dioxide
7311 – Containers for compressed or liquefied gas, of iron or steel	Carbon dioxide

Aluminium

CN code	**Greenhouse gas**
7601 – Unwrought aluminium	Carbon dioxide and perfluorocarbons
7603 – Aluminium powders and flakes	Carbon dioxide and perfluorocarbons

7604 – Aluminium bars, rods and profiles	Carbon dioxide and perfluorocarbons
7605 – Aluminium wire	Carbon dioxide and perfluorocarbons
7606 – Aluminium plates, sheets and strip, of a thickness exceeding 0,2 mm	Carbon dioxide and perfluorocarbons
7607 – Aluminium foil (whether or not printed or backed with paper, paper-board, plastics or similar backing materials) of a thickness (excluding any backing) not exceeding 0,2 mm	Carbon dioxide and perfluorocarbons
7608 – Aluminium tubes and pipes	Carbon dioxide and perfluorocarbons
7609 00 00 – Aluminium tube or pipe fittings (for example, couplings, elbows, sleeves)	Carbon dioxide and perfluorocarbons