CLIMATE CHANGE
46/2026

Final report

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publisher:
German Environment Agency

CLIMATE CHANGE 46/2026

Ressortforschungsplan of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Project No. (FKZ) 3717 42 506 0

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On behalf of the German Environment Agency

Imprint

Publisher
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
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Fax: +49 340-2103-2285
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Internet: www.umweltbundesamt.de

Report performed by:
Ecologic Institute
Pfalzburger Strasse 43/44
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Report completed in:
March 2023

Edited by:
Section V 3.3 Economic Aspects of Emission Trading, Monitoring, Evaluation
Alexandra Zirkel, Frank Gagelmann

Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4359

Dessau-Roßlau, July 2026

Abstract: Analysis of the competitive situation and the carbon leakage risk of European industries

This report presents the results of the project "Analysis of the competitive situation and the carbon leakage risk of European industries". The project aimed to examine the impact of new developments in climate policy on the established carbon leakage debate, and to derive policy measures to address these developments. The work was carried out by Ecologic Institute, Öko-Institut and CE Delft. The first of four work packages investigated the level of knowledge, definitions and operationalization of the carbon leakage risk. This comprises a review of the literature and an examination of the connection between NDCs under the Paris Agreement on the one hand and carbon leakage on the other. The second work package analysed the climate policies of the EU's largest trading partners and assessed their relevance for the carbon leakage risk. It provides a detailed description of the 12 biggest EU trading partners following the Paris agreement and their climate-related policies applied to specific industry sectors. Each country is assessed in terms of its climate policy stringency and compared to the EU stringency level in order to evaluate potential carbon leakage risk. The aim of the third work package was to investigate the effect of the allocation rules in the 3rd trading period and higher carbon price on carbon leakage risk by implementing an econometric model. The fourth package analysed how adjustments of the trade intensity indicator in response to developments in climate ambition in the EU's trading partner countries would affect the number of sectors and sub-sectors eligible for the carbon leakage list for 2021-2030.

Kurzbeschreibung: Analyse der Wettbewerbssituation und des Carbon-Leakage-Risikos europäischer Industrien

Dieser Bericht stellt die Ergebnisse des Projekts "Analyse der Wettbewerbssituation und des Carbon Leakage-Risikos europäischer Industrien" vor. Ziel des Projekts war es, zu untersuchen, wie sich neue klimapolitische Entwicklungen auf die etablierte Carbon Leakage-Debatte auswirken und welche politischen Maßnahmen erforderlich sind, um diesen Entwicklungen zu begegnen. Die Arbeit wurde vom Ecologic Institut, dem Öko-Institut und CE Delft durchgeführt. Das erste von vier Arbeitspaketen untersuchte den Wissensstand, die Definitionen und die Operationalisierung des Carbon Leakage-Risikos. Dies umfasst eine Literaturrecherche und eine Untersuchung des Zusammenhangs zwischen NDCs unter dem Pariser Abkommen einerseits und Carbon Leakage andererseits. Das zweite Arbeitspaket analysierte die Klimapolitik der größten Handelspartner der EU nach dem Paris-Abkommen und bewertete ihre Relevanz für die Bewertung von Carbon Leakage. Es enthält eine detaillierte Beschreibung der 12 größten EU-Handelspartner und ihrer klimabezogenen Politik, die auf bestimmte Industriesektoren angewandt wird. Jedes Land wird hinsichtlich seiner klimapolitischen Stringenz bewertet und mit dem EU-Stringenzniveau verglichen, um das potenzielle Carbon Leakage-Risiko zu bewerten. Ziel des dritten Arbeitspakets war die Untersuchung der Auswirkungen der Zuteilungsregeln in der 3. Handelsperiode und des höheren Kohlenstoffpreises auf das Carbon Leakage-Risiko durch die Implementierung eines ökonometrischen Modells. Das vierte Paket analysierte , wie sich Anpassungen des Indikators für die Handelsintensität als Reaktion auf Entwicklungen bei den Klimazielen der EU- Handelspartnerländer auf die Anzahl der Sektoren und Subsektoren auswirken würden, die für die Carbon-Leakage-Liste für 2021-2030 in Frage kommen.

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1 Overview and summary of the project

This project aimed to examine the impact of new developments in climate policy on the established carbon leakage debate, and to derive policy measures to address these developments. The work was carried out by Ecologic Institute, Öko-Institut and CE Delft.

The analyses in this report reflect the situation around 2020. Free allocation has been, and still is at the time of publication (2025), the central policy instrument to encounter carbon leakage risks related to the EU-ETS.

With the ETS reform adopted in 2023 as part of the "fit-for-55" package, free allocation is to be gradually replaced by a so-called "Carbon Border Adjustment Mechanism" (CBAM) which imposes a levy on imports at a level that mirrors the prevailing ETS allowance price. Starting in 2026, this levy will gradually be phased in over an eight-year period for imports of iron&steel, cement, fertilisers, aluminium and hydrogen, while free allocations for the respective production in the EU is phased out in parallel. Potential extensions to further ETS industry sectors will be decided in the coming years.

The results contained in this report can provide valuable insights also for the future situation in which a CBAM takes over free allocation's function to address carbon leakage. For example, the insights from work package 2, which analyses options to compare the climate ambition in the main EU trading partners with respect to industry, can help in assessing which challenges can be expected in acknowledging the explicit, and possibly implicit, CO_2 prices paid by importers in the country of origin, in order to deduct these from the CBAM obligation.

1.1 Work package 1 – Level of knowledge, definitions and operationalization

1.1.1 Carbon Leakage Risks in the Post-Paris World

With the adoption of the Paris Agreement, the climate policy world has changed insofar as that all countries that are parties to the Paris Agreement have set themselves climate targets in a bottom-up process – the so-called Nationally Determined Contributions (NDCs). This marks a change from the Kyoto regime, where only the industrialised countries (listed in the Annex I) had fixed emission targets, but where the vast majority of countries had essentially no obligations regarding their emissions.

Since there is no common agreed format or structure, the NDCs differ widely in terms of the type of target they set, the ambition that these targets embody, whether or not targets are conditional on other factors, such as financial assistance, their timeframe, the sectoral coverage and the detail on envisaged policy measures. But – despite their diversity, with few exceptions the NDCs represent a clear commitment towards limiting and reducing greenhouse gas emissions. By doing so, they set a medium- to long-term framework which can help companies and investors to form their expectations about future climate policy. As each country individually formulated its NDC in line with its national circumstances, priorities and preferences, one could expect that there is a higher chance that national governments will actually follow up and make good on the commitments expressed in the NDCs.

For the large majority of countries, and the overwhelming majority of global GDP, the existence of the NDCs means that carbon leakage now comes with a consequence for the leakage recipient country. For the recipient, leakage is no longer just a welcome boost that stimulates foreign investment in the domestic economy and increases demand for domestic products. Instead, carbon leakage now also comes at a cost to the recipient country in the form of associated emissions. Thus, there will be a trade-off to make between the benefits of carbon leakage (for recipient countries) and its downsides – as the additional emissions make it harder for a country to achieve its own NDC targets, and will necessitate additional mitigation action.

Under the Kyoto protocol, there was a concern that carbon leakage would lead to a net increase in emissions. This concern is justified for carbon leakage from Annex-I-countries – who all had binding emission reduction targets (so-called QELROs, i.e. quantified emission limitation and reduction objectives from a historic base year) – to non-Annex-I-countries that effectively had no constraint on their emissions, so that receiving leaked emissions had no consequence or penalty for them. However, with the transition from the Kyoto system to the Paris world, whether or not carbon leakage leads to a net increase in emissions will depend on the actual constellation of targets in the alleged "source country" and the "recipient country," respectively. Assuming that the leakage source country has a QELRO, the following constellations are possible:

- If the leakage recipient country also has a **binding and stringent QELRO** (be it expressed as an absolute emission target, or as a reduction below a fixed baseline, but, importantly, with no "buffer" for potential received leakage), the leaked industrial activity and associated emissions will be in direct conflict with the domestic target – hence every ton of emission increases from leaked activities will need to be compensated through domestic action in other sectors. Emission leakage will not result in additional emissions.
- If the leakage recipient country has a **non-stringent QELRO** (e.g. with an absolute emissions target so lax that it does not impose an effective constraint on emissions), leakage will result in a *de facto* (though not *de jure*) net increase in emissions.
- If the leakage recipient country has an **intensity-based target**, the situation is more complex – but since the leaked activities include particularly emission-intensive processes, whereas the intensity target is typically formulated for the economy as a whole, the carbon leakage will tend to move the recipient country away from its target, and thus require intensified mitigation efforts in other sectors, thereby compensating part of the emission increase from leaked activities.
- A similar situation may arise if the leakage recipient country has a target to reduce emissions below **BAU**, but updates the BAU in light of stronger-than-expected economic growth – possibly augmented by leakage. In this case, leakage would result in additional net emissions – but the additional leeway from the BAU update should be less than the leaked emissions.
- If the leakage recipient country has **sector-specific, technology-specific or even installation-specific targets**, there could be a potential conflict to the extent these targets cover the leakage-recipient sector; yet this appears to be a relatively rare constellation.
- Finally, if the NDC does not include specific targets, or only unrelated ones – such as resilience, adaptation or the expansion of renewable energies – the leakage would have no further consequences, and leaked emissions would indeed constitute net additional emissions.

Thus, in most cases the leakage recipient country will face some kind of trade-off: leaked emissions will require some amount of compensation through increased domestic efforts by the leakage recipient country. Compared to the situation under the Kyoto Protocol, receiving leaked emissions is no longer "free" for many non-Annex-I-countries: it requires increased mitigation ambition in other sectors, or an increased risk of missing the pledged target.

Other than the trade-off faced by the regulator, the mere existence of NDCs also has an important signalling function for private plant operators and investors. In this context, it is necessary to distinguish between operational and investment leakage. Day-to-day production decisions on the basis of existing production capacities (operational leakage) are generally taken with a limited time horizon. They will therefore only factor in the costs of current climate policies, irrespective of the targets, or whether current policies are compatible with them. Thus, NDCs and their targets by themselves will have little influence on operational leakage – what matters is the actual policy on the ground. Investment leakage, however, involves decisions with a longer time horizon. It will therefore also factor in expectations of future policies, which will be derived from (or informed by) the long-term targets embodied in the NDCs. Even if there should be a discrepancy between targets and current policies, investors would not be well advised to ignore this discrepancy.

1.1.2 Literature Review

The work developed in WP 1.2 provides a literature review of state-of-the-art (up to 2019) studies on the risk and extent of carbon leakage resulting from differences in climate and energy policy and particularly the EU Emissions Trading System (EU ETS). Various approaches are used in the literature to determine the risk and extent of carbon leakage, including simple descriptive approaches, surveys, modelling and econometric analyses. Ex-ante analyses are most often carried out using descriptive methods and modelling approaches, while ex-post analyses use surveys, descriptive approaches and econometric analyses.

As several general reviews of the literature already exist, we focus on a specific type of approach, namely ex-post econometric studies directly estimating carbon leakage effects. The choice of limiting the review to this type of studies is to provide a basis for the analysis in other parts of the current research project "Wettbewerbsfähigkeit und Carbon Leakage-Risiko der europäischen Industrie".

Specification options for the direct estimation of carbon leakage are diverse and the empirical evidence shows that results and also the statistical quality of estimates vary greatly depending on the concrete design of the approach, the data used and geographical and temporal horizons covered. We, therefore, zoom in on the main methodological differences between those studies and their repercussions for the estimated carbon leakage effects.

We give an overview of ten studies. We find that studies differ in the carbon leakage indicator used, their analysis level (sector vs. firm data), the indicator used to reflect policy stringency and to what extent results are differentiated by sectors. We find that the choices made by authors are closely related to the main research question asked and all have advantages and disadvantages that should be considered when designing the research.

While ex-ante studies often expect carbon leakage effects to occur, existing ex-post studies unanimously refute the existence of important carbon leakage effects (at least in the short term). Studies specifically looking at the EU ETS in particular find no significant effects, while studies that take into account differences in overall energy and climate policies (often approximated by a proxy) find significant, but small effects on carbon leakage.

1.2 Work package 2 – Analysis of the carbon leakage risk after the Paris Agreement

Ever since the introduction of the EU ETS, there has been debate about how the instrument would affect the competitiveness of European industries compared to their competitors abroad. The issue of carbon leakage – relocation of economic activities driven by differences in the stringency of climate policy – has taken centre stage in the political discussions. As a result, the EU – as indeed all other countries with emissions trading systems that cover industrial sectors – has included mechanisms to protect its industries against the risk of carbon leakage.

While plenty of research attention has been devoted to the issue of carbon leakage, to the question of how to assess the carbon leakage risk and how to mitigate it effectively, one issue that receives surprisingly scant treatment is the actual difference in the stringency of climate policies: how far apart are the ambition and stringency of climate policy between the home country and third countries? The political debate – and also the official determination of the carbon leakage risk, as applied by the European Commission – is based on the simplified premise that the EU is the only country that imposes a carbon constraint on its domestic economy. This premise, however, ignores the fact that as signatories to the Paris Agreement, countries around the world have committed to reducing their emissions, or at least to slow the growth of emissions. A number of them have also started to enact domestic climate policies in order to achieve their objectives, including by imposing constraints on their emission-intensive industries.

The work presented in WP2 addresses this gap from the perspective of the European Union. For the EU itself and its 12 main trading partners, it assesses the stringency of the climate-related regulations that apply to industrial installations, with particular focus on eight industry sectors that are typically deemed to be at risk of carbon leakage. To do so, this study follows a broad (and thereby more comprehensive) approach to defining the effective carbon constraint that applies to industry emitters. In addition to the carbon price as the most evident and most clearly identifiable instrument of climate policy applied to industrial emitters, neighbouring areas are also considered. Given that domestic climate policies typically employ a broad range of instruments and that pricing tools are only one part of the mix of regulation, energy efficiency is examined, as are air quality standards, which are also applicable to industrial installations. Different countries and their economies differ in the extent to which they are amenable to carbon pricing – taking account factors like the overall economic and regulatory framework, the endowment of pre-existing climate and energy policies, but also political preferences for a particular type of regulation. Also, while climate protection, energy conservation and air quality are separate policy objectives, the policy instruments deployed to achieve them do not always distinguish clearly which objective they are intended to achieve.[1] To the contrary, the capactity to deliver on multiple objectives simultaneously – referred to as synergies or co-benefits – can even be a strong political argument in favour of climate action. To what extent regulation is primarily viewed as climate-related (with energy efficiency and air quality co-benefits), or as primarily air quality or energy efficiency-related – with climate mitigation as co-benefit – will differ from country to country, and may even be presented differently in different contexts in the same country.

[1] For instance, also the EU ETS Directive (2003/87/EC) mentions on several occasions that provisions in the Directive are meant to provide incentives not only for incentives for reductions in greenhouse gas emissions, but also for more widespread use of energy efficient techniques, such as district heating, cogeneration, waste heat recovery etc.

A particular challenge that comes with this broad approach is the need to aggregate the stringency of regulation across the different categories. To answer the question that is at the heart of the investigation – how stringent are the EU's climate-related policies relative to those of its main trading partners – the stringency of the effective carbon constraints needs to be expressed in a single metric. This would ideally be done in monetary terms, comparing the compliance costs that different types of regulation impose on the regulated entities, which could then easily be combined with the carbon price to produce a monetary estimate of the cost of compliance. Yet to do so for 13 countries, for eight industrial sectors and across three climate-related policy domains would be a herculean task, which would far exceed the resources that were available for this effort. Instead, this study presents a clear and transparent approach in which the relevant categories (carbon prices, energy efficiency standards and air quality standards) are first assessed separately, and then combined using a pre-defined weight to yield an overall score of the stringency of climate-related policies. This is presented for three approaches with different weights, or otherwise changing key assumptions, in order to test how robust the findings are towards such changes.

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presents an overview of the 13 countries' scores in the three categories, the indicator for the quality of enforcement, and the results of three ways of aggregating the categories: As the first option, the three categories are weighted based on the estimated cost of compliance for the EU. When applying this metric, the effective carbon price receives a weight of 80%, whereas the energy efficiency and air quality component are each weighted with a factor of 10%. As the second option, the three categories are aggregated with equal weight attached to each of them. In a third, step, the weights remain as in the first option (i.e. based on estimated EU compliance costs), but instead the results in all three categories are combined with a correction factor, which is supposed to control for differences in the enforcement of the respective regulations.

In general, both the different choice of weights and the inclusion of an enforcement factor do not change the ranking of the countries significantly, as compared to the initial option with 80-10-10 weights and without correcting for differences in enforcement. In all instances, the top group of countries is formed by Norway, Switzerland and Korea. They are followed by the EU and Japan – which, depending on the assumptions made, either score almost equal, or with a somewhat higher value for the EU. The middle section is occupied by the US, India and China. Finally, the bottom group of countries with least ambitious climate-related policies for industry is composed of Singapore, Turkey, Brazil, Russia and Saudi Arabia. Singapore is the one case where the choice of assumptions has a strong impact on the ranking: in the version corrected for differences in enforcement, Singapore moves up considerably from 11th to 8th rank, thanks to its much stricter enforcement. In this sense, the results are robust to changes of key assumptions.

What does change markedly, however, between the different modes of aggregating the results, are the distances between the countries, as Figure 1 below illustrates. The weighting of the criteria in the first option places a particularly high emphasis on the effective carbon price. Therefore, a large number of countries that have no or only a very low carbon price in place also receive a low overall score. This also means that there is hardly any middle section: Norway, Korea and Switzerland occupy the top spots, followed by the EU. Japan (and India, unless the enforcement correction factor applies) are still relatively close. The rest of the world – including the economic heavyweights China and the US – are far behind, and score less than a third of the EU value.

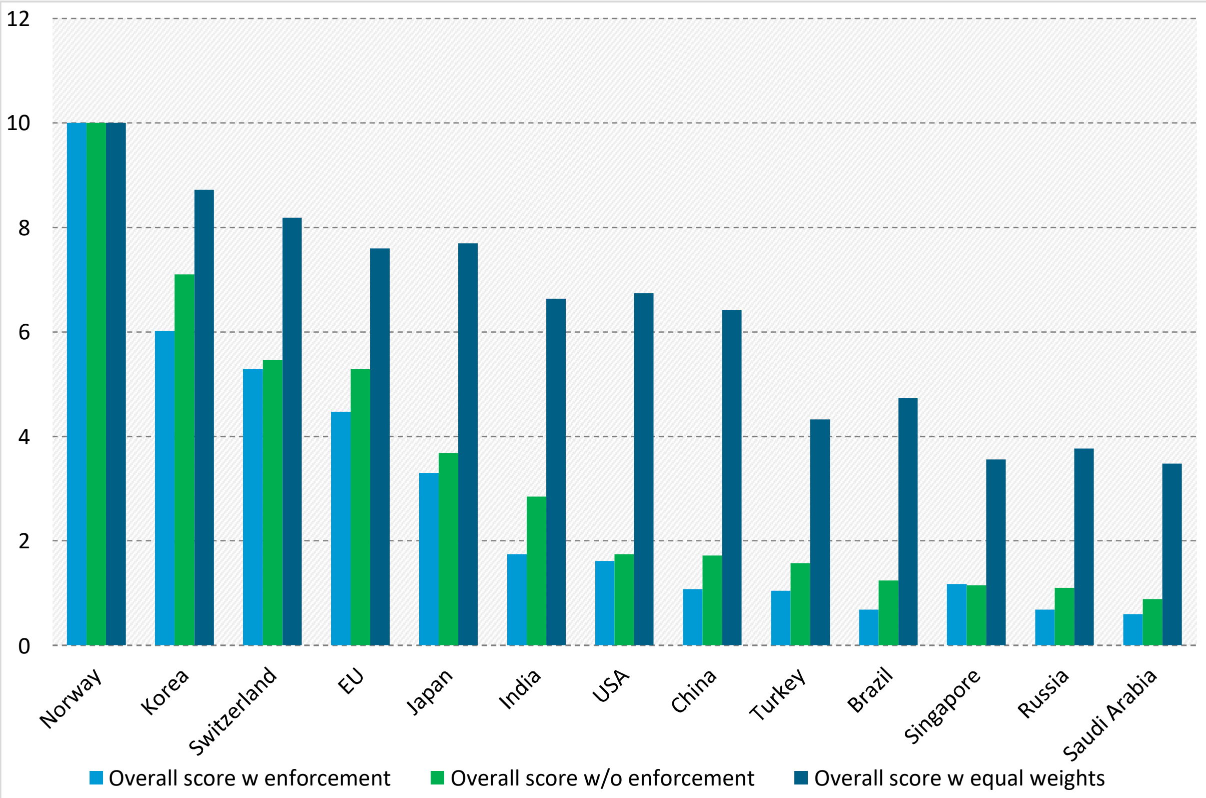
Table 1 Overview of countries' scores

Scores Country		Effective Carbon Prices Norm'sd Score	Energy Efficiency Norm'sd Score	Air Quality Norm'sd Score	Enforcement Score	Overall Score (80/10/10) Rank	Overall Score (80/10/10) Norm'sd Score	Overall Score (80/10/10) Score	Overall Score w equal weights Rank	Overall Score w equal weights Norm'sd Score	Overall Score w equal weights Score	Overall Score (80/10/10) with Enforcement Rank	Overall Score (80/10/10) with enforcement Norm'sd Score	Overall Score (80/10/10) with enforcement Score
Norway		10	4.91	9.07	83.08	1	10	9,40	1	10	7.99	1	10	7.81
Korea		6.55	8.05	6.3	70.46	2	7,10	6,67	2	8.72	6.97	2	6.02	4.7
Switzerlan d		4.53	5.1	10	80.46	3	5,46	5,13	3	8.19	6.54	3	5.29	4.13
EU		4.5	8	5.71	70.22	4	5,29	4,97	5	7.6	6.07	4	4.47	3.49
Japan		2.31	9.34	6.81	74.34	5	3,69	3,46	4	7.7	6.15	5	3.3	2.58
India		1.54	7.04	7.35	50.88	6	2,84	2,67	7	6.64	5.31	6	1.74	1.36
USA		0.03	10	6.13	76.77	7	1,74	1,64	6	6.74	5.39	7	1.61	1.26
China		0.1	9.14	6.15	52.15	8	1,72	1,61	8	6.42	5.13	9	1.08	0.84
Turkey		0.63	7.17	2.59	55.07	9	1,57	1,48	10	4.33	3.46	10	1.04	0.81
Brazil		0.04	5.02	6.27	45.73	10	1,24	1,16	9	4.73	3.78	12	0.68	0.53
Singapore		0.33	3.35	4.85	84.79	11	1,15	1,08	12	3.56	2.84	8	1.17	0.92
Russia		0.18	2.88	5.99	51.75	12	1,10	1,03	11	3.77	3.02	11	0.68	0.53
Saudi Arabia		0	3.67	4.66	55.75	13	0,89	0,83	13	3.48	2.78	13	0.59	0.46

Source: authors' own calculations (Ecologic Institute)

This picture changes markedly if the three categories are weighted equally in the aggregation process. In this instance, there is a distinct middle section of countries (India, the USA and China) that are rated as only moderately less ambitious than the EU, with a score corresponding to 84-89% of the EU value. And even the laggards (with Turkey, Brazil, Singapore, Russia and Saudi Arabia) perform considerably better if the categories are weighted equally. The reason for this divergence is, quite simply, that most of the countries that do not apply a carbon price do score relatively well in terms of air quality standards, but particularly in terms of energy efficiency regulations (where the USA, China, Turkey and India all score relatively high marks). In the default case with an 80-10-10 weighting, however, these results hardly affect the overall score.

Figure 1: Overview of overall scores of countries analysed, using different aggregation methods



Source: authors' own calculations (Ecologic Institute)

For the assessment of the carbon leakage risk, one clear result is that there is a subset of EU trading partners for whom a carbon leakage risk is clearly not given. Based on the methodology applied in this study, and irrespective of the assumptions chosen for weighting or correcting for enforcement – the finding is robust that the ambition levels of Norway, Switzerland and Korea exceeds that of the EU.

It is also clear that the ambition embodied in the climate-related regulations of Turkey, Brazil, Singapore, Russia and Saudi-Arabia is clearly below that of the EU – depending on the metric applied and the assumptions chosen, the ambition of climate-related regulations is at most half the score of the EU, and in other cases lower.

What is more difficult to ascertain is the middle section of EU trading partners, for which it matters how the different categories are weighted in the aggregation process. If the carbon price receives a higher weight, the overall ambition of climate-related regulations in the USA, India and China is significantly lower than that of the EU; depending on whether results are corrected for enforcement, the scores are between 24% and 54%. However, if the categories are weighted equally, this difference shrinks markedly – and the three countries achieve scores of 84% to 89% of the EU value, i.e. a comparable level of ambition. The evaluation of this middle section is particularly relevant since this comprises the heavyweights among the EU's external trading partners. The countries in the middle section - USA, India and China – account for between 13.5% and 43.7% of the EU's EU-external trade. By contrast, the share of the three leading countries – Norway, Switzerland and Korea – ranges from 6% to 15.8% of EU-external trade.

This report is structured as follows: chapter 2 presents the trade profiles of EU-external trade for eight selected emission-intensive commodities, and on this basis, presents a selection of the 12 most relevant trading EU partners, which will subsequently be analysed. Chapter 3 introduces the methodology for the assessment of the different countries' efforts, i.e. the main categories, the main data sources and indicators used to assess the performance in these categories, and the method for aggregating them. Chapter 4 presents summary overviews of the climate policy landscape in the EU itself and its 12 main trading partner countries. In chapter 5, the performance of the 12 countries and the EU itself is assessed for the three main categories (effective carbon price, energy efficiency policies and air quality standards), and subsequently aggregated to yield an overall score, as well as sensitivity analyses to assess the impact of key assumptions on the outcome of the analysis. Chapter 6 concludes. In this context, it should be noted that the assessment in chapter 5 draws on different data sets and overview publications, which allow to draw on a single, internally consistent source for the assessment. The country descriptions in chapter 4 serve to illustrate and provide detail on the different countries' efforts, but generally would not enter the assessment – with few exceptions, e.g. where individual countries were lacking from cross-country assessments, these gaps were filled with information from the national-level analyses.

1.3 Work package 3 – Effect of allocation rules in the 3rd trading period on carbon leakage risk

The fear that unequal carbon prices have an adverse impact on the competiveness of EU industries has been a dominant concern since the start of the EU ETS in 2005. Adverse impacts of unequal carbon prices would translate themselvesinto changes in the market shares of EU industries in global markets, or on the domestic EU markets. Such change in market shares will be accompanied by a change in trade patterns where EU carbon prices would stimulate imports from and reduce exports to non-EU countries if these producers are not being faced with comparable carbon policies.

The impact of unequal carbon prices on trade patterns has been subject to theoretical and empirical research efforts. The empirical literature so far has largely used simplistic econometric approaches (an analysis of the situation before and after the introduction of carbon prices) or investigated the impact of energy price differentials in generalized trade models. Relatively few efforts have tried to estimate the impact of carbon prices on trade directly.

Within this research, we have attempted to fill the gap by investigating the influence of carbon prices (both as carbon prices and as energy price differentials) directly in complicated trade models. In order to keep the research focussed (and the dataneeds manageable) we have been focussing on a few selected energy intensive industries and a limited number of trade relations. The data in our work consists of trade relations between the 28 individual EU27 member states (MS) + UK (EU ETS until 2020) and a group of 7 countries (Switzerland; China; India; South-Korea; Russia; Turkey; United States of America) for the 15 most energy intensive sectors in the

EU ETS (defined as NACE4 digit level). The included sectors were: basic iron and steel and ferro-alloys; Refined petroleum products; Cement; Other organic basic chemicals; Fertilisers and nitrogen compounds; Lime and plaster; Paper and paperboard; Aluminium; Other inorganic basic chemicals; Hollow glass; Sugar; Industrial gases; Coke oven products; Bricks, tiles and construction products, in baked clay; Flat glass. The empirical analysis used annual data for the period 2000-2016.

Compared to other approaches in the literature our study aimed to combine the better of two methods:

(i) the full richness of gravity trade models that have been used to investigate the impacts of cost differentials on trade, such as in the influential paper by Sato and Dechezleprêtre (2015) that have estimated impacts of energy prices on trade at the NACE 2-digit level;

(ii) The much more granular statistical basis of ex-post analysis such as Ecorys/Öko-Institut (2014) that used ETS data to determine eventual impacts of ETS costs on trade patterns.

However, the results of this effort have been disappointing. We noticed that the Sato and Dechezleprêtre model did not properly describe our situation: most of the gravity variables were insignificant casting doubts about the appropriateness of these models. A concise trade model resulted in large impacts of unequal carbon or energy prices on trade, especially in the long-run. The impact would imply an Armington elasticity (price elasticity of export) that is a factor 4 higher than commonly found in literature and macro-economic models .Combined with the low explanatory power of the models, we have doubts about the appropriateness of these results. Further methodological refinements have been sought in the area of alternative model specifications. However, these alternative model specifications did not provide a better explanation of the impacts of unequal carbon prices on trade.

All in all, we draw the following conclusions from our work:

All of our modelling efforts used annual data, as this was the basis of our data collection using the annual index of energy prices from the Sato *et al*. (2019) paper. However, our regressions show that that annual data are probably too coarse to provide a realistic picture of the impact of carbon pricing on trade. Time lag models provided no realistic results indicating that a time lag of a year is too long for the processes underlying the (potential) impact of carbon prices on trade.

Our results provide some evidence that by focussing only on the most energy intensive sectors, impacts of unequal carbon prices on trade may be much larger than indicated in previous academic studies. However, given the relatively poor quality of our models in terms of explanatory power, stability of the estimators and plausibility of the long-term results we cannot state this with any degree of certainty. The real impacts of unequal carbon pricing on the competitive position of companies should therefore be more investigated in future work.

For future work, we would primarily recommend to consider using physical indicators of trade. The present work has, like all other efforts that we are aware of, used monetary indicators of trade (values of imports and exports). However, the direct impact of a price increase in carbon on monetary indicators is ambiguous as the price increase on the one hand increases the value of trade as the carbon price is forwarded in the costs but on the other hand diminishes the volume of trade through the Armington elasticities. As these two impacts counteract each other, the net impact may be small – too small to discern in our trade models. This could as well explain the lack of results from our efforts. In addition to this recommendation we would recommend using monthly data as these may be better able to capture the dynamics of carbon pricing over the year.

1.4 Work package 4 – Implications of an adjusted indicator for trade intensity

With the “Fit-for-55” climate policy package adopted in 2023, the ambition level of the EU’s GHG reduction target for 2030 has been raised to at least 55 % below 1990 levels. This represents a substantial increase compared to the existing target of at least 40 % and has far-reaching implications for industrial sectors in Europe. Given that the EU Emissions Trading System (ETS) is the key instrument for reducing GHG emissions from power and industrial sectors, there is a concern that this enhanced level of ambition will lead to an increase in direct and indirect CO_2 costs that may undermine their international competitiveness and result in carbon leakage.

To limit the risk of carbon leakage, it was agreed within the revision to Phase IV of the EU ETS to continue to provide free allowances to industry with those sectors deemed at risk of carbon leakage receiving 100 % of their allocation up to the relevant benchmark for free. The carbon leakage list for 2021-2030 defines ‘significant risk’ on the basis of each sector’s carbon leakage indicator value (i.e. calculated by their emission intensity multiplied by their trade intensity). If a sector has a carbon leakage indicator value above a threshold of 0.2 it is deemed at ‘significant risk’ of carbon leakage and is put on the list. In total, 44 sectors and sub-sectors at the NACE 4-digit level have been included in the carbon leakage list for 2021-2030 based upon this first level assessment (European Commission 2018).[2]

The carbon leakage list for 2021-2030 did not, however, take into account the comparable efforts internationally to address climate change. The purpose of this study was to therefore calculate an alternative carbon leakage indicator value for each of the sectors and sub-sectors at the NACE 4-digit level by adjusting the trade intensity indicator value in order to reflect the climate policies of countries outside of the EU ETS (i.e. by deducting the EU ETS related trade with a selection of non-EU ETS countries[3] if they have adopted comparable climate policies to the EU from the trade intensity calculation).

The study showed that even if the trade intensity indicator values were considerably reduced to reflect the very optimistic assumption that the non-EU ETS countries selected in this study have completely comparable climate policies to the EU (i.e. deducting 100 % of the EU ETS related trade of selected non-EU ETS countries from the trade intensity calculation), many sectors and sub-sectors (accounting for a large share of EU ETS emissions) would still remain eligible for carbon leakage support. The high emission intensity indicator values for many sectors and sub-sectors (that were fixed at the reference level in this assessment) ensure that the overall carbon leakage indicator remains above the 0.2 threshold. Given that the emission intensity indicator is based on average historical values for 2013-15 and may not be updated during the 2021-30 period, this raises the question as to whether the emission intensity indicator provides a true reflection of a sector or sub-sector’s risk of carbon leakage as it fails to take into account efforts to decarbonise over the coming decade. Therefore, an adjustment to the carbon leakage calculation, i.e. such as an increase in the carbon leakage indicator threshold value for determining carbon leakage risk, could be an option to further consider in order to respond to the increased climate policy ambition of non-EU ETS countries.

2 Sectors can also be eligible for the carbon leakage list via a qualitative assessment if lower thresholds of the carbon leakage indicator value are met.

3 The countries assessed included the USA, China, Switzerland, Russia, Turkey, Japan, India, Brazil, South Korea, Saudi Arabia and Singapore.

2 Überblick über das Projekt und Zusammenfassung

Ziel dieses Projekts war es, die Auswirkungen neuer klimapolitischer Entwicklungen auf die etablierte Carbon Leakage-Debatte zu untersuchen und politische Maßnahmen abzuleiten, um diesen Entwicklungen zu begegnen. Die Arbeit wurde vom Ecologic Institut, Öko-Institut und CE Delft durchgeführt.

Die Analysen in diesem Bericht reflektieren die Situation in den Jahren um das Jahr 2020. Die kostenlose Zuteilung war, und ist auch zum Zeitpunkt der Veröffentlichung (2025) noch, das zentrale politische Instrument, um Carbon Leakage-Risiken im Zusammenhang mit dem EU-ETS zu begegnen. Mit der ETS-Reform im Rahmen des 2023 verabschiedeten "Fit-for-55"-Pakets soll die kostenlose Zuteilung schrittweise durch einen so genannten "Carbon Border Adjustment Mechanism" (CBAM) ersetzt werden, der eine Abgabe auf Einfuhren in Höhe des geltenden ETS-Zertifikatspreises erhebt. Ab 2026 werden diese Abgaben für Eisen und Stahl, Zement, Düngemittel, Aluminium und Wasserstoff schrittweise bis 2034 eingeführt, während parallel die kostenlose Zuteilung für die jeweilige Produktion in der EU abgeschmolzen wird und bis 2034 ausläuft. Über eine mögliche Ausweitung auf weitere ETS-Branchen wird in den kommenden Jahren entschieden,

Die Ergebnisse in diesem Bericht können wertvolle Erkenntnisse auch für die künftige Situation liefern, in der ein CBAM anstelle der kostenlosen Zuteilung das Carbon Leakage-Risiko adressiert. So wurden im Arbeitspaket 2 Optionen für einen Vergleich der Klimaambition in den wichtigsten EU-Handelspartnerländern in Bezug auf die Industrie analysiert. Die Ergebnisse illustrieren die Herausforderungen bei der Anerkennung der CO_2-Bepreisung (explizit oder implizit) im Herkunftsland der CBAM-Importe.

2.1 Arbeitspaket 1 – Kenntnisstand, Definition und Operationalisierung

2.1.1 Carbon Leakage-Risiken in der Post-Paris-Welt

Mit der Verabschiedung des Pariser Abkommens hat sich die Welt der Klimapolitik insofern verändert, als sich alle Länder in einem Bottom-up-Prozess eigene Klimaziele gesetzt haben. Dies stellt eine fundamentale Änderung gegenüber dem vorherigen Kyoto-Regime dar, bei dem nur die Industrieländer (die sogenannten Annex-I-Staaten) feste Emissionsziele hatten, bei dem aber die überwiegende Mehrheit der Länder keine konkreten Verpflichtungen hatte, ihre Emissionen zu begrenzen oder gar zu verringern.

Für die national bestimmten Beiträge (NDCs) der Vertragsstaaten des Pariser Abkommens gibt es nach wie vor kein gemeinsam vereinbartes Format oder eine gemeinsame Struktur. Daher unterscheiden sich die NDCs stark hinsichtlich der Art des darin festgelegten Ziels, des Ambitionsniveaus, das diese Ziele verkörpern, der Konditionierung der Ziele von anderen Faktoren, wie z.B. finanzieller Unterstützung, ihrem Zeitrahmen, der sektoralen Abdeckung und dem Detailgrad der geplanten Maßnahmen zur Erreichung der Ziele. Aber ungeachtet ihrer vielfältigen Formen stellen die NDCs mit wenigen Ausnahmen ein klares Bekenntnis zur Begrenzung und Reduzierung der Treibhausgasemissionen dar. Damit setzen sie mittel- bis langfristige Rahmenbedingungen, die Unternehmen und Investoren helfen können, sich Erwartungen an die zukünftige Klimapolitik zu bilden und ihre Entscheidungen daran auszurichten. Da jedes Land sein NDC individuell nach seinen nationalen Gegebenheiten, Prioritäten und Präferenzen formuliert hat, könnte die Wahrscheinlichkeit höher ausfallen, dass die nationalen Regierungen die in den NDCs eingegangenen Verpflichtungen auch tatsächlich weiterverfolgen und einhalten werden.

Für die große Mehrheit der Länder und den überwiegenden Teil des globalen BIP bedeutet die Existenz der NDCs, dass die Verlagerung von CO_2-Emissionen (das sogenannte *Carbon* Leakage) nun eine Konsequenz für das Empfängerland hat. Für den Empfänger ist solches Leakage nicht mehr nur ein willkommener Impuls, der ausländische Investitionen in die Binnenwirtschaft stimuliert und die Nachfrage nach heimischen Produkten erhöht. Stattdessen geht die Verlagerung von CO_2-Emissionennun auch zu Lasten des Empfängerlandes. So entsteht ein trade-off zwischen den Vorteilen der CO_2-Verlagerung (für die Empfängerländer) und ihren Nachteilen: da die zusätzlichen Emissionen es dem Empfängerland erschweren, seine eigenen NDC-Ziele zu erreichen, und so zusätzliche Minderungsanstrengungen erforderlich machen.

Im Rahmen des Kyoto-Protokolls bestand die Sorge, dass Carbon Leakage zu einem Nettoanstieg der Emissionen führen könnte. Diese Besorgnis ist gerechtfertigt für den Fall der Verlagerung von CO_2 aus Annex-I-Ländern in Nicht-Annex-I-Länder: Während die Annex I-Länder allesamt verbindliche Reduktionsziele hatten (sogenannte QELROs, d.h. quantifizierte Emissionsobergrenzen und Reduktionsziele), lag in Nicht-Annex-I-Ländern praktisch keine Begrenzung ihrer Emissionen vor. Somit hatte der Anstieg ihrer Emissionen durch Carbon Leakage für sie keine weiteren Folgen und erforderte folglich keine Reaktion. Mit dem Übergang vom Kyoto-System in die Welt des Pariser Abkommens hängt es jedoch von der tatsächlichen Konstellation der Ziele im "Herkunftsland" und im "Empfängerland" des Carbon Leakage ab, ob diese zu einem Nettoanstieg der Emissionen führt. Unter der Annahme, dass das Herkunftsland ein QELRO hat, sind die folgenden Konstellationen möglich:

- Wenn das Empfängerland auch über ein verbindliches und strenges QELRO verfügt (sei es als absolutes Emissionsziel oder als Reduktion unter eine festgelegte Basislinie), stehen die verlagerte industrielle Produktion und die damit verbundenen Emissionen in direktem Konflikt mit dem inländischen Klimaziel – daher muss jede Tonne Emissionssteigerung durch Carbon Leakage durch inländische Maßnahmen in anderen Sektoren ausgeglichen werden. Carbon Leakage führt daher nicht zu zusätzlichen Emissionen.
- Wenn das Empfängerland ein schwaches QELRO hat (z.B. mit einem absoluten Emissionsziel, das aber so hoch angesetzt ist, dass es die Emissionen nicht wirksam deckelt), führt Carbon Leakage de facto (wenn auch nicht de jure) zu einem Nettoanstieg der Emissionen.
- Wenn das Empfängerland ein intensitätsbasiertes Ziel hat, ist die Situation komplexer - aber da die verlagerten Aktivitäten besonders emissionsintensive Prozesse betreffen, während das Intensitätsziel typischerweise für die Gesamtwirtschaft formuliert ist, wird Carbon Leakage, die Zielerreichung im Empfängerland tendenziell unterlaufen und somit verstärkte Minderungsmaßnahmen in anderen Sektoren erforderlich machen, wodurch ein Teil der Emissionssteigerung durch Carbon Leakage wieder kompensiert wird.
- Eine ähnliche Situation kann eintreten, wenn das Empfängerland ein Ziel hat, die Emissionen unter die BAU zu senken, die BAU aber im Hinblick auf ein unerwartet starkes Wirtschaftswachstum aktualisiert – womöglich mit bedingt durch den „Wachstumsimpuls“ Carbon Leakage. In diesem Fall würde Carbon Leakage zu zusätzlichen Nettoemissionen führen - der zusätzliche Spielraum durch das BAU-Update sollte jedoch geringer sein als die verlagerten Emissionen.
- Wenn das Empfängerland sektorspezifische, technologiespezifische oder sogar installationsspezifische Ziele hat, könnte es zu einem potenziellen Konflikt kommen, sofern diese Ziele den Leakage-Sektor abdecken; dies stellt jedoch eine eher seltene Konstellation dar.

- Wenn das NDC keine oder nur thematisch nicht relevante Ziele enthält – wie Erhöhung der Resilienz, Anpassung an den Klimawandel oder den Ausbau erneuerbarer Energien – hätte die Carbon Leakage keine weiteren Folgen, und die verlagerten Emissionen würden tatsächlich per saldo zusätzliche Emissionen darstellen.

In den meisten Fällen wird das Empfängerland von Carbon Leakage daher mit einem trade-off konfrontiert sein: Verlagerte Emissionen erfordern zumindest teilweise einen Ausgleich durch verstärkte klimapolitische Anstrengungen des Empfängerlandes. Im Vergleich zur Situation zu Zeiten des Kyoto-Protokolls sind die geleakten Emissionen – und die damit verbundenen wirtschaftlichen Aktivitäten – für viele Drittländer nicht mehr "kostenlos": sie erfordern erhöhte Minderungsambitionen in anderen Sektoren oder aber ein erhöhtes Risiko, das gesetzte Ziel zu verfehlen.

Abgesehen von dieser Abwägung, mit der sich die politische Führung konfrontiert sieht, hat die bloße Existenz von NDCs auch eine wichtige Signalfunktion für private Anlagenbetreiber und Investoren. Dabei muss zwischen operativem und Investitionsleakage unterschieden werden. Laufende Produktionsentscheidungen auf Basis der vorhandenen Produktionskapazitäten (*Operational Leakage*) werden in der Regel mit begrenztem Zeithorizont getroffen. Sie werden daher nur die Kosten der aktuellen Klimapolitik berücksichtigen, unabhängig von den Zielen oder der Frage, ob das aktuelle klimapolitische Instrumentarium mit den Zielen vereinbar ist. Daher werden NDCs und die darin formulierten Ziele allein wenig Einfluss auf das operative Leakage haben – entscheidend dafür sind die tatsächlichen politischen Maßnahmen, ihre Ausgestaltung und ihr Ambitionsniveau. Dies stellt sich etwas anders dar für Investitionsleakage. Investitionen sind Entscheidungen mit einem längeren Zeithorizont und müssen damit auch Erwartungen an die künftige Politik berücksichtigen. Diese sollten sich aus den in den NDCs verankerten langfristigen Zielen ableiten lassen, oder ihnen entsprechen. Selbst wenn es eine Diskrepanz zwischen den erklärten Zielen und der aktuellen Ausgestaltung der Politik geben sollte, wären Investoren gut beraten, ihre Entscheidungen nicht nur auf der aktuellen Politik zu basieren, sondern auch zukünftige Anpassungen einzuplanen.

2.1.2 Literaturübersicht

Die im AP1.2 durchgeführte Arbeitet beinhaltet einen Literaturüberblick über den Stand der Technik (bis 2019) zu Risiko und Ausmaß von Carbon Leakage, die sich aus Unterschieden in der Klima- und Energiepolitik und insbesondere durch den EU-Emissionshandelssystem (EU ETS) ergeben. In der Literatur werden verschiedene Ansätze zur Bestimmung des Risikos und des Ausmaßes von Carbon Leakage verwendet, darunter einfache deskriptive Ansätze, Erhebungen, Modellierung und ökonometrische Analysen. Ex-ante-Analysen werden meist mit deskriptiven Methoden und Modellierungsansätzen durchgeführt, während für Ex-post-Analysen Umfragen, deskriptive Ansätze und ökonometrische Analysen verwendet werden.

Da es bereits mehrere allgemeine Literaturübersichten gibt, konzentrieren wir uns auf einen bestimmten Typ von Ansatz, nämlich auf ex-post-ökonometrische Studien, die Carbon Leakage-Effekte direkt abschätzen. Die Literaturübersicht dieser Art von Studien soll eine Grundlage für die Analyse in anderen Teilen des laufenden Forschungsprojekts "Wettbewerbsfähigkeit und Carbon Leakage-Risiko der europäischen Industrie" bieten.

Die Spezifizierungsmöglichkeiten für die direkte Abschätzung von Carbon Leakage sind vielfältig und die empirische Evidenz zeigt, dass die Ergebnisse und auch die statistische Qualität der Schätzungen je nach konkreter Ausgestaltung des Ansatzes, der verwendeten Daten und der abgedeckten geographischen und zeitlichen Horizonte stark variieren. Wir gehen daher näher auf die wichtigsten methodischen Unterschiede zwischen diesen Studien und ihre Auswirkungen auf die geschätzten Carbon-Leakage-Effekte ein.

Wir geben einen Überblick über zehn Studien. Wir stellen fest, dass sich die Studien hinsichtlich des verwendeten Carbon-Leakage-Indikators, ihres Analyselevels (Sektor- vs. Firmendaten), des Indikators, der verwendet wird, um die Stringenz der Politik widerzuspiegeln, und der sektoralen Differenzierung unterscheiden. Es zeigt sich, dass die von den Autoren getroffenen Entscheidungen über Methoden und Annahmen in engem Zusammenhang mit ihrer jeweiligen Forschungsfrage stehen und alle Vor- und Nachteile haben, die bei der Gestaltung der Forschung berücksichtigt werden sollten.

Während Ex-ante-Studien häufig das Auftreten von Carbon-Leakage-Effekten erwarten, widerlegen bestehende Ex-post-Studien einstimmig die Existenz bedeutender Carbon-Leakage-Effekte (zumindest kurzfristig). Studien, die sich speziell mit dem EU-Emissionshandelssystem befassen, finden keine signifikanten Effekte, während Studien, die Unterschiede in der allgemeinen Energie- und Klimapolitik berücksichtigen (oft durch einen Proxy approximiert), signifikante, aber geringe Auswirkungen auf die Verlagerung von CO2-Emissionen feststellen.

2.2 Arbeitspaket 2 – Analyse des Carbon Leakage-Risikos nach dem Paris-Abkommen

Seit der Einführung des EU-ETS wird darüber diskutiert, wie sich das Instrument auf die Wettbewerbsfähigkeit der europäischen Industrien gegenüber ihren ausländischen Konkurrenten auswirken würde. Das Thema Carbon Leakage - die Verlagerung von wirtschaftlichen Aktivitäten aufgrund unterschiedlicher Stringenz in der Klimapolitik - stand im Mittelpunkt der politischen Diskussionen. Infolgedessen hat die EU - wie auch alle anderen Länder mit Emissionshandelssystemen, die Industriesektoren abdecken - Mechanismen zum Schutz ihrer Industrien vor dem Risiko des Carbon Leakage.

Während viel Forschungsarbeit geleistet wurde hinsichtlich der Problematik von Carbon Leakage, in Bezug auf die Frage, wie man Carbon Leakge bewertet und wie man dem Carbon Leakage Risiko begegnet, hat die Frage nach dem tatsächlichen Unterschied in der Stringenz der Klimapolitik erstaunlich wenig Beachtung gefunden: Wie weit liegen Ehrgeiz und Stringenz der Klimapolitik zwischen dem Heimatland und Drittländern auseinander? Die politische Debatte - und auch die offizielle Bestimmung des Carbon Leakage-Risikos, wie sie von der Europäischen Kommission angewandt wird - basiert auf der vereinfachten Prämisse, dass die EU das einzige Land ist, das seiner heimischen Wirtschaft eine Kohlenstoffbeschränkung auferlegt. Diese Prämisse ignoriert jedoch die Tatsache, dass sich Länder auf der ganzen Welt als Unterzeichner des Pariser Abkommens verpflichtet haben, ihre Emissionen zu reduzieren oder zumindest das Wachstum der Emissionen zu verlangsamen. Eine Reihe von ihnen haben auch damit begonnen, zum Erreichen ihrer Ziele nationale Klimapolitiken zu erlassen –indem sie unter anderem ihren emissionsintensiven Industrien Beschränkungen auferlegen.

Die Arbeit in AP2 befasst sich mit dieser Lücke aus der Perspektive der Europäischen Union. Für die EU selbst und ihre 12 wichtigsten Handelspartner bewertet sie die Stringenz der klimabezogenen Vorschriften, die für Industrieanlagen gelten, mit besonderem Schwerpunkt auf acht Industriesektoren, die typischerweise als von Carbon Leakage bedroht gelten. Zu diesem Zweck verfolgt diese Studie einen relativ breiten (und damit umfassenderen) Ansatz zur Definition der effektiven Kohlenstoffbeschränkung, die für Industrieemittenten gilt. Neben dem Kohlenstoffpreis als dem offensichtlichsten und am klarsten erkennbaren klimapolitischen Instrument, das auf Industrieemittenten angewandt wird, werden auch benachbarte Bereiche der Regulierung betrachtet. Vor dem Hintergrund, dass nationale Klimapolitiken typischerweise eine breite Palette von Instrumenten einsetzen und dass Preisinstrumente nur ein Teil des Mixes sind, werden Energieeffizienz ebenso wie Luftqualitätsstandards untersucht, die ebenfalls auf Industrieanlagen anwendbar sind. Die verschiedenen Länder und ihre Volkswirtschaften unterscheiden sich darin, inwieweit sie für die Bepreisung von Kohlenstoff geeignet sind - wobei Faktoren wie der allgemeine wirtschaftliche und regulatorische Rahmen, die Ausstattung mit bereits bestehenden Klima- und Energiepolitiken, aber auch politische Präferenzen für eine bestimmte Art der Regulierung berücksichtigt werden. Auch wenn Klimaschutz, Energieeinsparung und Luftqualität separate politische Ziele sind, unterscheiden die politischen Instrumente, die zur Erreichung dieser Ziele eingesetzt werden, nicht immer klar, welches Ziel sie erreichen sollen. Im Gegenteil: Die Fähigkeit, mehrere Ziele gleichzeitig zu erreichen - als Synergien oder Co-Benefits bezeichnet - kann sogar ein starkes politisches Argument für Klimaschutzmaßnahmen sein. Inwieweit die Regulierung primär als klimabezogen (mit Energieeffizienz und Luftqualität als Co-Benefits) oder als primär luftqualitäts- oder energieeffizienzbezogen - mit Klimaschutz als Co-Benefit - angesehen wird, ist von Land zu Land unterschiedlich und kann sogar in verschiedenen Kontexten in ein und demselben Land unterschiedlich dargestellt werden.

Eine besondere Herausforderung, die mit diesem breit angelegten Ansatz einhergeht, ist die Notwendigkeit, die Stringenz der Regulierung über die verschiedenen Kategorien hinweg zu aggregieren. Um die Frage zu beantworten, die im Mittelpunkt der Untersuchung steht - wie stringent die klimabezogenen Politiken der EU im Vergleich zu denen ihrer wichtigsten Handelspartner sind - muss die Stringenz der effektiven Kohlenstoffbeschränkungen in einer einzigen Metrik ausgedrückt werden. Dies würde idealerweise in monetärer Hinsicht geschehen, indem man die Compliance-Kosten vergleicht, die verschiedene Arten von Regulierung den regulierten Einheiten auferlegen, die dann leicht mit dem Kohlenstoffpreis kombiniert werden könnten. So ließe sich eine monetäre Schätzung der Compliance-Kosten erhalten. Doch dies für 13 Länder, acht Industriesektoren und drei klimabezogene Politikbereiche zu tun, wäre eine Herkulesaufgabe, die die dafür zur Verfügung stehenden Ressourcen bei weitem übersteigen würde. Stattdessen stellt die vorliegende Studie einen klaren und transparenten Ansatz vor, bei dem die relevanten Kategorien (Kohlenstoffpreise, Energieeffizienzstandards und Luftqualitätsstandards) zunächst getrennt bewertet und mit einem vordefinierten Gewicht kombiniert werden, um eine Gesamtbewertung der Stringenz der klimabezogenen Politiken zu erhalten. Dies wird für drei Ansätze mit unterschiedlicher Gewichtung oder sich anderweitig ändernden Schlüsselannahmen dargestellt, um zu testen, wie robust die Ergebnisse gegenüber solchen Veränderungen sind.

Tabelle gibt einen Überblick über die Ergebnisse der 13 Länder in den drei Kategorien, den Indikator für die Qualität der Durchsetzung und die Ergebnisse von drei unterschiedlichen Aggregationsmöglichkeiten bezüglich der Kategorien: Bei der ersten Möglichkeit werden die drei Kategorien auf der Grundlage der geschätzten Kosten der Einhaltung der Vorschriften für die EU gewichtet. Bei Anwendung dieser Metrik erhält der effektive Kohlenstoffpreis ein Gewicht von 80%, während die Komponenten Energieeffizienz und Luftqualität jeweils mit einem Faktor von 10% gewichtet werden. Bei der zweiten Option werden die drei Kategorien aggregiert, wobei jede von ihnen gleich gewichtet wird. In einem dritten Schritt werden die Gewichte wie bei der ersten Option beibehalten (d.h. auf der Grundlage der geschätzten EU-Einhaltungskosten), aber stattdessen werden die Ergebnisse in allen drei Kategorien mit einem Korrekturfaktor kombiniert, der Unterschiede in der Durchsetzung der jeweiligen Vorschriften kontrollieren soll.

Tabelle 2: Überblick über Ländererergebnisse

Scores Country	Effective Carbon Prices Norm'sd Score	Energy Efficiency Norm'sd Score	Air Quality Norm'sd Score	Enforcement Score	Overall Score (80/10/10) Rank	Overall Score (80/10/10) Norm'sd Score	Overall Score (80/10/10) Score	Overall Score w equal weights Rank	Overall Score w equal weights Norm'sd Score	Overall Score w equal weights Score	Overall Score (80/10/10) with Enforcement Rank	Overall Score (80/10/10) with enforcement Norm'sd Score	Overall Score (80/10/10) with enforcement Score
Norway	10	4.91	9.07	83.08	1	10	9,40	1	10	7.99	1	10	7.81
Korea	6.55	8.05	6.3	70.46	2	7,10	6,67	2	8.72	6.97	2	6.02	4.7
Switzerland	4.53	5.1	10	80.46	3	5,46	5,13	3	8.19	6.54	3	5.29	4.13
EU	4.5	8	5.71	70.22	4	5,29	4,97	5	7.6	6.07	4	4.47	3.49
Japan	2.31	9.34	6.81	74.34	5	3,69	3,46	4	7.7	6.15	5	3.3	2.58
India	1.54	7.04	7.35	50.88	6	2,84	2,67	7	6.64	5.31	6	1.74	1.36
USA	0.03	10	6.13	76.77	7	1,74	1,64	6	6.74	5.39	7	1.61	1.26
China	0.1	9.14	6.15	52.15	8	1,72	1,61	8	6.42	5.13	9	1.08	0.84
Turkey	0.63	7.17	2.59	55.07	9	1,57	1,48	10	4.33	3.46	10	1.04	0.81
Brazil	0.04	5.02	6.27	45.73	10	1,24	1,16	9	4.73	3.78	12	0.68	0.53
Singapore	0.33	3.35	4.85	84.79	11	1,15	1,08	12	3.56	2.84	8	1.17	0.92
Russia	0.18	2.88	5.99	51.75	12	1,10	1,03	11	3.77	3.02	11	0.68	0.53
Saudi Arabia	0	3.67	4.66	55.75	13	0,89	0,83	13	3.48	2.78	13	0.59	0.46

Source: authors' own calculations (Ecologic Institute)

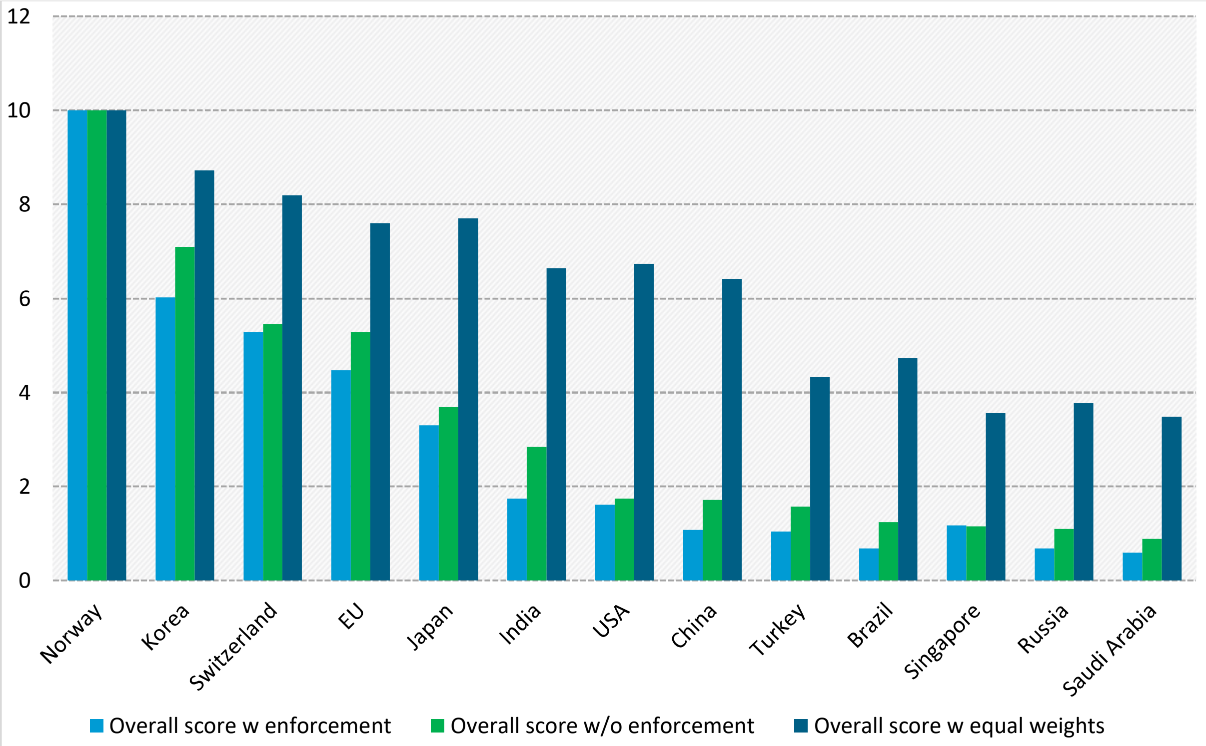
Im Allgemeinen verändern sowohl die unterschiedliche Wahl der Gewichte als auch die Einbeziehung eines Durchsetzungsfaktors die Rangfolge der Länder im Vergleich zur ursprünglichen Option mit 80-10-10 Gewichten (und ohne Korrektur für die unterschiedliche Durchsetzung) nicht wesentlich. In allen Fällen bilden Norwegen, die Schweiz und Korea die Spitzengruppe der Länder. Es folgen die EU und Japan - die je nach den getroffenen Annahmen entweder fast gleich oder mit einem etwas höheren Wert für die EU abschneiden. Im mittleren Bereich liegen die USA, Indien und China. Die unterste Gruppe der Länder mit der am wenigsten ehrgeizigen Klimapolitik für die Industrie schließlich bilden Singapur, die Türkei, Brasilien, Russland und Saudi-Arabien. Singapur ist der einzige Fall, in dem die Wahl der Annahmen einen starken Einfluss auf die Rangfolge hat: In der um Unterschiede in der Durchsetzung korrigierten Version rückt Singapur dank seiner wesentlich strengeren Durchsetzung deutlich von Platz 11 auf Platz 8 vor. In diesem Sinne sind die Ergebnisse robust gegenüber Änderungen der Schlüsselannahmen.

Was sich jedoch zwischen den verschiedenen Arten der Aggregation der Ergebnisse deutlich ändert, sind die Abstände zwischen den Ländern, wie Abbildung 1 unten veranschaulicht. Die Gewichtung der Kriterien in der ersten Option legt einen besonders hohen Schwerpunkt auf den effektiven Kohlenstoffpreis. Daher erhält eine große Anzahl von Ländern, die keinen oder nur einen sehr niedrigen Kohlenstoffpreis haben, auch eine niedrige Gesamtpunktzahl. Dies bedeutet auch, dass es kaum einen Mittelbereich gibt: Norwegen, Korea und die Schweiz nehmen die Spitzenplätze ein, gefolgt von der EU. Japan (und Indien – es sei denn, es gilt der Durchsetzungskorrekturfaktor) liegen noch relativ nahe beieinander. Der Rest der Welt - darunter die wirtschaftlichen Schwergewichte China und die USA - liegen weit zurück und erreichen weniger als ein Drittel des EU-Wertes.

Dieses Bild ändert sich deutlich, wenn die drei Kategorien bei der Aggregation gleich gewichtet werden. In diesem Fall gibt es einen ausgeprägten Mittelbereich von Ländern (Indien, USA und China), die mit Werten von 84-89% des EU-Wertes nur geringfügig weniger ehrgeizig sind als die EU. Selbst die Nachzügler (mit der Türkei, Brasilien, Singapur, Russland und Saudi-Arabien) schneiden bei gleicher Gewichtung der Kategorien deutlich besser ab. Der Grund für diese Divergenz liegt ganz einfach darin, dass die meisten Länder, die keinen Kohlenstoffpreis anwenden, bei den Luftqualitätsstandards, vor allem aber bei den Energieeffizienzvorschriften relativ gut abschneiden (wo die USA, China, die Türkei und Indien relativ gut abschneiden). Im Standardfall mit einer Gewichtung von 80-10-10 wirken sich diese Ergebnisse jedoch kaum auf die Gesamtpunktzahl aus.

Für die Bewertung des Carbon-Leakage-Risikos ist ein eindeutiges Ergebnis, dass es eine Untergruppe von EU-Handelspartnern gibt, für die ein Carbon-Leakage-Risiko eindeutig nicht gegeben ist. Auf der Grundlage der in dieser Studie angewandten Methodik und unabhängig von den Annahmen, die für die Gewichtung oder die Korrektur der Durchsetzung gewählt wurden, ist das Ergebnis robust, dass das Anspruchsniveau von Norwegen, der Schweiz und Korea über dem der EU liegt.

Abbildung 1: Überblick über die Gesamtpunktzahlen der analysierten Länder unter Verwendung verschiedener Aggregationsmethoden



Source: authors' own calculations (Ecologic Institute)

Es ist auch klar, dass der Ehrgeiz der klimabezogenen Regelungen der Türkei, Brasiliens, Singapurs, Russlands und Saudi-Arabiens deutlich unter dem der EU liegt - je nach angewandter Metrik und gewählten Annahmen ist der Ehrgeiz der klimabezogenen Regelungen höchstens halb so hoch wie der der EU, in anderen Fällen niedriger.

Schwieriger zu ermitteln ist der mittlere Teil der EU-Handelspartner, bei dem es darauf ankommt, wie die verschiedenen Kategorien bei der Aggregation gewichtet werden. Wenn der Kohlenstoffpreis ein höheres Gewicht erhält, ist das Gesamtziel klimabezogener Regulierungen in den USA, Indien und China deutlich niedriger als das der EU; je nachdem, ob die Ergebnisse für die Durchsetzung korrigiert werden, liegen die Werte zwischen 24% und 54%. Bei gleicher Gewichtung der Kategorien schrumpft dieser Unterschied jedoch deutlich - und die drei Länder erreichen Scores von 84% bis 89% des EU-Wertes, also ein vergleichbares Anspruchsniveau. Die Bewertung dieses mittleren Abschnitts ist besonders relevant, da er die Schwergewichte unter den Außenhandelspartnern der EU umfasst. Zwischen 13,5% und 43,7% des EU-Außenhandels entfallen auf die Länder des mittleren Abschnitts – USA, Indien und China. Im Gegensatz dazu liegt der Anteil der drei führenden Länder - Norwegen, Schweiz und Korea - zwischen 6 % und 15,8 % des EU-Außenhandels.

Der Bericht dieses Arbeitspakets ist wie folgt aufgebaut: In Kapitel 2 werden die Handelsprofile des EU-Außenhandels für acht ausgewählte emissionsintensive Rohstoffe dargestellt und auf dieser Grundlage eine Auswahl der 12 wichtigsten Handelspartner der EU vorgestellt, die anschließend analysiert werden. Kapitel 3 stellt die Methodik für die Bewertung der Anstrengungen der verschiedenen Länder vor, d.h. die Hauptkategorien, die wichtigsten Datenquellen und Indikatoren, die zur Bewertung der Leistung in diesen Kategorien verwendet werden, sowie die Methode für deren Aggregation. Kapitel 4 gibt einen zusammenfassenden Überblick über die klimapolitische Landschaft in der EU selbst und ihren 12 wichtigsten

Handelspartnerländern. In Kapitel 5 wird die Leistung der 12 Länder und der EU selbst für die drei Hauptkategorien (effektiver Kohlenstoffpreis, Energieeffizienzpolitik und Luftqualitätsstandards) bewertet und anschließend aggregiert, um eine Gesamtpunktzahl sowie Sensitivitätsanalysen zur Bewertung der Auswirkungen von Schlüsselannahmen auf das Ergebnis der Analyse zu erhalten. Kapitel 6 beinhaltet die Schlussfolgerungen. In diesem Zusammenhang sei darauf hingewiesen, dass die Bewertung in Kapitel 5 auf verschiedene Datensätze und Übersichtspublikationen zurückgreift, die es ermöglichen, für die Bewertung auf eine einzige, innerlich konsistente Quelle zurückzugreifen. Die Länderbeschreibungen in Kapitel 4 dienen der Veranschaulichung und detaillierten Betrachtung der Bemühungen der verschiedenen Länder, gehen aber im Allgemeinen nicht in die Bewertung ein. Einige wenige Ausnahmen bestehen, z.B. wenn einzelne Länder bei länderübergreifenden Bewertungen fehlten, wurden diese Lücken mit Informationen aus den Analysen auf nationaler Ebene gefüllt.

2.3 Arbeitspaket 3 – Wirkung der Zuteilungsregeln in der 3. Handelsperiode auf das Carbon Leakage-Risiko

Die Befürchtung, dass ungleiche Kohlenstoffpreise negative Auswirkungen auf die Wettbewerbsfähigkeit der EU-Industrien haben, ist seit Beginn des EU-ETS im Jahr 2005 ein beherrschendes Thema. Nachteilige Auswirkungen ungleicher Kohlenstoffpreise würden sich in Veränderungen der Marktanteile der EU-Industrien auf den globalen Märkten oder auf den heimischen EU-Märkten niederschlagen. Eine solche Veränderung der Marktanteile wird mit einer Veränderung der Handelsstrukturen einhergehen, bei der die Kohlenstoffpreise der EU die Importe aus Nicht-EU-Ländern stimulieren und die Exporte in diese Länder reduzieren würden, sofern diese Produzenten nicht mit einer vergleichbaren Kohlenstoffpolitik konfrontiert werden.

Die Auswirkungen ungleicher Kohlenstoffpreise auf die Handelsstruktur waren Gegenstand theoretischer und empirischer Forschungsarbeiten. In der empirischen Literatur wurden bisher weitestgehend vereinfachende ökonometrische Ansätze verwendet (eine Analyse der Situation vor und nach der Einführung der Kohlenstoffpreise) oder die Auswirkungen von Energiepreisunterschieden in verallgemeinerten Handelsmodellen untersucht. Relativ wenige Bemühungen haben versucht, die Auswirkungen von Kohlenstoffpreisen auf den Handel direkt abzuschätzen.

AP3 des Projekts hat versucht, die Lücke zu füllen, indem wir den Einfluss der Kohlenstoffpreise (sowohl als Kohlenstoffpreise als auch als Energiepreisdifferenzen) direkt in komplizierten Handelsmodellen untersucht haben. Um den Fokus der Forschung zu begrenzen (und die Datenbestände überschaubar zu halten), haben wir uns auf einige wenige ausgewählte energieintensive Industrien und eine begrenzte Anzahl von Handelsbeziehungen konzentriert. Die Daten in unserer Arbeit bestehen aus den Handelsbeziehungen zwischen den 28 einzelnen EU27-MS + UK (EU ETS bis 2020) und einer Gruppe von 7 Ländern (Schweiz, China, Indien, Südkorea, Russland, Türkei, Vereinigte Staaten von Amerika) für die 15 energieintensivsten Sektoren im EU-ETS (definiert als NACE4-Stellen-Ebene). Die einbezogenen Sektoren waren: Roheisen, Stahl und Ferrolegierungen; Raffinierte Erdölerzeugnisse; Zement; sonstige organische Grundchemikalien; Düngemittel und Stickstoffverbindungen; Kalk und Gips; Papier und Pappe; Aluminium; sonstige anorganische Grundchemikalien; Hohlglas; Zucker; Industriegase; Kokereierzeugnisse; Ziegel, Fliesen und Bauprodukte aus gebranntem Ton; Flachglas. Für die empirische Analyse wurden jährliche Daten für den Zeitraum 2000-2016 verwendet.

Im Vergleich zu anderen Ansätzen in der Literatur zielte unsere Studie darauf ab, das Beste aus zwei Methoden zu kombinieren:

(i) die Fülle der Gravitationshandelsmodelle, die zur Untersuchung der Auswirkungen von Kostenunterschieden auf den Handel verwendet wurden, wie z.B. in dem einflussreichen Papier von Sato und Dechezleprêtre (2015), welche die Auswirkungen der Energiepreise auf den Handel auf der zweistelligen NACE-Ebene geschätzt haben;

(ii) die viel differenziertere statistische Grundlage der Ex-post-Analyse, wie z.B. Ecorys/Öko-Institut (2014), die ETS-Daten zur Bestimmung der möglichen Auswirkungen von ETS-Kosten auf das Handelsverhalten verwendete.

Die Ergebnisse dieser Bemühungen waren jedoch enttäuschend. Wir stellten fest, dass die Modelle von Sato und Dechezleprêtre unsere Situation nicht richtig beschrieben: Die meisten Gravitationsvariablen waren nicht signifikant, was Zweifel an der Angemessenheit dieser Modelle aufkommen ließ. Ein prägnantes Handelsmodell führte zu großen Auswirkungen ungleicher Kohlenstoff- oder Energiepreise auf den Handel, insbesondere auf lange Sicht. Die Auswirkungen würden eine Armington-Elastizität (Preiselastizität des Exports) implizieren, die um einen Faktor 4 höher ist als in der Literatur und in makroökonomischen Modellen üblich. In Verbindung mit der geringen Erklärungskraft der Modelle haben wir Zweifel an der Angemessenheit dieser Ergebnisse. Weitere methodische Verfeinerungen wurden im Bereich der alternativen Modellspezifikationen angestrebt. Diese alternativen Modellspezifikationen lieferten jedoch keine bessere Erklärung für die Auswirkungen ungleicher Kohlenstoffpreise auf den Handel.

Alles in allem ziehen wir aus unserer Arbeit die folgenden Schlussfolgerungen:

Bei allen unseren Modellierungsbemühungen wurden jährliche Daten verwendet, da diese die Grundlage unserer Datenerhebung mit dem jährlichen Energiepreisindex aus dem Papier von Sato et al. (2019) bildeten. Unsere Regressionen zeigen jedoch, dass diese jährlichen Daten wahrscheinlich zu grob sind, um ein realistisches Bild der Auswirkungen der Kohlenstoffpreise auf den Handel zu liefern. Zeitverschiebungsmodelle lieferten keine realistischen Ergebnisse, die darauf hindeuten, dass eine Zeitverschiebung von einem Jahr für die Prozesse, die den (potenziellen) Auswirkungen der Kohlenstoffpreise auf den Handel zugrunde liegen, zu lang ist.

Unsere Ergebnisse liefern einige Anhaltspunkte dafür, dass die Auswirkungen ungleicher Kohlenstoffpreise auf den Handel viel größer sein können, als in früheren akademischen Studien angegeben wurde, wenn man sich nur auf die energieintensivsten Sektoren konzentriert. Angesichts der relativ schlechten Qualität unserer Modelle in Bezug auf die Erklärungskraft, die Stabilität der Schätzer und die Plausibilität der langfristigen Ergebnisse können wir dies jedoch nicht mit Sicherheit sagen. Die tatsächlichen Auswirkungen ungleicher Kohlenstoffpreise auf die Wettbewerbsposition von Unternehmen sollten daher in zukünftigen Arbeiten stärker untersucht werden.

Für künftige Arbeiten würden wir in erster Linie empfehlen, die Verwendung physischer Indikatoren für den Handel in Betracht zu ziehen. Die vorliegende Arbeit hat, wie alle anderen uns bekannten Bemühungen, monetäre Indikatoren des Handels (Werte der Importe und Exporte) verwendet. Die direkte Auswirkung eines Preisanstiegs bei Kohlenstoff auf die monetären Indikatoren ist jedoch nicht eindeutig, da der Preisanstieg einerseits den Wert des Handels erhöht, da der Kohlenstoffpreis in den Kosten weitergegeben wird. Andererseits wird aber das Handelsvolumen durch die Armington-Elastizitäten verringert. Da diese beiden Auswirkungen einander entgegenwirken, kann die Nettoauswirkung klein sein - zu klein, um in unseren Handelsmodellen erkennbar zu sein. Dies könnte ebenso gut die fehlenden Ergebnisse unserer Untersuchungen erklären. Zusätzlich würden wir empfehlen, monatliche Daten zu verwenden, da diese möglicherweise besser in der Lage sind, die Dynamik der Kohlenstoffpreisgestaltung über das Jahr hinweg zu erfassen.

2.4 Arbeitspaket 4 – Wirkung eines angepassten Indikators für die Handelsintensität

Mit dem 2003 verabschiedeten "Fit-for-55"-Klimapaket wird das Ambitionsniveau des EU-Treibhausgas-Reduktionsziels für 2030 auf mindestens 55 % unter das Niveau von 1990 angehoben. Dies stellt einen erheblichen Anstieg gegenüber dem vorherigen Ziel (minus 40 %) dar. Da das EU-Emissionshandelssystem (ETS) das Schlüsselinstrument zur Verringerung der Treibhausgasemissionen aus dem Energie- und Industriesektor ist, gibt es Bedenken, dass die höhere Ambition zu höheren CO_2-Kosten führen wird, was wiederum die internationale Wettbewerbsfähigkeit europäischer Unternehmen beeinträchtigen und zu einer Verlagerung von CO_2-Emissionen führen könnte.

Zur Begrenzung des Carbon-Leakage-Risikos wurde im Rahmen der Überarbeitung der Phase IV des EU-ETS vereinbart, der Industrie weiterhin kostenlose Zertifikate zur Verfügung zu stellen, wobei die Sektoren, bei denen ein Carbon-Leakage-Risiko besteht, 100 % ihrer Zuteilung bis zum entsprechenden Richtwert kostenlos erhalten. Die Carbon-Leakage-Liste für 2021-2030 definiert „erhebliches Risiko“ auf der Grundlage des Carbon-Leakage-Indikatorwerts jedes Sektors (d. h. berechnet aus ihrer Emissionsintensität multipliziert mit ihrer Handelsintensität). Wenn ein Sektor einen Carbon-Leakage-Indikatorwert über einem Schwellenwert von 0,2 aufweist, gilt er als „erhebliches Risiko“ für Carbon-Leakage und wird in die Liste aufgenommen. Basierend auf dieser Bewertung der ersten Stufe wurden insgesamt 44 Sektoren und Teilsektoren auf der 4-stelligen NACE-Ebene in die Carbon-Leakage-Liste für 2021-2030 aufgenommen (Europäische Kommission 2018).

Die Carbon-Leakage-Liste für 2021-2030 berücksichtigt jedoch nicht die vergleichbaren internationalen Anstrengungen zur Bekämpfung des Klimawandels. Der Zweck dieser Studie bestand daher darin, einen alternativen Carbon-Leakage-Indikatorwert für jeden der Sektoren und Teilsektoren auf der 4-stelligen Ebene der NACE zu berechnen, indem der Handelsintensitätsindikatorwert angepasst wird, um die Klimapolitik von Ländern außerhalb des EU-ETS widerzuspiegeln (d.h. durch Abzug des EU-ETS-bezogenen Handels mit einer Auswahl von Nicht-EU-ETS-Ländern, wenn diese vergleichbare Klimapolitiken wie die EU von der Berechnung der Handelsintensität übernommen haben).

Die Studie zeigte, dass selbst wenn die Werte der Handelsintensitätsindikatoren erheblich reduziert wurden, um die sehr optimistische Annahme widerzuspiegeln, dass die in dieser Studie ausgewählten Nicht-EU-ETS-Länder eine vollständig vergleichbare Klimapolitik wie die EU haben (d.h. Abzug von 100 % des EU-ETS-bezogenen Handels ausgewählter Nicht-EU-ETS-Ländern bei der Berechnung der Handelsintensität) würden viele Sektoren und Teilsektoren (die einen großen Anteil an den EU-ETS-Emissionen ausmachen) weiterhin für eine Carbon-Leakage-Förderung in Frage kommen. Die hohen Indikatorwerte für die Emissionsintensität für viele Sektoren und Teilsektoren (die in dieser Bewertung auf dem Referenzniveau festgelegt wurden) stellen sicher, dass der Carbon-Leakage-Indikator insgesamt über dem Schwellenwert von 0,2 bleibt. Da der Emissionsintensitätsindikator auf historischen Durchschnittswerten für 2013-15 basiert und im Zeitraum 2021-30 möglicherweise nicht aktualisiert wird, stellt sich die Frage, ob der Emissionsintensitätsindikator das Risiko der Verlagerung von CO2-Emissionen eines Sektors oder Teilsektors wirklich widerspiegelt, da er die Bemühungen um eine Dekarbonisierung in den kommenden zehn Jahren nicht berücksichtigt. Daher könnte eine Anpassung der Carbon-Leakage-Berechnung, d.h. etwa eine Erhöhung des Schwellenwerts des Carbon-Leakage-Indikators zur Bestimmung des Carbon-Leakage-Risikos, eine weiter zu prüfende Option sein, um auf die gestiegenen klimapolitischen Ambitionen der Nicht-EU-EHS-Länder zu reagieren.

Work package 1 – Level of knowledge, definitions and operationalization

3 Carbon Leakage Risks in the Post-Paris World

The result of the work package 1.1 "Carbon Leakage Risks in the Post-Paris World" was published in the report 43/2019 of the series "Climate Change" of the Federal Environment Agency. It is available on the homepage of the Federal Environment Agency:

Görlach, B. und Zelljadt, E.: Carbon Leakage Risks in the Post-Paris World, Climate Change 43/2019, Umweltbundesamt, Dessau-Roßlau. Verfügbar unter: https://www.umweltbundesamt.de/publikationen/carbon-leakage-risks-in-the-post-paris-world, last retrieved on 26.11.2020

4 Literature Review

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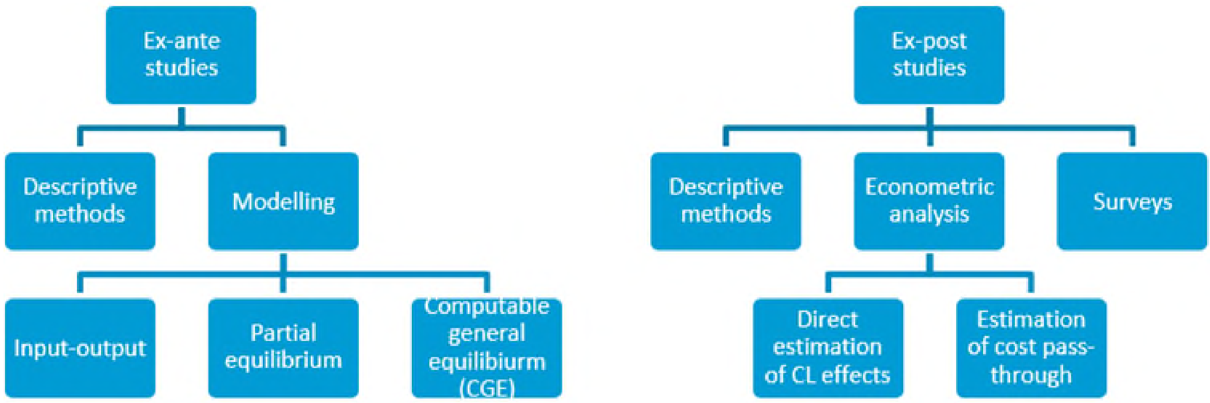
4.1 Introduction

Various approaches are used in the literature to determine the risk and extent of carbon leakage, including simple descriptive approaches, surveys, modelling and econometric analyses. Ex-ante analyses are most often carried out using descriptive methods and modelling approaches, while ex-post analyses use surveys, descriptive approaches and econometric analyses.

The best-known indicator-based on an ex-ante approach is the indicator used to define sectors and sub-sectors at risk of carbon leakage in the ETS Directive (European Union (EU) 2018). It uses trade intensity and emission intensity to proxy the risk of carbon leakage. It is assumed that industries at risk of suffering competitive disadvantages are those that manufacture products which are traded internationally to a large extent or industries for which the additional costs due to the EU Emissions Trading System (EU ETS) are substantial. The approach is simple and transparent, but disregards many other, potentially important, factors and it has been questioned to what extent it adequately approximates the risk of carbon leakage (cf. Carbon Trust and Climate Strategies 2010; Dröge and Cooper 2010; Juergens et al. 2013).

The main methods applied in ex-ante modelling are input-output approaches, partial equilibrium models and computable general equilibrium (CGE) models (Carbone and Rivers 2017; Vivid Economics and Ecofys 2014). Which of these methods are best suited for the research setting at hand depends, amongst others, on the policy instrument to be studied, geographical scope and assumptions about market failures and terms-of-trade effects (Carbone and Rivers 2017).

Figure 2: Overview of main analysis options for ex-ante and ex-post investigation of carbon leakage risk



Source: Own illustration compiled by the authors (Öko-Institut)

The main methods applied in ex-post analysis, include surveys (Kenber et al. 2009; Martin et al. 2013; Martin et al. 2014b; Martin et al. 2014a), sometimes combined with descriptive analysis (Ecorys et al. 2013) and econometric approaches, where time-series data covering different sectors and countries are analysed in order to gain insights into carbon leakage that has already occurred.

Studies using econometric approaches can be differentiated by the exact research question they try to answer: i) some studies analyse carbon leakage directly by looking at effects on trade flows, production, profit margins, employment or innovation (Aldy and Pizer 2015; Naegele and Zaklan 2019; Sato and Dechezleprêtre 2015); ii) other studies place their focus on whether the EU ETS-related CO_2 costs can be passed through into product prices and how this affects the competitiveness of EU industries with possible risks for carbon leakage (Alexeeva-Talebi 2010, 2011; CE Delft and Öko-Institut 2015).

The main analysis options for ex-ante and ex-post investigation of carbon leakage risk are summarised in Figure 2.

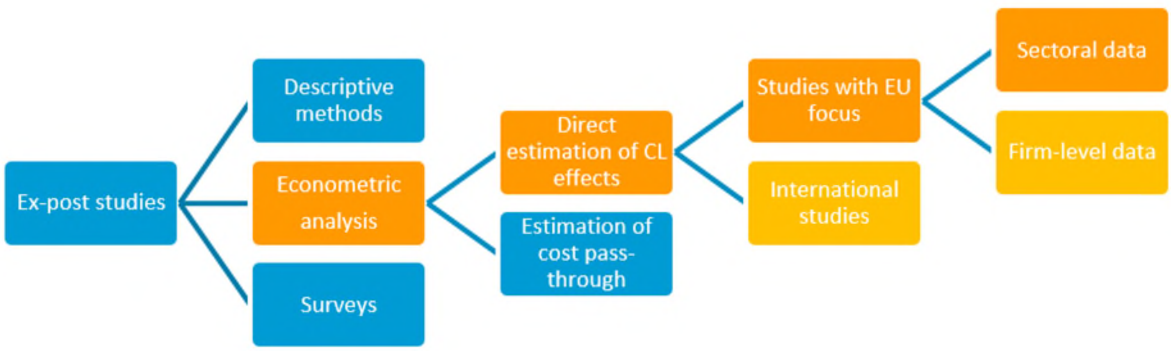
Several general reviews of the literature already exist. For two recent and exhaustive reviews we refer the reader to Dechezleprêtre and Sato (2017) for ex-post empirical analyses and Carbone and Rivers (2017) for ex-ante modelling. Thus, instead of summarising the literature once more, we will focus on a specific type of approach, namely ex-post econometric studies directly estimating carbon leakage effects (Section 4.2). This choice of limiting the review to this type of studies is to provide a basis for the analysis in later work packages within the research project "Wettbewerbsfähigkeit und Carbon Leakage-Risiko der europäischen Industrie".

Specification options for the direct estimation of carbon leakage are diverse and the empirical evidence shows that results and also the statistical quality of estimates vary greatly depending on the concrete design of the approach, the data used and geographical and temporal horizons covered. We will, therefore, further zoom in on the main methodological differences between those studies and their repercussions for the estimated carbon leakage effects (Section 4.3). In a final section (4.4) we discuss and conclude.

4.2 Approach and studies investigated

This section details the list of studies investigated in the literature review. To this end, the relevant studies are broadly grouped according to their geographical scope (EU focus vs. international studies) and their analysis level, i.e. at the sector or firm level. As Figure 3 shows besides focussing on econometric studies directly estimating carbon leakage effects, a stronger focus is placed on studies looking at the EU and using sectoral data, while one international study (i.e. using data from the U.S.) and one study using firm-level data are discussed in more detail and also included in the analysis matrix.

Figure 3: Main focus of the literature review



Source: Own illustration compiled by the authors (Öko-Institut)

Applying this focus, ten ex-post studies that directly estimate carbon leakage effects are selected for an in-depth review, while the remaining studies are considered as part of a more general review (Table 1).

Table 1: List of studies investigated

Author / year	Title	Geographical focus	Analysis level	In-depth review	General review
Naegele and Zaklan (2019)	Does the EU ETS Cause Carbon Leakage in European Manufacturing?	EU	Sectoral	x	
Branger et al. (2016)	Carbon Leakage and Competitiveness of Cement and Steel Industries Under the EU ETS: Much Ado About Nothing	EU	Sectoral	x	
Sato and Dechezleprêtre (2015)	Asymmetric industrial energy prices and international trade	EU	Sectoral	x	
Ifo-Institut (2013)	Entwicklung eines Maßes für die Intensität des internationalen Wettbewerbs auf Unternehmens- oder Sektorebene	EU	Sectoral	x	
Costantini and Mazzanti (2012)	On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports	EU	Sectoral	x	
Sartor (2013)	Carbon Leakage in the Primary Aluminium Sector: What evidence after 6 ½ years of the EU ETS?	EU	Sectoral	x	
Dechezleprêtre et al. (2018)	The joint impact of the European Union emissions trading system on carbon emissions and economic performance	EU	Firm-level		x
Calel and Dechezleprêtre (2016)	Environmental Policy and Directed Technological Change	EU	Firm-level		x
Koch and Basse Mama (2019)	European Climate Policy and Industrial Relocation: Evidence from German Multinational Firms	EU	Firm-level	x	
Petrick and Wagner (2014)	The Impact of Carbon Trading on Industry: Evidence from German Manufacturing Firms	EU	Firm-level		x
Abrell et al. (2011)	Assessing the impact of the EU ETS using firm level data	EU	Firm-level		x
Commins et al. (2011)	Climate Policy & Corporate Behavior	EU	Firm-level		x
Fowlie et al. (2016)	Measuring Leakage Risk	U.S.	Firm-level	x	
Aldy and Pizer (2015)	The competitiveness impacts of climate change mitigation policies	U.S.	Sectoral		x

Author / year	Title	Geographical focus	Analysis level	In-depth review	General review
Garsous and Kozluk (2017)	Foreign Direct Investment and The Pollution Haven Hypothesis - Evidence from Listed Firms	Internat.	Firm-level		x
Dechezleprêtre and Sato (2017)	The Impacts of Environmental Regulations on Competitiveness	Review article		x	
Carbone and Rivers (2017)	The Impacts of Unilateral Climate Policy on Competitiveness: Evidence from Computable General Equilibrium Models	Review article		x	

Source: compiled by the authors (Öko-Institut)

A list of guiding questions is developed to structure the in-depth review paying special attention to methodological approach and data employed:

- What is the main research question?
- Which time horizon is considered?
- Which countries and sectors are analysed?
- Are differentiated results derived for individual sectors or groups of sectors?
- What is the carbon leakage indicator used?
- Which estimation method is employed?
- How is the carbon leakage indicator operationalised (i.e. what is the endogenous variable)?
- Which explanatory (exogenous) variables are used?
- Which data series are used and which data sources do they come from?
- What are the estimated carbon leakage effects?
- Limitations

The full review matrix is available in the Annex.

4.3 Methodological differences

4.3.1 Main methodological differences between studies

The main methodological differences between the studies considered are summarised in Table 2. A range of carbon leakage indicators is used in the literature. The most widely used indicators are related to trade or trade flows, but also output, employment and investment are considered. The choice of indicator also depends on the type of carbon leakage to be studied, i.e. production vs. investment leakage. Studies also differ regarding their level of analysis. This is mainly defined by the data used for analysis and whether this data is at the firm or sector level (or, very rarely, at the country level).

The indicator of policy stringency can take many different forms and consist of a simple yes/no argument, differences in carbon or energy prices between different countries and sectors or, for example, energy or environmental tax revenues. The choice of the stringency indicator is closely linked to the exact focus of the analysis, in particular whether climate policy in general or the EU ETS as a specific instrument is considered.

Finally, studies differ in the way in which results can be interpreted for different sectors. Sometimes results are specifically derived for individual sectors or groups of sectors (e.g. energy-intensive vs. non-energy-intensive), sometimes there is an implicit differentiation through, for example, other exogenous variables, such as transportation costs.

Table 2: Main methodological differences between studies

	Available alternatives
Carbon leakage indicator	Domestic view: (net) import or export, output, employment, investment International view: Bilateral flows
Analysis level	Firm, sector, (country) level
Indicator of policy stringency	Dummy variable (existence of / inclusion in climate policy: yes/no) Focus on the EU ETS: carbon prices, carbon costs (direct and indirect, taking into account free allocation and other compensation) More general focus on energy and climate policy: Energy prices, energy costs, energy and environmental tax revenues, spending on pollution abatement
Differentiation of results by sector	Direct differentiation (energy-intensive vs. all sectors), implicit differentiation (e.g. via transport costs)

Source: compiled by the authors (Öko-Institut)

Each of these main methodological differences between studies will be discussed in detail in the following sections, showing examples from the literature and outlining advantages and limitations of the methodological choice in question.

4.3.2 Carbon leakage indicator

We refer to the carbon leakage indicator as the metric that is used to approximate whether or not carbon leakage has occurred and to what extent this has been the case. A range of indicators is available to authors and the choice of which one to use depends on the exact focus of analysis, as well as data availability. Taking a domestic view (i.e. not collecting information on trading partners), the following indicators are available: (net) imports and exports, output, employment and foreign direct investment (Branger et al. 2016; Fowlie et al. 2016; Koch and Basse Mama 2019; Petrick and Wagner 2014; Sartor 2013).

Authors also take a more international view and also include information on (main) trading partners in the analysis. In this case, the favoured indicator for carbon leakage are bilateral trade flows (Costantini and Mazzanti 2012; Ifo-Institut 2013; Naegele and Zaklan 2019; Sato and Dechezleprêtre 2015). The advantage of taking this international view and using bilateral trade flows over, for example, net imports is that intra-industry trade between two countries can be accounted for in this framework (Naegele and Zaklan 2019). Furthermore, changes in trade flows can be differentiated by trading partner countries. The disadvantage of using bilateral trade flows lies in the fact that all endogenous and exogenous variables have to be collected not only for the main country or region under investigation (e.g. EU), but also for all trading partner countries.

Table 3 summarises these considerations with regards to the different carbon leakage indicators that can be used.

Table 3: Carbon leakage indicator: Examples, advantages and limitations of different options

	Examples	Advantages	Limitations
Domestic indicators	(Net) import and export, output, employment, FDI	No need to collect detailed data on trading partner countries. Available both at the firm and sector level.	Some indicators cannot account for some potentially important effects, e.g. looking at net imports neglects intra-industry trade between countries, which is only reflected in bilateral trade flows. Does not always allow estimation of differentiated effects for different trading partners.
International indicators	Bilateral trade flows	Accounts for intra-industry trade between trading partners and approximates both production relocation and loss of market share. Differentiated effects by trading partner country can be estimated.	More data needs to be collected, as all variables have to be available for all trading partner countries investigated.

Source: compiled by the authors (Öko-Institut)

4.3.3 Analysis level

As is the case with the choice of carbon leakage indicator, the choice on the analysis level follows more or less directly from the exact focus of the study and is in particular linked to the choice of the carbon leakage indicator (see above).

Some carbon leakage indicators, such as export, output, employment or investment are available at both the firm and sector level. Since firm-level data has some methodological advantages (as described below) over sector-level data, authors looking at export, output and employment (Abrell et al. 2011; Commins et al. 2011; Petrick and Wagner 2014) or foreign direct investment (Garsous and Kozluk 2017; Koch and Basse Mama 2019) as well as patenting activities (Calel and Dechezleprêtre 2016) have often resorted to carrying out the analysis at the firm level. Other indicators, such as (net) imports (Branger et al. 2016; Sartor 2013) and in particular bilateral trade flows are only available at the sector level (Costantini and Mazzanti 2012; Ifo-Institut 2013; Naegele and Zaklan 2019; Sato and Dechezleprêtre 2015).

If the desired carbon leakage indicator is available at the firm level, using this data has advantages in terms of the estimation. In particular, it is possible to construct “quasi-experimental” data (cf. Stock and Watson 2012, Chapter 13) with which the effect of the EU ETS (“treatment effect”) can be estimated. In the studies looking at the impact of the EU ETS using firm level data, this is usually achieved by constructing a dataset that contains information on both regulated and non-regulated firms, spanning the time periods both before and after the introduction of the ETS. For estimation purposes, it is important that both groups ("treated" and "not treated") exhibit similar features, so that the treatment effect of the ETS appears as if randomly assigned. In order to achieve this, studies usually match each treated firm to a non-treated firm based on variables not affected by the ETS (Abrell et al. 2011; Dechezleprêtre et al. 2018; Koch and Basse Mama 2019). Finding comparable non-treated observations is only possible at the firm and not at the sector level.

Firm-level data, however, usually has to be purchased from commercial sources, while sector-level data is often available from public sources (e.g. Eurostat, Comext). At which level of disaggregation sector data is available (e.g. 2-, 3- or 4-digit NACE) depends on the variables (endogenous and explanatory, as well as geographical coverage) that are to be included in the analysis.

Table 4 lists examples and summarises main advantages and limitations of using firm- over sector-level data.

Table 4: Analysis level: Examples, advantages and limitations of different options

	Examples	Advantages	Limitations
Firm level	For the following CL indicators analyses have been carried out at the firm level: export, output, employment, FDI and patenting activities	Methodologically: Additional data points, easier to correct for unobserved heterogeneity	If the focus lies on production relocation, more often sector data is used. Usually other focus if data at firm level is used (output, employment, FDI). Data may have to be purchased.
Sector level	Sector-level analyses mostly focus on production relocation and use either bilateral trade flows or net imports/exports as the CL indicator.	If the impact on production leakage is to be estimated, sector level data is most suitable for this question. In particular bilateral trade flows are only available at the sector (and not at the firm) level. Data often available free of charge.	Using sectoral data may pose some methodological challenges, e.g. in accounting for unobserved heterogeneity.

Source: compiled by the authors (Öko-Institut)

4.3.4 Indicator of policy stringency

Carbon leakage can be a result of differences in policy stringency between jurisdictions. The choice of the indicator used for policy stringency (e.g. the EU vs. trading partner countries) follows directly from the specific research question being asked. If the focus lies on impacts related to the EU ETS (and its design elements), it is natural to use carbon (EUA) prices (Branger et al. 2016; Sartor 2013) and to account for other design elements, such as free allocation and potential compensation for electricity price increases (Naegele and Zaklan 2019). At the firm level, one can use a dummy indicating whether a firm is taking part in the EU ETS or not (Koch and Basse Mama 2019).

If researchers want to investigate the impact of differences in overall energy and climate policy, i.e. the sum of actions and regulations, they often use differences in energy prices between trading partner countries as a proxy, assuming that the level of energy prices is reflective of policy stringency, e.g. via taxes and surcharges (Sato and Dechezleprêtre 2015). The assumption is that more stringent climate policy will increase the prices of inputs to production (including energy) and that this effect can be approximated by using energy prices (or price indices). Other authors (Costantini and Mazzanti 2012) have used composite indices, e.g. looking at environmental and energy tax revenue and spending, as well as using other proxies, such as import tariffs (Ifo-Institut 2013).

Researchers have also noted that in case observed carbon prices are very low, it may be hard to disentangle their impact from more dominant factors (cf. Sato and Dechezleprêtre 2015). If the reaction of firms to differences in CO_2 prices is assumed to be similar to differences in energy prices, using energy price differentials as a proxy for CO_2 price differentials is a good way forward (cf. Fowlie et al. 2016; Sato and Dechezleprêtre 2015). In this case, the impact of current energy price differentials can be used to approximate the impact of future differences in carbon prices.

If one is interested in the specific impact of the EU ETS, it makes sense to use carbon (EUA) prices and associated costs, as this allows to account for specific ETS features, in particular taking into account the method and level of free allocation. For trading partner countries without an explicit carbon price, shadow or implicit carbon prices have to be constructed or other indicators found that proxy the stringency of climate policy in these countries. This may not be trivial.

Energy prices, on the other hand, are usually available for many trading partners and longer timescales and allow for a consistent comparison. However, breaking these price series down to sectors faces several data availability issues (Sato et al. 2015).

Table 5 summarises examples, advantages and limitations of the two main indicators used to reflect climate policy stringency: differences in carbon vs. energy prices.

Table 5: Indicator of policy stringency: Examples, advantages and limitations of different options

	Examples	Advantages	Limitations
Carbon prices	Differences between trading partners in the level of carbon prices (e.g. EUA prices) and carbon costs per sector.	Specific features of the ETS investigated (in particular free allocation and further compensation) can be taken into account. Detailed information on carbon prices and costs are available at the sector level if an ETS is in place.	Need to collect a (shadow) carbon price or other indicator for trading partner countries. This may be challenging if no explicit price in place. If the focus is placed on carbon prices, authors may miss other aspects of energy and climate policy.
Energy prices	Differences between trading partners in the level of energy prices (including taxes and tariffs).	Differences in energy prices have been used as an encompassing indicator to reflect differences in policy stringency. Energy prices are usually readily available for all countries.	Differences in energy price cannot readily take into account ETS specific effects, e.g. free allocation or other form of compensation. Need to construct sector-specific energy price indices by country, which faces potential data availability issues.

Source: compiled by the authors (Öko-Institut)

4.3.5 Differentiation of results by sector

Some studies estimate carbon leakage effects only for certain sectors (e.g. (Branger et al. 2016) for cement; Sartor 2013 for primary aluminium). Other studies estimate effects for all sectors covered by the EU ETS (Naegele and Zaklan 2019) or differentiate explicitly between energy-intensive and other sectors (Sato and Dechezleprêtre 2015). Koch and Basse Mama (2019) are especially interested in effects of the EU ETS on investment relocation and therefore differentiate between capital-intensive vs. less capital-intensive sectors (using data at the firm level).

If sectoral data is used, the advantage of including more than one sector in the estimation is that a panel model can be applied. If only one sector is investigated, authors have a time-series dataset, i.e. data on one entity (in this case one sector) observed at different points in time, at their disposal and use the corresponding time-series estimation techniques (cf. Branger et al. 2016). If the data set consists of observations of multiple entities (in this case multiple sectors) at different points in time, this is called a panel dataset (Naegele and Zaklan 2019; Sato and Dechezleprêtre 2015), on which special estimation techniques can be used. One advantage of panel data over time-series data is that unobserved variables (e.g. on certain sector-specific characteristics) that have the potential to bias results, can be controlled for.

If not enough data points are available and a lot of coefficients are to be estimated, it may be challenging to carry out separate estimations for different sectors. Some data may only be available at quarterly or yearly timescales (e.g. free allocation in the EU ETS), limiting the amount of data points available.[4]

However, even if it is not possible to explicitly estimate effects differentiated by sector, it is still possible to implicitly derive sector-specific effects. This can be done, for example, if additional variables are included in the regression that differ by sector, e.g. transport costs (which are, for example, high for cement and low for refined products) or total carbon costs. If these variables are significant in explaining differences in the carbon leakage indicator, implicit sector-specific effects can be derived by applying the estimated coefficient of the transport costs observed in this sector.

Table 6: Differentiation of results by sector: Examples, advantages and limitations of different options

	Examples	Advantages	Limitations
Implicit differentiation	Via coefficients on other explanatory variables, such as transportation costs or total carbon cost	Running one regression using the full sample, is likely to generate more precise results. If many coefficients are to be estimated, separate regressions are not possible.	No direct effects estimated for different sectors

[4] In order to generate meaningful results using regression analysis, it is important that the number of data points available is adequate. In regression analysis, variations in the outcome variable (e.g. net imports) are explained by variations in the explanatory variables (e.g. CO_2 prices). The more data is available, the easier it becomes to fit the model to the data in a meaningful way, as the relationship between the explanatory and the outcome variable can be established using many "pairs" of observations and the estimation result is likely to be closer to the "real" relationship between the explanatory and outcome variable. As a general rule, the more explanatory variables in the regression (i.e. the more relationships have to be estimated), the higher the requirements for the number of data points.

	Examples	Advantages	Limitations
Explicit differentiation	Running the model separately for certain sectors or sector groups (e.g. energy-intensive)	Running separate regressions returns direct and explicit effects for different sectors or sector groups	Estimating for subsamples reduces data points and may limit accuracy of the model. For some specifications, separate regressions may not be possible due to limited data availability.

Source: compiled by the authors (Öko-Institut)

4.3.6 A note on the relationship between methodological differences and estimated carbon leakage effects

During the review of the literature, it became clear that the methodological approach chosen seems to influence the results found with respect to carbon leakage risk. While ex-ante studies often estimate carbon leakage effects (Carbone & Rivers 2017) ex-post studies generally find either no indication of carbon leakage (Branger et al. 2016; Naegele and Zaklan 2019; Petrick and Wagner 2014) or rather small effects (Garsous & Kozluk 2017; Sato & Dechezleprêtre 2015) and these often only for energy-intensive sectors (Aldy & Pizer 2015; Sato & Dechezleprêtre 2015). Koch and Basse Mama (2019) also find that in general the EU ETS has not led to investment leakage, but note that they find an increase in FDI for sectors that are not directly impacted by the EU ETS, such as those producing machines or electrical appliances, which they explain with higher mobility in these sectors due to lower capital costs.

Interestingly, ex-post studies finding no evidence for carbon leakage are usually the ones looking specifically at the EU ETS and its design features (Branger et al. 2016; Koch and Basse Mama 2019; Naegele and Zaklan 2019). Ex-post studies finding significant, but small effects are usually the ones using energy differentials or other indicators to proxy for differences in overall policy stringency or potentially higher differences in future carbon prices, but disregarding ETS-specific effects such as free allocation (Ifo-Institut 2013; Sato and Dechezleprêtre 2015).

This may point to the fact that the EU ETS, taking into account all its specific features, including free allocation and other compensatory measures, has not induced carbon leakage to date, whereas differences in energy prices do have effects on the relocation of production. Differences in results may also have to do with the design of the research. It is therefore of utmost importance to clearly define the research question (i.e. carbon leakage as a result of the EU ETS vs. more general climate policy) and carefully design it.

4.4 Discussion and conclusion

In this paper, we review the literature on estimating carbon leakage effects resulting from differences in climate and energy policy and particularly the EU Emissions Trading System (EU ETS). We focus our in-depth literature review on research that econometrically estimates carbon leakage effects ex-post, in particular looking at studies using sectoral data.

We give an overview of the methodological differences found between the studies, using ten studies as the main input for this analysis. We find that studies differ in the carbon leakage indicator used, their analysis level (sector vs. firm data), the indicator used to reflect policy stringency and to what extent results are differentiated by sectors. We find that the choices made by authors are closely related to the main research question asked and all have advantages and disadvantages that should be considered when designing the research.

While ex-ante studies often expect carbon leakage effects to occur, existing ex-post studies unanimously refute the existence of important carbon leakage effects (at least in the short term). Studies specifically looking at the EU ETS in particular find no significant effects, while studies that take into account differences in overall energy and climate policies (often approximated by a proxy) find significant, but small effects on carbon leakage.

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A Annex

Literature review matrix

Authors	Naegele and Zaklan (2019)	Branger, Quirion and Chevallier (2016)	Sato and Dechezleprêtre (2015)	Ifo-Institut (2013)
Title	Does the EU ETS Cause Carbon Leakage in European Manufacturing?	Carbon Leakage and Competitiveness of Cement and Steel Industries Under the EU ETS: Much Ado About Nothing	Asymmetric industrial energy prices and international trade	Entwicklung eines Maßes für die Intensität des internationalen Wettbewerbs auf Unternehmens- oder Sektorebene
Topic / Research question	Evidence of carbon leakage due to the EU ETS	Impact of the EU ETS on net imports of cement and steel to the EU	Short-term effects of assymmetric energy prices on bilateral trade	Sectoral export price elasticities on the basis of trade and import tariff data
Time horizon	2004-2011 Analysis years: 2004, 2007, 2011	1999-2012 2005-2012 (for regressions with carbon price included)	1996-2011	Results given for 2007
Countries / sectors	EU + trading partners: 66 regions and 25 manufacturing sectors	- EU27 vs rest of world - Cement and steel	42 countries, 62 sectors (manufacturing)	22 producing sectors, agriculture, mining and aggregated services sector Not clear how many countries included
Differentiation of ETS sectors	No direct differentiation for the results; but deduced effects from including variables such as transports costs (plus interaction terms) and total net cost, which can be used to identify sectors, however, coefficients on these variables are insignificant	Separate regressions for cement and steel Sensitivity analysis for clinker and long products	Explicit sensitivity for energy-intensive sectors, however, not differentiation between large ETS sectors	Separate regression for individual sectors = individual export elasticity for each sector

Authors	Costantini and Mazzanti (2012)	Sartor (2013)	Koch and Basse Mama (2019)	Fowlie, Reguant and Ryan (2016)	Dechezleprêtre and Sato (2017)
Title	On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports	Carbon Leakage in the Primary Aluminium Sector: What evidence after 6 ½ years of the EU ETS?	European Climate Policy and Industrial Relocation: Evidence from German Multinational Firms	Measuring Leakage Risk	The Impacts of Environmental Regulations on Competitiveness
Topic / Research question	Testing the Porter Hypothesis: Effect of environmental regulation on export dynamics through competitiveness effects	Impact of the EU ETS on the EU aluminium sector	Changes in FDI of German firms due to inclusion in the EU ETS	Impact of changes in energy price levels on domestic production, export and import of 6-digit US sectors	Literature review of ex-post analyses of the effect of environmental regulation on competitiveness
Time horizon	1996-2007	1999-2011	1999-2013	2010-2015	First review article since Jaffe (1995) covering studies between 1995 and 2017.
Countries / sectors	EU 15 (14 countries) plus 145 trading partners 2 specifications: i) 4 aggregate manufacturing sectors: high, medium-high, medium-low and low technology (strong PH) ii) green sector (narrowly strong)	EU, primary aluminium	Focus on Germany: firm-level data in 20 sectors with FDI in 58 countries	U.S., 6-digit NAICs industries	
Differentiation of ETS sectors	ETS regulated firms are represented by one sector (i.e. medium-low technology sector)	One sector investigated: Primary aluminium	- All sectors - CL sectors (as aggregate) - capital-intensive industry sectors (steel, cement, paper, etc.) vs. less capital-intensive sectors (machinery, elec. equipment, automotive) - Short vs. long firms (most short firms in less capital-intensive sectors)	Firm level assigned to 96 NAICS 6-digit sectors	

Authors	Naegele and Zaklan (2019)	Branger, Quirion and Chevallier (2016)	Sato and Dechezleprêtre (2015)	Ifo-Institut (2013)
Carbon Leakage indicator	Trade flows: - Net imports - Bilateral trade	Trade flows: Net imports	Trade flows: Bilateral	Trade flows: Bilateral trade flows
Estimation method	Ex-post econometric analysis Country panel from GTAP Issues: Endogeneity, omitted variable bias Solutions: Fixed effects, normalisation of indicator variables, including transport costs in regressions Country-sector and time fixed effects (i.e. only differences in CL between sectors can be measured, a common CL component would be filtered out by FE) Several functional forms: Linear (main), cubic polynomial Several specifications: Interaction terms (e.g. stringency indicators with transport cost)	Time-series analysis: ARIMA and Prais-Winsten Time series are I(1), regression carried out in first differences Simplifying assumptions: Perfect competition, no product differentiation Transportation costs not included because of endogeneity 1999-2012: Regression w/o carbon price (only demand indicators) 2005-2012: Regression including carbon price	Econometric panel analysis Dynamic count data model with fixed effects Poisson pseudo-maximum likelihood	Econometric panel data analysis Gravitational model with fixed effects
Endogeno us variables	Two specifications: - Net imports (difference of imports and exports at sector-country-year level) measured in value or in embodied carbon - Bilateral trade flows ((two-way) intra-industry trade, at the sector-source-destination-year level) Normalised by a sector's total output (value) or total sectoral carbon emissions (embodied carbon), it is later checked whether this normalisation is viable Authors suggest that using quantity or embodied carbon instead of the value of trade flows is advantageous since these are not subject to price fluctuations	Net imports of cement and steel to the EU	Bilateral net imports	Exports (direct and indirect)

Authors	Costantini and Mazzanti (2012)	Sartor (2013)	Koch and Basse Mama (2019)	Fowlie, Reguant and Ryan (2016)	Dechezleprêtre and Sato (2017)
Carbon Leakage indicator	Trade flows	Trade flows: Net imports	Investment (FDI)	i) domestic production ii) domestic exports iii) foreign imports	The authors list indicators used in studies surveyed, these include: production volume, product prices, investments (firm responses), profitability, employment, market share (economic outcomes), trade flows, investment location, FDI (internat. Outcomes), etc.
Estimation method	Country-sector panel; Dynamic panel estimator AR(2) Gravity model Variables in logs or dummy vars	Econometric regression Johansen cointegration method Four models: Including neither coal or gas prices, 2 models including either coal or gas prices, one model including secondary aluminium production	Difference-in-difference / Two stage estimation Design stage: construct sample on the basis of pre-treatment variables so that both groups have similar make-up Analysis stage: Difference-in-difference with bias-adjusted matching on observed covariates	Sector panel with sector- and year-fixed effects Many different specifications varying fixed effects, including lagged variables, different functional forms, etc.	Literature review: definitions of key parameters (e.g. competitiveness), discussion of theoretical background (Pollution Haven vs. Porter hypothesis), choice of variables, methodological considerations (e.g. endogeneity)
Endogenous variables	Bilateral trade flows: Exports	Net imports to the EU	Foreign direct investment (FDI)	i) Domestic production ii) Domestic production for export iii) Foreign imports Using $$ values	

Authors	Naegele and Zaklan (2019)	Branger, Quirion and Chevallier (2016)	Sato and Dechezleprêtre (2015)	Ifo-Institut (2013)
Exogenous variables	Four indicators of ETS stringency covering both direct and indirect cost: - binary treatment indicator (=1 if subject to the EU ETS, 0 otherwise) - direct emission cost = EUA price*emissions - indirect emission cost = EUA price*amount of emissions embodied in electricity consumption of the sector - subsidy due to the ETS = EUA price*free allocation The sum of all indicators presents the total net cost of the ETS Continuous indicators normalised by material cost in order to obtain emission intensities Control variables: - EU's average import tariff per sector - Fixed effects depending on specification: year, sector, country [- sector-level factor payments to unskilled labor, skilled labor (omitted) and capital in percentage of total value added] - transportation costs between source and destination countries, normalised by the free-on-board (FOB) value of trade flows - time trend (?)	- EUA price (futures) - Domestic demand proxied by EU industrial output (steel) and construction index (cement) - Foreign demand proxied by BRICS industrial output (both steel and cement) Time lag of three months for exogenous vars	- Lagged energy price differentials (reason: Majority of the differences caused by taxes, should therefore also reflect energy and climate policy) - Control variables: GDP, capital-labor ratio, wages, exchange rate, gravity variables (same currency, same language, etc.)	- Import tariff - Distance between trading partners - Futher vars: common border, common language, colonial past, trade agreement

Authors	Naegele and Zaklan (2019)	Branger, Quirion and Chevallier (2016)	Sato and Dechezleprêtre (2015)	Ifo-Institut (2013)
Data sources	For trade flows, CO2 emissions, factor payments, transport costs, output, and material costs: GTAP version 9.2: - Not full databased used, but 25 out of 57 sectors, 140 countries aggregated to 66 regions - GTAP only includes emissions from fossil fuels, correction for process emissions made - both direct and indirect emissions (throught I-O information in GTAP) Emissions and allocation from the EUTL: - using NACE 4-digit classification for sectors - matched to GTAP by NACE / ISIC correspondence tables Allowance prices from EEX Question: Import taxes from where?	- Net imports from EU Trade Database (HS2, 4, 6 and CN8 dataset; code for cement: 2523 (cement, including clinker, whether or not coloured) and 72 (iron and steel) - CO2 price from ICE - EU industrial output and EU construction index from Eurostat - BRICS industrial output constructed from several different data sources	- trade data: 2-digit level, 62 sectors, CEPII's BACI database based on COMTRADE (further disaggregation causes missing data problem) - energy prices: industrial energy price indices, 48 countries, 12 industry sectors (constructed by Sato 2015 based on IEA Energy end-use prices database and world energy balances) - GDP, population: IMF World Economic Outlook - wages: UNIDO - standard gravity variables: Gravity Dataset by CEPII	- Import tariff data: TRAINS database from UNCTAD - Data sources to determine direct and indirect export: German Staistical Office, Eurostat

Authors	Costantini and Mazzanti (2012)	Sartor (2013)	Koch and Basse Mama (2019)	Fowlie, Reguant and Ryan (2016)	Dechezleprêtre and Sato (2017)
Exogenous variables	- Environmental regulation (compulsory and voluntary) Control variables: - Common border - Distance - GDP in various forms - Population - "Stock of knowledge" based on patenting activity (by sector) Also taking into account structural breaks and regional dummies	- EUA price Control variables: - Volume of industrial production in the EU - Coal price - Natural gas price - Exchange rate - Dummy for a structural break in long-term contracts Quarterly data	Treatment dummy For matching: FDI, total assets, sales, number of countries invested in, number of affiliates (all before start of ETS)	Energy price indices (applying different weighting methodologies): i) Differentiated by sector ii) For main import and export partners (weighted average) Control variables: - Energy and emissions intensity - Capital and labour inputs	The authors discuss different options to measure (differences in) the stringency of environmental regulations: pollution level (environmental outcome), compliance cost as share of value added, environmental or energy tax revenue, renewable energy capacity, recycling rates, legislation counts, and composite indicators
Data sources	- Export: UNCTAD-COMTRADE - Sector classification: OECD / WTO - Distance: CEPII - GDP: World Bank - Environmental measures: Eurostat - Patents: EPO, OECD-STAN and Eurostat	- CO2 spot price: Bluenext - Trade data: COMEXT - Industrial production: Eurostat - Coal and natural gas prices: IMF world commodities database - Exchange rate: Eurostat	- FDI per firm: Microdatabase Direct Investment (MiDi) gathered by Deutsche Bundesbank - Inclusion in EU ETS: EUTL installation-level data matched to firms via algorithm	- Various US firm-level databases on output, import / export, ownership, etc. - State-level US energy prices - Global energy prices from Enerdata and IEA	List methodological issues, e.g. aggregation bias, endogeneity, reverse causality which are problematic when using country or sector level data. These obstacles can be overcome by using disaggregated data (at the firm level) and constructing a panel (before / after the policy was introduced). The whole article is somewhat geared toward disaggregated data.

Authors	Naegele and Zaklan (2019)	Branger, Quirion and Chevallier (2016)	Sato and Dechezleprêtre (2015)	Ifo-Institut (2013)
Estimated Carbon Leakge effects	No evidence for leakage from European manufacturing sectors.	No significant effect of the carbon price on net imports of steel and cement. Authors conclude that at carbon prices below 30 Euro no threat of operational leakage in these sectors.	Small positive effect of changes in relative prices on imports: 10% change in energy price differentials between two countries in one sector leads to an average increase in imports of 0.2%; hypothetical CO2 price of 40-65 € in the EU ETS would increase EU import by less than 0.05% and decrease exports by 0.2%. Other factors are more important for trade flows (energy price differentials only account for 0.01% of variation in trade flows.	This article does not aim at investigating carbon leakage, but was rather included due to methodological considerations. Therefore, no result on carbon leakage, however, relatively high export price elasticities estimated for some sectors
Limitations	Energy vs. carbon prices: Authors use only EU ETS prices; their research question: Is there evidence of carbon leakage due to the EU ETS rather than comparing the ETS to potential climate policy in other countries? For the timeframe considered: 2004-2011, this may make sense. For more recent years, may need other approach.	Only two sectors, only net import (instead of bilateral flows), only EUA price considered (not policy in trading partner countries) Some simplifying assumptions	- Relationship between trade flows and energy price differentials only estimated for the aggregate, not for individual sectors. Therefore, conclusions for ETS (and especially individual sectors and differences between these sectors) is limited. - Energy price differentials used as a proxy for differences in climate policy. However, this may not be reflective of CO2-price differentials, e.g. because process emissions would have to be taken into account.	Analysis of carbon leakage not main focus and estimation method described in less detail, therefore hard to appraise limitations.

Authors	Costantini and Mazzanti (2012)	Sartor (2013)	Koch and Basse Mama (2019)	Fowlie, Reguant and Ryan (2016)	Dechezleprêtre and Sato (2017)
Estimated Carbon Leakge effects	Main focus is testing the Porter Hypothesis for all sectors (not only ETS sector). However, some results shown for ETS sector (i.e. classified as medium-low tech sector), which shows that higher energy taxes encourage exports, while effect on ETS dummy variable is somewhat inconclusive (positive in one specification negative in the other)	Insignificant effect of CO2 price or negative effect of CO2 prices (i.e. wrong sign) Author concludes no evidence of effect of EU ETS on competitiveness of primary aluminium and discusses other potential factors influencing decline in competitiveness of EU primary aluminium (e.g. rising coal, gas and electricity prices and changes in EU competition law regarding long term contracts).	Overall effect of EU ETS on outbound FDI is insignificant. However, some firms that are neither energy- nor emissions-intensive and not targeted by CL provision, as well as being less capital-intensive (e.g. in machinery) have significanty increased outbound FDI. These firms only represent a small share of regulated emissions.	Given the noisiness of these estimates, they cannot estimate the transfer rate for any given industry with any degree of confidence. They rather summarize general patterns. The estimated market transfer rates, which should be viewed as an upper bound given that changes in net exports are unlikely to translate one-for-one into increases in foreign production, fall at or below 20 percent for most industries.	Environmental regulation can have minor (statistically significant) short-term effects on trade, employment, location and productivity. However, other influences play a greater role.
Limitations	Limitations related to the investigation in this project: Broad focus on all sectors (not only energy- or emissions-intensive ones).	Only one sector; net imports used not bilateral trade flows (which is considered as more informative) Limitation cited by the author: Short time period and importance of long-term contracts and technical characteristics in this sector only allow for statements about limited, short-term effects.	Focus on carbon leakage investement channel, dependent on suitability of control group Limitations cited by authors: Ignoring indirect through higher electricity prices (which would affect firms in both groups)	see previous column	

Authors	Naegele and Zaklan (2019)	Branger, Quirion and Chevallier (2016)	Sato and Dechezleprêtre (2015)	Ifo-Institut (2013)
Full reference	Naegele, H.; Zaklan, A. (2019): Does the EU ETS cause carbon leakage in European manufacturing? In: Journal of Environmental Economics and Management 93, pp. 125–147. Online available at https://doi.org/10.1016/j.jeem.2018.11.004	Branger F.; Quirion P. & Chevallier J. (2016): Carbon Leakage and Competitiveness of Cement and Steel Industries Under the EU ETS: Much Ado About Nothing. The Energy Journal, 37(3).	Sato, Misato; Dechezleprêtre, Antoine (2015): Asymmetric industrial energy prices and international trade. In: Energy Economics 52, S130–S141.	Ifo-Institut (2013): Entwicklung eines Maßes für die Intensität des internationalen Wettbewerbs auf Unternehmens- oder Sektorebene: Kurzgutachten im Auftrag des Bundesministerium s für Wirtschaft und Technologie.

Authors	Costantini and Mazzanti (2012)	Sartor (2013)	Koch and Basse Mama (2019)	Fowlie, Reguant and Ryan (2016)	Dechezleprêtre and Sato (2017)
Full reference	Costantini V. & Mazzanti M. (2012): On the green and innovative side of trade competitiveness?: The impact of environmental policies and innovation on EU exports. Research Policy, 41(1), pp. 132–153. doi:10.1016/j.respol.2011.08.004.	Sartor, Oliver (2012): Carbon Leakage in the Primary Aluminium Sector: What evidence after 6 1/2 years of the EU ETS? (Working Paper No. 2012-12). Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2205516, last accessed on 17 Jan 2020.	Koch, N.; Basse Mama, H. (2019): Does the EU Emissions Trading System induce investment leakage? Evidence from German multinational firms. In: Energy Economics 2019 (Volume 81), pp. 479–492. Online available at https://doi.org/10.1016/j.eneco.2019.04.01, last accessed on 1 Oct 2019.	Fowlie, Meredith L.; Reguant, Mar & Ryan, Stephen P. (2016): Measuring Leakage Risk. Available at https://www.arb.ca.gov/cc/capandtrade/meetings/20160518/ucb-intl-leakage.pdf, last accessed on 7 Feb 2018.	Dechezleprêtre A. & Sato M. (2017): The Impacts of Environmental Regulations on Competitiveness. Review of Environmental Economics and Policy, 11(2), pp. 183–206. doi:10.1093/reep/rex013.

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Work package 2 – Analysis of the carbon leakage risk after the Paris Agreement

5 Analysis of the carbon leakage risk after the Paris Agreement

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5.1 Introduction

Ever since the introduction of the EU ETS, there has been debate about how the instrument would affect the competitiveness of European industries compared to their competitors abroad. The issue of carbon leakage – relocation of economic activities driven by differences in the stringency of climate policy – has taken centre stage in the political discussions. As a result, the EU – as indeed all other countries with emissions trading systems that cover industrial sectors – has included mechanisms to protect its industries against the risk of carbon leakage.

At the same time, there has been plenty of research attention devoted to the issue of carbon leakage:[5] does it exist, and how can it be measured? How large is the carbon leakage risk, and which sectors are most exposed to it? Which policy measures are effective to mitigate the leakage risk, and how to evaluate their technical and legal feasibility?

In the assessment of leakage risk, one issue that receives surprisingly scant treatment is the delta in climate policy stringency: what is the actual difference in the ambition and stringency of climate policy between the home country and third countries? Most of the political debate – and also the official determination of the carbon leakage risk, as applied by the European Commission – is based on the simplified premise that the EU is the only country that imposes a carbon constraint on its domestic economy. This premise, however, ignores the fact that as signatories to the Paris Agreement, countries around the world have committed to reducing their emissions, or at least to slow the growth of emissions. A number of them have also started to enact domestic climate policies in order to achieve their objectives, including by imposing constraints on their emission-intensive industries.

This study addresses this gap from the perspective of the European Union. For the EU itself and its 12 main trading partners, it assesses the stringency of the climate-related regulations that apply to industrial installations, with particular focus on eight industry sectors that are typically deemed to be at risk of carbon leakage.

However, comparing climate efforts across jurisdictions, entails its own set of difficulties:

- First, while the carbon leakage debate in the EU is tied to the EU ETS as the flagship instrument of EU climate policy, climate policy on the whole extends beyond carbon pricing instruments. Carbon prices of course lends themselves to international comparisons – the

[5] For a recent overview, see the literature review in chapter 4.

comparison merely requires adjusting carbon prices for the exchange rate, and possibly addressing differences in scope and the question of free allocation – but otherwise the comparison is straightforward, as the carbon price already provides a measure of the stringency and ambition of the climate policy instrument.

- But, secondly, while the coverage of carbon pricing tools is growing, it is still a minority of countries (and of EU trading partners) that rely on carbon prices. For a number of reasons – the regulatory culture and endowment with policy instruments, political preferences, administrative capacity or the emission profile, countries employ a suite of other climate policy instruments and tools to reduce emissions. And even where they do apply a carbon price, the role of the carbon price in the domestic policy mix may differ: if the carbon price is supposedly the main instrument in the mix (or even the only one), a high carbon price is needed to effect the necessary changes. If, however, the carbon price is only one among many instruments, or even only a support while other instruments are expected to drive the transformation, a lower carbon price is needed to bring about the same results, as the other instruments carry a greater burden. To complicate things further, the complementary policy instruments may not be primarily climate policy instruments: for instance, policies that promote renewables or improve energy efficiency are to some extent climate policy instruments, but also pursue other goals.
- This leads over to the third point: climate policy is embedded in a broader policy landscape. The carbon leakage debate is of course derived from climate policy, and is therefore about comparing climate policy efforts across countries. Yet a comparison also needs to reckon with the fact that climate policy is often part of an amalgamation of different policy objectives, which includes air quality and energy efficiency, but also industrial policy, regional development, reducing dependence from fossil fuel imports, and many others. This may even go as far as conceiving climate mitigation as a co-benefit of other policies that address more immediate concerns, e.g. reducing air pollution to tackle acute health effects (Mayrhofer and Gupta, 2016).

To grapple with these difficulties, this study has chosen a relatively broad (and thereby hopefully more comprehensive) approach to define the effective carbon constraint that applies to industry emitters. In addition to the carbon price, as the most evident and most clearly identifiable instrument of climate policy applied to industrial emitters, it also looks at neighbouring areas of regulation, i.e. energy efficiency and air quality standards applicable to industrial installations.

A particular challenge that comes with this broad approach is the need to aggregate the stringency of regulation across the different categories. To answer the question that is at the heart of the investigation – how stringent are the EU's climate-related policies relative to those of its main trading partners – the stringency of the effective carbon constraints needs to be expressed in a single metric. This would ideally be done in monetary terms, comparing the compliance costs that different types of regulation impose on the regulated entities, which could then easily be combined with the carbon price to produce a monetary estimate of the cost of compliance. Yet to do so for 13 countries, for eight industrial sectors and across three climate-related policy domains would be a herculean task, which would far exceed the resources that were available for this effort. Instead, this study presents a clear and transparent approach in which the relevant categories (carbon prices, energy efficiency standards and air quality standards) are first assessed separately, and the combined using a pre-defined weight to yield an overall score of the stringency of climate-related policies. This also includes sensitivity analyses with different weights, or otherwise changing key assumptions, in order to test how robust the findings are towards such changes.

This report is structured as follows: chapter 2 presents the trade profiles of EU-external trade for eight selected emission-intensive commodities, and on this basis, presents a selection of the 12 most relevant trading EU partners, which will subsequently be analysed. Chapter 3 introduces the methodology for the assessment of the different countries' efforts, i.e. the main categories, the main data sources and indicators used to assess the performance in these categories, and the method for aggregating them. Chapter 4 presents summary overviews of the climate policy landscape in the EU itself and its 12 main trading partner countries. In chapter 5, the performance of the 12 countries and the EU itself is assessed for the three main categories (effective carbon price, energy efficiency policies and air quality standards), and subsequently aggregated to yield an overall score, as well as sensitivity analyses to assess the impact of key assumptions on the outcome of the analysis. Chapter 6 concludes. In this context, it should be noted that the assessment in chapter 5 draws on different data sets and overview publications, which allow to draw on a single, internally consistent source for the assessment. The country descriptions in chapter 4 serve to illustrate and provide detail on the different countries' efforts, but generally would not enter the assessment – with few exceptions, e.g. where individual countries were lacking from cross-country assessments, these gaps were filled with information from the national-level analyses.

Finally, it should be noted that the main research for this report was carried out in 2018 – 2019, with minor adjustments and updates over the winter of 2019-2020. As mentioned, it uses common data sources for the assessment to ensure compatibility and comparability. However, an important drawback is that these databases themselves typically use the latest year for which full coverage could be ensured, which would often be 2015 - 2016. Four to five years is a long time in climate policies – as witnessed e.g. by the carbon price in the EU ETS, which was still at 7 – 8 EUR in 2015, and has since then climbed to more than 25 Euro in 2020. Finally, the time lag involved in the data also means that the analysis does not even begin to reflect the implications of the Corona pandemic on trade volumes and trade relations, or possibly on different countries' climate efforts.

5.2 Trade profiles in selected carbon intensive commodities

The analysis focuses on selected industrial sectors that are covered by the EU ETS, exposed to international competition and therefored deemed to be at risk of carbon leakage according to Commission Decision 2014/746/EU. These are: (i) manufacturing of iron and steel; (ii) manufacturing of organic and inorganic chemicals including fertilisers; (iii) manufacturing of non-ferrous metals such as copper and aluminium; mineral processing industries producing (iv), cement and lime, (v) glass, or (vi) ceramics; (vii) manufacturing of pulp and paper and (viii) manufacturing of refined petroleum products.[6]

For these sectors, we (a) analyse their import and export volumes of their products as a measure of their exposure to international competition, and (b) identify the top twelve external (i.e. non-EU) trade partners and their respective trade shares. This gives a reasonably good picture of the non-EU countries that are most relevant for European industries – either as the most important

[6] The analysis contained in this report builds and expands on the analysis conducted in a previous project, documented in the report "Carbon Leakage Risk in a World of Converging Carbon prices" (UBA 11/2018), including a further substantiation of the method and inclusion of several new sets of data to arrive at a more comprehensive analysis.

target markets of European exporters from the industry sectors covered by the EU ETS, or as the most important competitors of European industries covered by the EU ETS.[7]

5.2.1 Classification of industrial sectors based on products

The analysis uses trade volumes provided by Eurostat via its external trade database (Eurostat, 2017a), also referred to as the easy comext database in the following. Trade volumes are given for different products from industrial sectors which are classified according to the Statistical Classification of Products by Activity (CPA).

Commission Decision 2014/746/EU lists the industrial activities covered under the EU ETS that are considered to be at risk of carbon leakage together with their respective NACE code (European Classification of Economic Activities) (see European Comission, 2014). The NACE code corresponds to the CPA code (Classification of Products by Activity) (see e.g. (Eurostat, 2008)), so that respective trade volumes for the selected industrial sectors can be identified. Table 1 gives an overview of the selected industries, including the NACE and CPA code as well as the related products.

Table 7: Most important sectors at risk of carbon leakage, their NACE/CPA codes and respective products

Sectors	NACE and CPA code	Product name
Iron and steel	2410	Iron and steel
Chemicals	2013, 2014, 2015	Inorganic and organic chemicals, and fertilisers
Non-ferrous metals	2442, 2443, 2444, 2445	Copper, aluminium, lead, zinc and tin and others
Cement and lime	2351, 2352	Cement, lime and plaster
Glass	2311, 2313, 2314, 2319	Glass and glassware
Ceramics	2331, 2341 - 2344, 2349	Ceramic products
Pulp and Paper	1711, 1712, 1724	Pulp, paper and paperboard, wallpaper
Refineries	1920[8]	Refined petroleum products

Source: Own compilation based on Commission Decision 2014/746/EU stating NACE codes for activities at risk of carbon leakage

5.2.2 Selection of countries

Trade Volumes in the selected industries

Of the selected industrial sectors, and for the year 2017, refinery products account for the highest trade value of more than EUR 297 billion, followed by products from the chemical

[7] As benefits were considered marginal compared to the significant additional workload, this analysis does not take into account the competitive situation in third markets. Therefore, countries that play a decisive role in global industrial trade and thus are potential competitors may fall outside the scope. An explorative analysis for two sectors (cement and steel) also explored whether there are countries that were significant producers at the world level, but not major trading partners of the EU, but found that both categories largely overlap.

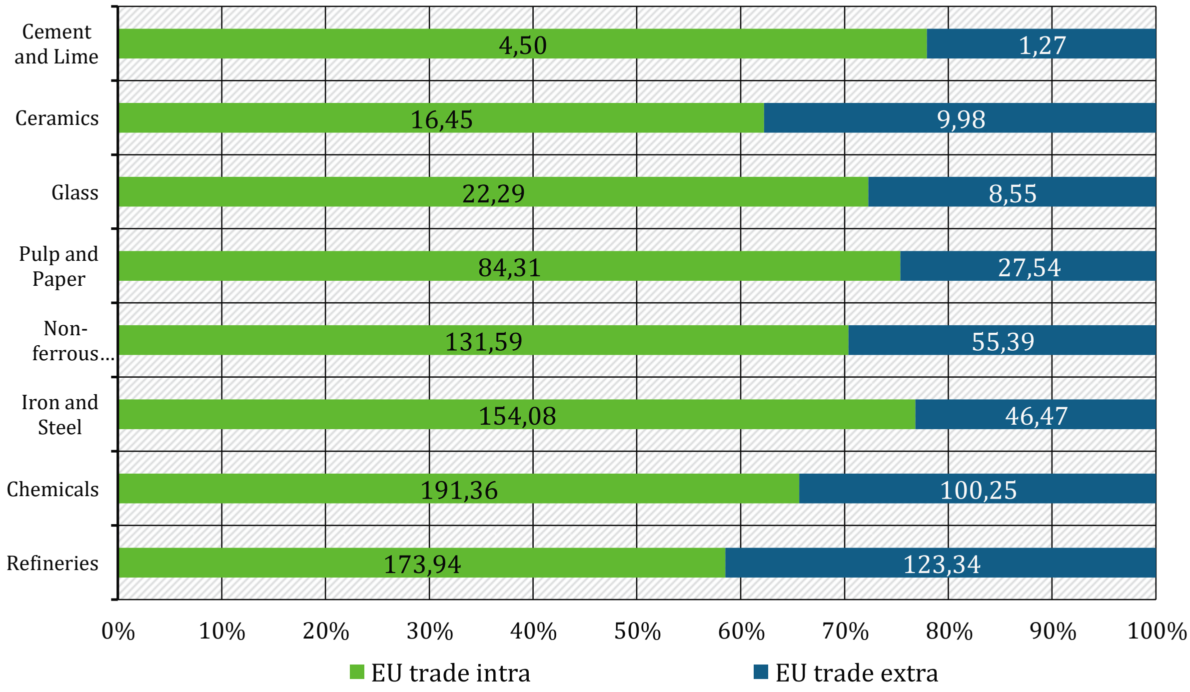
[8] Excluding coke and semi-coke of coal, of lignite or of peat; retort carbon; tar distilled from coal, lignite or peat; other mineral tars; pitch and pitch coke; briquettes, ovoids and similar solid fuels manufactured from coal or lignite. In addition, light petroleum oils for undergoing a specific process and gaseous hydrocarbons were excluded as these products are mainly produced during crude oil and natural gas extraction and are rather unimportant products of refineries.

industry with EUR 292 billion, then iron and steel with about EUR 200 billion, non-ferrous metals with EUR 187 billion and pulp and paper with EUR 112 billion. The trading volume of each of the other industrial products is less than EUR 50 billion: trade in glass products amounts to EUR 31 billion, ceramics to EUR 26 billion and cement and lime to around EUR 6 billion (see Figure 4). In comparison to 2016, the most substantial changes can be observed in the non-ferrous metals industry (+18%) and in the iron and steel industry (+24%).

Around two thirds (68%) of the trade in goods from the selected industrial sectors takes place within the EU.[9] About one third (32%) is traded with countries outside the EU. Intra-EU trade is particularly high, respectively, in the cement and lime (78%) sector, pulp and paper (75%) and iron and steel (77%), where trade with countries outside the EU accounts for a much lower share. At the other extreme, the share of external (non-EU) trade is highest for refinery products, with 41% of total trade (see Figure 4).

Also in terms of absolute volumes, the external trade volume is highest for refinery products with EUR 123 billion, followed by chemicals with EUR 100 billion. Non-ferrous metals (EUR 55 billion) and iron and steel trade (EUR 46 billion) are followed by pulp and paper (EUR 28 billion), ceramics (EUR 10 billion), glass (EUR 9 billion) and cement and lime (EUR 1 billion).

Figure 4: Intra-EU trade volumes compared to external trade volumes in 2017 (numbers in billion EUR)



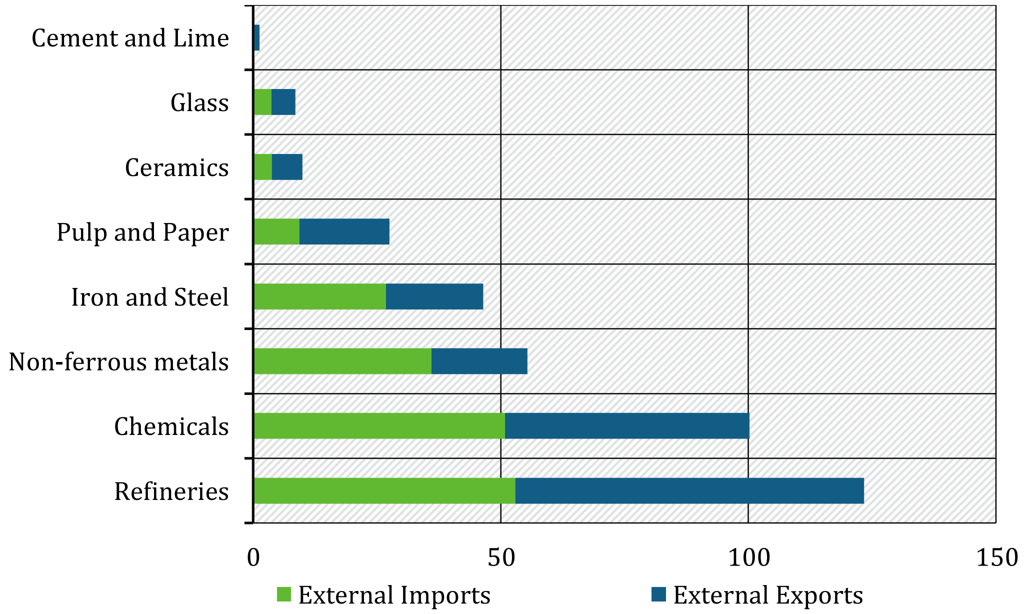
Source: own compilation based on Eurostat (2017)

[9] Intra-EU trade is the trade between Member States, i.e. exports or imports of one Member State with one of the other 27 Member States. Intra-EU imports do not equal intra-EU exports (although one would expect this) as exports are given with the free-on board (FOB) value (at the frontier of the exporting country) while imports are given with the cost, insurance and freight (CIF) price (at the frontier of the importing country). Thus, intra-EU imports should be slightly higher than the exports; however, coverage of intra-EU exports is generally better resulting in higher export values (Eurostat, 2017a).

B Overall, EU external imports and exports within these sectors are fairly balanced. Still, a few sectors stand out: whereas imports make up 65% for non-ferrous metals, export volumes exceed imports in other sectors, ranging from 79% of total external exports of cement and lime, 66% for pulp and paper, and 63% for ceramics (see Figure 5 and Annex B: Annex

Trade volumes and partners in the selected industrial sectors).

Figure 5: Imports and exports of the EU with external trading partners for the different industrial products (in EUR billion)



Source: own compilation based on Eurostat (2017)

Most relevant trading partners

Regarding the most important trading partners outside the EU, major economies dominate EU trade statistics. In fact, these are the largest economies in the world (China, the United States, Japan), as well as the EU's closest neighbours (Switzerland, Russia, Turkey and Norway) (Eurostat, 2017b). Going further down the list of main trading partners, based on data provided by the easy comext database, the analysis also included Brazil, Singapore, India, Korea and Saudi Arabia – in light of their trading volumes with the EU in the respective sectors (Eurostat, 2017a).

Table 8 presents the twelve main trading partners and the respective trade volume, in 2017, for the selected industrial sectors. The United States rank highest with a trading volume of EUR 56 billion, which accounts for around 5% of the overall EU trade for all the analysed sectors. The United States are followed by Russia with EUR 41 billion (3.5%). China's trade with the EU in the selected industrial sectors amounts to around EUR 29 billion (2.5%) followed by Switzerland with around EUR 23 billion (2.0%), Turkey with EUR 20 billion (1.7%) and Norway with EUR 16 billion (1.4%). Saudi Arabia trades around EUR 14 billion (1.2%) and Singapore EUR 12 billion (1.1%) with the EU in the respective sectors. Around EUR 11 billion (1.0%) is being traded between India and the EU. Brazil, South Korea and Japan all trade products worth around EUR 7-8 billion (<1%) with the EU.

Table 8: Top 12 external trade partners of the EU for the selected industrial sectors

Rank	Top 25 countries total	Trade vol. in EUR billion	Share or total EU trade for all sectors combined
1	United States	55,81	4.8%
2	Russian Federation (Russia)	40,09	3.5%
3	China (People's Republic of)	28,82	2.5%
4	Switzerland	22,54	2.0%
5	Turkey	19,63	1.7%
6	Norway	16,27	1.4%
7	Saudi Arabia	14,20	1.2%
8	Singapore	12,36	1.1%
9	India	11,42	1.0%
10	Brazil	7,64	0.7%
11	Korea, Republic of (South Korea)	7,30	0.6%
12	Japan	6,71	0.6%

Source: own compilation based on Eurostat (2017)

These trading patterns are remarkably stable. A comparison of all merchandise trade (i.e. not only for the eight sectors above) shows that nine of the countries above are also among the EU's top 10 trading partners for all merchandise trade (with Brazil ranking 12th, Saudi Arabia 13th and Singapore 14th). Moreover, the variety of countries is also stable over time: comparing the most recent data (2018) with past information (from 2016) shows that the EU's top ten trading partners remained the same (European Commission - DG Trade, 2019, 2017). The ranking itself also stays similar – changes are only confined to some countries swapping positions. Also, the volume of trade with the EU has grown in all countries – most striking with Russia and China.

Looking at the individual industrial sectors (see Table 9), the United States is the most important trading partner for three of the selected eight industrial sectors (chemicals, cement and lime, and pulp and paper) and the second most important trading partner for four other selected sectors. China is the most important trading partner for glass and ceramics, as well as the second biggest partner for chemicals, cement and lime, and pulp and paper. Non-ferrous metals and refinery products are mostly traded with Russia. Turkey is the most important trading partner for iron and steel. (see also Annex C: Annex Trade volumes and partners in the selected industrial sectors. The section presents detailed information about trade volumes for each of the industrial sectors and trading partners).

Table 9: Top 10 trading partners in the selected industrial sectors and respective trading volume (in EUR billion)

	Iron & Steel	Chemicals	Non-Ferrous metals	Cement & Lime	Glass	Ceramics	Pulp & Paper	Refineries
1	TUR: 5.03	USA: 20.78	RUS: 6.44	USA: 0.22	CHN: 1.90	CHN: 1.96	USA: 4.38	RUS: 20.07
2	RUS: 4.54	CHN: 12.38	USA: 6.19	CHE: 0.10	USA: 1.649	USA: 1.66	CHN: 2.73	USA: 16.71
3	CHN: 4.27	CHE: 7.88	CHN: 5.55	TUR: 0.08	CHE: 0.55	TUR: 0.53	BRA: 2.49	SAU: 7.21
4	USA: 4.24	RUS: 6.53	NOR: 5.00	NOR: 0.07	TUR: 0.45	CHE: 0.52	TUR: 1.91	NGA: 4.66
5	IND: 3.20	SGP: 5.91	CHE: 3.78	ISR: 0.05	RUS: 0.36	JPN: 0.38	RUS: 1.77	ARE: 4.27
6	UKR: 3.12	IND: 4.18	TUR: 3.24	CIV: 0.05	JPN: 0.336	RUS: 0.36	CHE: 1.34	GBZ: 4.01
7	KOR: 2.70	JPN: 4.18	CHL: 1.70	GHA: 0.05	NOR: 0.23	KOR: 0.27	NOR: 0.91	CHE: 3.89
8	BRA: 2.32	KOR: 3.09	ARE: 1.45	CMR: 0.05	IND: 0.19	MKD: 0.26	IND: 0.75	NOR: 3.55
9	CHE: 2.00	TUR: 3.09	CDN: 1.14	BIH: 0.04	MYS: 0.16	ARE: 0.24	CHL: 0.66	SGP: 3.48
10	NOR: 1.40	NOR: 2.72	MOZ: 0.97	COL: 0.03	SRB: 0.16	ISR: 0.21	URY: 0.66	TUR: 3.12

3-letter country abbreviations: ARE: United Arab Emirates, BIH: Bosnia and Herzegovina; BRA: Brazil, CDN: Canada; CIV: Cote d'Ivoire, CHE: Switzerland, CHL: Chile , CHN: China, CMR: Cameroon, COL: Colombia;GBZ: Great Britian Gibraltar, GHA: Ghana, IND: India, ISR: Israel; JPN: Japan, KOR: South Korea, MKD: Macedonia, MOZ: Mozambique, MYS: Malaysia, NGA: Nigeria, NOR: Norway, RUS: Russia, SAU: Saudi Arabia, SGP: Singapore, SRB: Serbia, TUR: Turkey, UKR: Ukraine, URY: Uruguay; USA: United States of America.

Light grey countries are not covered by the analysis of carbon constraints and prices in this paper.

Selected countries

Based on Table 8 (Top 12 external trade partners of the EU for the selected industrial sectors) and Table 9 (Top 10 trading partners in the selected industrial sectors and respective trading volume), we selected twelve countries for the analysis of carbon constraints and pricing as these represent a significant share of the EU trade in the selected industrial sectors. Added to this was the EU itself, in order to have a benchmark to which the carbon constraints could be compared. This ultimately yielded the following 13 countries and country groupings:

5.3 Criteria influencing the analysis and assessment of the ambition level of climate policies for industry

This section describes the criteria that were used to assess the ambition level of climate policies for industry in the EU and its most relevant industrial trading partners. It focuses on the status quo situation (based on the most up-to-date data as of March 2020), but where appropriate also considers past trends and expectations for the foreseeable future (e.g. countries' carbon prices). The analysis provides the basis for the assessment of the competitive situation and the carbon leakage risk of EU industries, which follows in section 5.5.

The criteria used to analyse the ambition level of climate policies for industry can be grouped into three categories:

- Effective carbon prices,
- Energy efficiency standards,
- Air quality standards and other measures

5.3.1 Methodology for the assessment of individual categories

5.3.1.1 Effective Carbon Prices

This section focuses on the application of price-based climate policy instruments – ETS, carbon taxes and specific taxes on energy that are relevant for industry. The assessment conducted in section 5 focuses only on aggregated data from OECD (2018a), which reports the proportion of industry emissions priced at or above certain thresholds: 0€, 5€, 30€ and 60€.[10] The

[10] In this regard, "priced" means that market based instruments from climate policy (ETS, carbon taxes, or specific taxes on energy use) impose a price to the corresponding greenhouse gas emission. If there is more than one instrument imposing a price on the

methodology and data is provided in OECD (2018a) Effective Carbon Rates 2018 (Table 3.4), which is considered the best available data source for comparing the ambition level of price based measures in different OECD countries.[11]

Table 3.4 from OECD (2018a) includes data on 10 of the 12 main trading partner countries of the EU analysed in this report. For the EU, the table includes data on 22 individual member states.[12] Due to lack of information on the remaining EU member states, the average of these 22 individual calculations will in this report be treated as "EU average". To obtain a qualified average, the proportion of priced emissions of these 22 countries is weighted with the total emissions level of the countries' respective industry sectors. This means, for instance, that Germany's average carbon price is weighted almost twice that of Italy's in the EU average due to Germany's higher level of industry emissions. Annex D.2.1 gives an overview of the specific emissions caused by the different industry sectors per country.

In order to find a single average carbon price for industry in each of the countries analyzed[13], a three-step approach was applied, illustrated below using South Korea as an example. In South Korea, 98% of industrial emissions are priced above the benchmark of EUR 0; 97% above the benchmark of EUR 5; 2% above the benchmark of EUR 30 and 2% above the benchmark of EUR 60.

The first step focuses on the percentages of emissions priced between the different thresholds, in order to identify the share of emissions priced between EUR 0 and EUR 5, EUR 5 and EUR 30, EUR 30 and EUR 60, and above 60. Thus, 1% of South Korean industrial emissions are priced between EUR 0 and EUR 5, 95% are priced between EUR 5 and EUR 30, 0% are priced between EUR 30 and EUR 60, and 2% are priced above EUR 60. The remaining 2% of South Korean industrial emissions are not priced. These shares measure the carbon price that applies to the industries in the respective country, irrespective of the type of (pricing) instrument – i.e. an ETS, a carbon tax, or both. They also do not distinguish whether companies or installations receive free allocation – which is indeed common across all ETS that cover industry emissions.

In a second step, the shares of emissions in each category is multiplied with the center value between the thresholds (i.e. EUR 2.5 is then the center value between EUR 0 and EUR 5, EUR 17.5 between EUR 5 and EUR 30, EUR 45 between EUR 30 and EUR 60. All emissions priced at or above the threshold of EUR 60 are valued with EUR 60.

In a third step, the average carbon price is calculated by adding up the results from step two, and multiplying them with the total share of emissions that are priced. This calculation is displayed in Table 10.

specific emission, these prices are summed up to reach the total price, also referred to as the 'effective carbon rate'. It is noteworthy that for ETS the prices of tradable emission permits are taken without considering the allocation method, thus representing the opportunity cost of emitting an extra unit of CO2. Moreover, specific taxes on energy use, which are usually set per unit of energy or physical unit, are translated into effective tax rates based on the carbon content of each form of energy. For more information on effective carbon rates, see OECD (2018), p. 14.

[11] In order to provide additional information on ETS, carbon taxes and taxes on energy use, these measures are analyzed individually within the country analyses in section 4.

[12] The EU member states not included are: Bulgaria, Croatia, Cyprus, Lithuania, Malta and Romania.

[13] The iron and steel, chemical and mineral processing industries account for around two thirds of industrial emissions in the EU ETS. In the other countries considered here, this share is above this in most cases. Only in the USA and Japan is the share lower, accounting for about half of the emissions. Therefore, it is very likely that in the countries considered, carbon prices affecting industry affect burden the same sectors as in the EU ETS.

Table 10: Percentage of South Korean industrial emissions priced against four specific benchmarks (2015 data)

	Benchmark: EUR 0	Benchmark: EUR 5	Benchmark: EUR 30	Benchmark: EUR 60
Emissions priced against benchmark	0,98	0,97	0,02	0,02
Emissions priced between benchmarks	0,01	0,95	0,00	0,02

Using the center value between each of the benchmarks, the effective carbon price is:
(0,01*2,5+0,95*17,5+0,00*45+0,02*60)*0,98 = EUR 17,49

Source: own calculations based on OECD (2018a)

After these three steps, the countries' average carbon prices are compared and translated into a scale from 0 to 10. The highest price receives the maximum of 10 points. All other prices are also expressed as values in relation to that price. This normalisation is necessary to make the results of other categories, i.e. energy efficiency and air quality standards, comparable with the results of the average carbon prices.

5.3.1.2 Energy efficiency standards

In terms of energy efficiency, the assessment conducted in this report is based on three sources, which allow for a comparison of different countries: the "Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018), the "2018 International Energy Efficiency Scorecard" from the American Council for an Energy-Efficient Economy (ACEEE) (Castro-Alvarez et al., 2018), and data on industrial energy use covered by mandatory energy efficiency policies (in 2017) from the International Energy Agency (IEA) (IEA, 2018a).

The RISE database

The RISE database evaluates each country's energy efficiency performance in terms of the policies in place. Hence, it does not score the actual energy efficiency performance of countries. A large advantage of the RISE is its broad coverage, including all countries analyzed in this report.[14] The database evaluates many sub-indicators with a specific scoring system. As some of the indicators are not relevant for measuring the ambition level of energy efficiency policies in the industry sector, we selected a subset of indicators of the RISE database that specifically describes a country's efforts directed at energy efficiency in industry. Of the selected indicators, some are more relevant for the risk of carbon leakage in the industry sector than others. For this reason, the selected sub-indicators were categorized into a) sub-indicators that clearly induce a cost for industrial companies (e.g. standards and regulations on industrial energy efficiency) and b) sub-indicators whose effect on industrial companies is indirect (e.g. information campaigns or specific advice related to energy efficiency in industry). Annex D.2.2 provides an overview of the selected sub-indicators.

Our evaluation conducted in section 5 in general follows the specific scoring system of the RISE database, which is explained in the appendix of World Bank (Energy Sector Management Assistance Program, 2018) and illustrated here in Annex C.1, Table 58.

[14] The RISE score contains 21 EU countries, by which the EU average is calculated. The missing EU countries are the following: Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta and Slovenia.

However, in contrast to their results which are based on equal weights to the above-mentioned categories a) and b), in our analysis we modify these weights as follows: We weigh all sub-indicators of the category a) (i.e. with cost implication) twice as high as those sub-indicators of the category b), i.e. without immediate cost implications. The resulting weights in each (sub-)category and the scores for all analysed countries are presented in Annex C.1 Table 71 ("RISE Score with Ecologic Institute Methodology") Thus, for example, one key category, the Indicator 5 "Incentives and Mandates: Industrial and Commercial End Users", is assigned a maximum of 600 points by us instead of 300 points in the original scores by World Bank.

In total, the selected RISE indicators combined with the adaptation of the scoring system (i.e. different weightings) in our Ecologic Institute Methodology lead to a maximum of 2065 points that can be reached by each country.

Note: The RISE Score only measures whether certain policies – or policy types – exist. It does not cover how ambitious these policies are, or each country's degree of compliance.

ACEEE International Energy Efficiency Scorecard

The ACEEE International Energy Efficiency Scorecard offers another large database on energy efficiency policy and performance worldwide. Compared to RISE, one benefit is that ACEEE covers not only the policies in place (and their ambition), but also indicators related to the performance of countries. As a downside, the country coverage is lower. To avoid double-counting the coverage of policy instruments (which is already included in the RISE database)[15], this analysis therefore considered only the sub-indicators that measure the energy efficiency performance of a country, selecting these from the ACEEE International Energy Efficiency Scorecard. The energy efficiency performance is crucial for international competitiveness since it drives down the production costs per unit, which in turn enables countries' companies to gain competitive advantages.

We follow the evaluation scheme of the original study and assign the same points to each sub-indicator. These sub-indicators are: energy intensity of the industrial sector (maximum of 6 points) and share of combined heat and power (CHP) in total installed capacity (max. 2 points).[16] A detailed overview of the assigned scores per country can be found in Annex C.2, Table 72.

One disadvantage of this database is that it does not include Norway, Singapore and Switzerland. Also, it only includes seven EU countries: Germany, Italy, France, Netherlands, Poland and Spain (United Kingdom was still included at the time of writing); the EU average was therefore calculated on the basis of the EU countries included in the database. Norway, Singapore and Switzerland are not covered by this indicator and therefore will be left out of this indicator's analysis.

[15] According to the policy scores that are part of the ACEEE score, the policies in place in the US and China are comparable: each of the countries scores 9 points in total in the policy section. This is in line with the policy evaluation by RISE, where the US scores only slightly higher than China (see below). By contrast, Japan and the EU perform better in the ACEEE score than they do in RISE when focusing on energy efficiency policies. Japan reaches a total of 14 points, while the EU (based on those European countries included in the ACEEE score) scores a little more than 10 points, placing them slightly ahead of China and the US. The methodology chosen for the overall energy efficiency rating in this analysis (which puts emphasis on the RISE score, in which the US and China perform relatively better) could therefore underestimate the policy performance of Japan and the EU, or exaggerate the difference between the EU and Japan on the one hand and the US and China on the other.

[16] As it is implemented in this study, the ACEEE score is a performance score. The share of CHP in total installed capacity is included, because CHP is more energy efficient. CHP is also commonly applied in industrial installations. However, since the indicator does not provide information about the share of industrial installations in total of CHP usage, this particular subindicator receives a lower weight in our assessnent.

IEA Industrial Energy Use Covered by Mandatory Energy Efficiency Policies

In addition to the RISE and ACEEE datasets, the assessment also covered IEA data on the share of industrial energy use that is covered by mandatory energy efficiency policies (in %). We do not adapt the IEA methodology and simply apply the original values assigned by IEA, i.e. the percentage rate of industrial energy use covered by mandatory energy efficiency policies.

Overall Energy Efficiency Rating

To obtain the overall energy efficiency rating that combines the three sub-indicators, the relative scores of each country expressed as percentages of the maximum points in the ACEEE score and the RISE score as well as the values of the IEA policy coverage indicator are calculated. Then, each of the three indicators receives a specific weight. The RISE score receives twice the weight of the ACEEE score and the IEA indicator, as it provides more detail and comprises a broader range of categories that are important for the evaluation of a country's energy efficiency performance. Thus, for instance, the RISE score covers financial aspects in form of tax incentives or energy efficiency bonds, but also mandatory criteria like audits, tracking reports and defined energy efficiency targets. Finally, the resulting values are aggregated.

In a next step, using the same procedure as with the average carbon rates, the obtained overall energy efficiency score is rated on a scale of 0 to 10, in which the top performing country receives 10 points and all other scores are defined in relation to that.

5.3.1.3 Air quality standards and other measures

The analysis of the air quality standards in each country is based on a large and comprehensive dataset compiled by Kutlar Joss et al. (Kutlar Joss et al., 2017), which covers air quality standards for all countries covered in this analysis. The evaluation included air quality standards for the following pollutants: particulate matter 10 (PM10), PM2.5, ozone (O_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO).[17] Where more recent data was available than that reported by Kutlar Joss et al. (2017), the updated set of standards was applied.

Again, the air quality standards were ranked on a scale from 0 to 10. More specifically, for every pollutant standards were ranked across countries. Where a country did not have a standard for a specific pollutant, it would receive zero points. Some countries have certain standards that are not suitable for a comparison, e.g. because they applied a different categorisation of air pollutants. In this case, the particular standard was not included in the comparative assessment. The overall score of a country is therefore the average of all ranked standards per pollutant. For comparison and evaluation purposes the overall score is ranked on the same scale as the other indicators, i.e. from 0 to 10. For a detailed investigation of the different standards per pollutant and country see Annex D.2.3.

5.3.2 Overall methodology

The purpose of this analysis is to derive one single value that can serve as a measure of each country's ambition level for environmental policy regulation applicable to industrial emitters, in the domains of carbon pricing, energy efficiency and air quality standards. This recognises that, while energy efficiency, air quality and climate protection are separate objectives, they also overlap, and some policy instruments will pay in on all three objectives (as exemplified in the

[17] In the case of air quality standards, climate protection is clearly a co-benefit, since the main objective is to protect health. Generally speaking, tighter air quality standards can be aligned with climate targets, in that they both support a transition from dirtier / fossil to cleaner / renewable fuels, as well as greater efficiency. There are, however, also trade-offs – reducing sulfur dioxide concentrations will actually exacerbate warming, as sulfur dioxide has a cooling effect on the climate. Likewise, in some instances the switch from fossil to renewable may also exacerbate local air pollution, e.g. when switching from natural-gas to solid biomass for generating heat.

European context by the industrial emissions directive). Also, whether policies are framed above all as energy efficiency, air quality or climate policies will differ between countries and within countries over time. For the issue of carbon leakage, it is rather the total burden of environmental regulation that determines a company's investment or production decisions.

Therefore, and similar to the approach in the assessment of energy efficiency policies, the three domains were aggregated with a specific weight for each domain. As it is most directly related to industrial competitiveness, and as it is most clearly related to climate objectives, the domain of carbon pricing is weighted four times as large as each of the other two categories. The other two ambition categories, energy efficiency and air quality standards, receive the same weight (i.e., 80% weight is given to carbon pricing, and 10% each to the remaining categories). As both categories do not give as direct a signal of the cost burden on industry, but rather a measure of the country's overall ambition and the intensity of regulation in the respective domains, they are weighted less than carbon pricing. The weights relate to findings from the European aluminium industry, where the ETS price was found to cost four times as much as the compliance with other environmental EU regulations (Renda et al., 2013).[18] As there are no direct cost estimates on air quality and energy efficiency regulations, these compliance costs estimates serve as an approximation, on which we base our assumption that the carbon price represents the lion's share of firms' compliance costs compared to both air quality standards and energy efficiency measures. Since this is a central assumption, we also provide sensitivity analyses using different weights.

The weighted combination of these domains is summed up in the overall score, which, again, is ranked on a scale from 0 to 10, with the best-in-class setting the benchmark at 10. To ensure that the overall scores are robust, a sensitivity factor is added. The enforcement factor relates to the fact that, while countries may have ambitious standards on paper, they may not enforce them. However, information on the quality of enforcement is typically anecdotal at best, and does not lend itself to a cross-country comparison. We have therefore used two indices – the Corruption Perception Index (CPI) by Transparency International (Transparency International, 2018) and the Doing Business Indicator (DBI) by the World Bank (Energy Sector Management Assistance Program, 2018) – as proxies for the quality and efficiency of the public administration. This is based on the assumption that lower corruption and a more efficient public administration will also, by and large, indicate a better enforcement of existing rules and regulations. Both CPI and DBI are combined (with equal weight) to yield a common, country-specific indicator for the overall stringency of enforcement. By way of a sensitivity analysis, this indicators is then applied to the country scores, in order to test for the reliability of those results, and to yield an adapted version of the score, which accounts for divergences in the quality of enforcement.

[18] It should be noted that, although the approach uses compliance cost estimates as a basis for the weighting this does not amount to calculating a shadow carbon price. Doing so would require estimates of compliance costs for all sectors and considered and for all countries, which was not feasible to derive in the scope of this project. Instead, the approach uses the results from one sector in one region as a proxy, understanding that this proxy is driven by the specific regulatory situation of the EU alumininium industry.

5.4 Carbon pricing and other constraints in the selected countries

5.4.1 Carbon constraints in Brazil (as of December 2019)

Most of Brazil's climate action programs and policies are set within the framework of the National Climate Law 12.187 "*Política Nacional sobre Mudança do Clima*" (PNMC) adopted in 2009 (Presidência de República, 2009). One of the main outcomes of PNMC was the establishment of nine sectoral plans on mitigation and adaptation to climate change, one of which focuses on industrial processes (MMA, 2019).

In its Nationally Determined Contribution (NDC) under the UNFCCC, Brazil has committed itself to reduce its GHG emissions by 37% by 2025 and by 43% by 2030 compared to 2005. The NDC does not mention a separate GHG reduction target for industry. Instead, it states that Brazil intends to promote new standards of clean technology and further enhance energy efficiency measures and low carbon infrastructure in the industry sector (Federative Republic of Brazil, 2016). The only document that mentions a GHG reduction target for Brazil's industry is the 'Sectoral Plan for the Industry' (*Plano Setorial de Mitigação e Adaptação à Mudança do Clima para a Consolidação de uma Economia de Baixa Emissão de Carbono na Indústria de Transformação*), which was published in 2013, i.e. before the NDC was put forward. The plan adopts a preliminary and voluntary commitment to reduce, by 2020, industry emissions related to energy use and industrial processes (including aluminum, lime, cement, pig iron and steel, paper and cellulose, chemicals and glass) by 5 percent compared to the baseline scenario projections (MMA, 2013).

Based on the implemented policies, total GHG emissions are expected to rise at least until 2030, which would be in violation of Brazil's NDC commitments. Current projections estimate an increase of about 4.5% (total GHG emissions, excluding LULUCF) between 2016 and 2023 (Climate Action Tracker, 2019a).

5.4.1.1 Average Carbon Prices

Brazil has neither a carbon tax, nor an emissions trading scheme in place. However, there are taxes on energy use that also apply to the industry sector.

All price based measures together address the following proportion of priced industry emissions in Brazil in 2015: 16 percent of industry emissions have a positive price on emissions, of which 2 percent are priced at or above 5 Euro. Prices above 30 Euro are not recorded (OECD, 2018).[19] These proportions of priced industry emissions add up to an average carbon price of EUR 0.11 for industrial emitters in Brazil.[20] Compared to the other countries analyzed in this report, Brazil ranks 10th out of 13 countries. In 2013, the OECD had noted that two industrial sectors (pulp and paper, cement) in particular face a much lower carbon price than other parts of the economy (OECD, 2013). However, this is similar to the situation in other countries, where these sectors are priced at lower levels. As the OECD states, that is probably due to competitiveness concerns. Therefore, as all countries price both sectors with relatively low rates this should not affect the overall effective carbon price in favor of one particular country.

5.4.1.1.1 Carbon taxes and specific taxes on energy use

The following national energy taxes influence the final energy prices paid by industrial companies in Brazil: a federal fuel tax called CIDE (*Contribuições de Intervenção no Domínio*

[19] A detailed description of carbon pricing gaps is provided in section 3.

[20] A detailed description of the methodology used to calculate the effective carbon price is provided in section 3.

Econômico - Contribution of Intervention in the Economic Domain) and a tax on electricity output. Companies in the industrial sector are obliged to pay the CIDE tax on gasoline and diesel, and the electricity output tax on diesel in case it is used for electricity generation. The main energy source used by the Brazilian industry, biomass, is currently untaxed – just like natural gas and coal (OECD, 2018b).

5.4.1.1.2 Emission Trading Systems

There is no national or regional ETS in place in Brazil.

5.4.1.1.3 Proposals for pricing carbon

Brazil's law on National Climate Policy explicitly mentions the development of "financial and economic mechanisms that are national in scope and referring to mitigation and adaptation to climate change" as well as the establishment of a Brazilian Emission Reduction Market (*Mercado Brasileiro de Redução de Emissões* – MBRE) (EDF et al., 2015).

Thus, different mechanisms to price greenhouse gas emissions, including a carbon tax and an ETS, have been discussed in the past (PMR, 2017). But implementation activities continue: Brazil is currently assessing both pricing instruments with the Ministry of Economy developing different design options and evaluating economic and regulatory impacts (ICAP, 2020a).

Proposals for a carbon tax

According to the Ministry of Finance (*Ministério da Fazenda*, MF), as presented within the World Bank's Partnership for Market Readiness Program, the Brazilian fuel tax CIDE could easily be transformed into a carbon tax. In order to do so, the government would need to „set the rates of CIDE according to the carbon content of each fuel" (PMR, 2017).

Additionally, the Brazilian Forum on Climate Change (*Fórum Brasileiro de Mudanças Climáticas* – FBMC), the official advisory board of the government, also recommends the transformation from CIDE to a carbon tax. However, FBMC mentions the eventual establishment of a national carbon tax, it does not propose any prices: "It is advisable to adopt a low initial threshold, preferably with fiscal neutrality and with the adoption of carbon intensity as a criterion for increasing or reducing taxation" (FBMC, 2018).

Proposals for an ETS

Although Brazil has no carbon market, the country can demonstrate experiences that provide important lessons to control greenhouse gas emissions by certain instruments:

- As one of the major participants in the creation and implementation of the Clean Development Mechanism (CDM) under the Kyoto Protocol, 339 such project activities were implemented in Brazil. Until today, the CDM is the main carbon-market related activity of Brazil (CPLC and CEBDS, 2018).
- Since 2013, the **Center for Sustainability Studies** of the School of Business Administration at the Getúlio Vargas Foundation (FGV) has simulated an Emissions Trading System with Brazilian companies based on cap-and-trade, called the EPC ETS (FGV, 2019).
- Brazil takes part in the Partnership for Market Readiness (PMR) program that is currently developing a proposal for a policy package on an ETS and a carbon tax (I. C. A. P. ICAP, 2019).

Currently the Brazilian government is working on the establishment of a national GHG emissions/removals registry as well as a national GHG Reporting Program (ebd.). A study from BDI (*Banco Interamericano de Desenvolvimento*) about the carbon market potential in Brazil summarizes different analyses about the possible implementations of carbon markets in the State of São Paulo (Ludena et al., 2015).

5.4.1.2 Energy efficiency standards

According to the recent national Energy Plan (*Plano Decenal de Expansão de Energia* – PDE), the industrial sector is the largest consumer of final energy of all economic sectors – accounting for about 45% in 2018 (37.2% in 2009). Electricity is the main source, accounting for 17% of the energy consumption in the industrial sector in 2018. In future years the total energy consumption is projected to increase by 2.3% per year on average. According to recent estimates, industry will be responsible for more than 46% of the country's final energy consumption in 2022 (MME and EPE, 2017).

Energy Efficiency Policies

With the adoption of the Energy Efficiency Act (*Lei de Eficiência Energética*, 10.295) in 2001, an interministerial Committee (*Comitê Gestor de Indicadores e Níveis de Eficiência Energética* - CGIEE), chaired by the Ministry of Mining and Energy (*Ministério de Minas e Energias* - MME), was mandated to introduce national efficiency standards (Ministério de Minas e Energia, 2001). The CGIEE is tasked with coordinating and monitoring various efficiency programs as well as updating existing norms and defining new ones. For instance, the Brazilian Labelling Program (*Programa Brasileiro de Etiquetagem* - PBE) is responsible for providing information on product performance, but mostly with a focus on the private consumer. The same is true for the National Energy Conservation Etiquette (*Etiqueta Nacional de Conservação de Energia* – ENCE), a mandatory label for all electronic devices, such as air conditioners, heaters and coolers (INMETRO, 2013, n.d.).

In 2008, the National Plan on Energy Efficiency (Plano Nacional de Eficiência Energética - PNEf) was published. According to this plan, Brazil intents to save up to 10% energy by 2030 (cumulative energy savings of 107 TWh from 2010 to 2030 - IEA 2018) to avoid approximately 30 million tCO_{2e} of emissions. Although the importance of energy efficiency for the industrial sector is highlighted in PNEf, no clear sectoral reduction target is mentioned. Several measures are named, but they are voluntary (Ministério de Minas e Energia, 2008).

The PNE is a long-term strategy for 2030 and 2050 that includes trends and projections on energy development in Brazil. The PNE 2030 sets the same target as the PNEf for energy savings. Additionally, different socio-economic scenarios and their impacts on efficiency goals are presented. Here, an increase of energy intensity between 2.6% and 4.4% per year is foreseen, depending on the population growth and economic development. The PNE for 2050 is still under elaboration (Ministério de Minas e Energia, 2007).

According to the IEA, Brazil saved 5% of additional final energy use in 2017 compared to 2000 due to energy efficiency gains. About 60% of these energy savings happened in the industry and service sector due to economic movement from energy-intensive industries to less-intensive manufacturing (IEA, 2018b).

Energy Efficiency Rating

Mandatory energy efficiency policies cover seven percent of industrial energy consumption (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and on the existence of energy efficiency policies (RISE indicators) (see Chapter 5.3). Brazil receives 1.5 out of 8 possible points for its industrial energy efficiency (19%) and 1245 out of 2065 possible points for the energy efficiency policy landscape (60%). Thus, Brazil ranks 8th out of 13 in industry energy efficiency performance and 10th out of 13 for its energy efficiency policies. Table 11 provides an overview of the country's performance in each of the selected sub-indicators for the RISE indicator.[21]

Table 11: RISE Indicator Score for Brazil

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	100/140	71%
EE Entities	75/75	100%
EE Incentives from Electricity Rate Structures	100/200	50%
Incentives & Mandates for Industrial and Commercial End Users	0/600	0%
Financing Mechanisms for EE	50/50	100%
Minimum EE Performance Indicators	520/600	87%
Energy Labelling Systems	400/400	100%
Overall	1245/2065	60%

Source: Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

According to the IEA, Brazil's increasing economic activity has been offset by structural changes and efficiency improvements. For example, in industry the strengthening of minimum energy performance standards (MPES) for electric motors is forecast to save over 11TWh of electricity between 2019 and 2030. Still, there remain large improvements for energy savings: in the industrial sector, the biggest opportunities are in the pulp & paper and the iron & steel manufactures. Metal recycling and the adoption of energy management systems present further potentials (IEA, 2018).

5.4.1.3 Air quality standards

Air quality standards

Legal and mandatory air quality standards have been in place since 1990, when Resolution 003/90 was introduced (Ministério do Meio Ambiente, 1990). The standards set by the Resolution were applied until November 2018, when the Brazilian Commission agreed on new criteria (Felin, 2018).

National air quality standards in Brazil are only binding in the absence of regional standards. Today, two out of 27 federal states have additional mandatory standards: São Paulo adjusted its benchmarks in 2013 on the basis of the WHO standards. Likewise, Espírito Santo established local air quality standards in 2013, which partly even exceed WHO standards (Governo do Estado do Espírito Santo, 2013; São Paulo Governo do Estado, 2013).

Table 12 provides an overview of Brazil's air quality standards for the most relevant air pollutants.

[21] For a detailed description of the sub-indicators of the RISE indicator see Annex C.2.2.

Table 12: Federal Air quality standards in Brazil

Pollutant		National level (µg/m³)	São Paulo Level (µg/m³)	Espírito Santos (µg/m³)
particulate matter (PM10)	Annual Daily	40 120	40 120	45 120
particulate matter (PM2.5)	Annual Daily	20 60	20 60	- -
ozone (O3)	8-hr-daily Hourly	140 160	140	140
sulphur dioxide (SO2)	Annual Daily Hourly	40 125 80	40 60	40 60
nitrogen dioxide (NO2)	Annual Daily Hourly	60 N/A 260	60 260	50 240
carbon monoxide (CO)	Daily 8-hr-daily Hourly	N/A 9 N/A	9	-

Source: (Governo do Estado do Espírito Santo, 2013; Ministério do Meio Ambiente, 2018; São Paulo Governo do Estado, 2013)

A resolution from 1989 (005/89) determines the monitoring of air pollution on federal level. However, only 9 out of 27 states monitored their air quality in 2018 (Instituto du Energia e Meio Ambiente, 2018). The lack of monitoring and sanctions as well as the low standards lead to extremely high pollution rates, especially in cities and industrial regions (Felin, 2018).

Further information:

The 2018 federal elections have moved Brazil further away from its climate action commitments: recent announcements made by the new government justify concern about the future development of climate policy in Brazil. In order to achieve its national and international pledges, the country will need to sustain and strengthen mitigation policies in all sectors (Climate Action Tracker, 2019a).

5.4.2 Carbon constraints in China (as of March 2020)

China officially “launched” a national ETS in December 2017, but a carbon market involving trading of emissions permits at the national level has been delayed ever since. In 2020, the ETS is expected to start with a simulation phase (i.e. a trial or pilot phase) lasting at least one year, after which only the power sector will be covered by a carbon cap. Seven additional sectors - including the types of industrial production relevant to this study – will be included eventually, but the timeline remains unclear.

Meanwhile, eight subnational carbon markets (most of which have started between 2013 and 2014) continue to operate in Shenzhen, Beijing, Shanghai, Guangdong, Tianjin, Hubei, Chongqing, and Fujian. They each differ in terms of design components including sectors covered, allowance allocation, and offset use.

Air quality standards feature prominently among China's longstanding environmental policies that have a bearing on effective carbon constraints. More recently, market-based approaches have been added to the broader policy mix for energy, climate and air pollution - these include a renewable energy quota, "green certificates," and a programme to promote zero-emission vehicles – all of which involve the trading of credits that have monetary value.

5.4.2.1 Effective Carbon Prices

While regional ETS are in place and the national ETS is being developed, China does not have a carbon tax in place. Moreover, it implemented a differentiated fee on energy use that also applies to the industry sector (see next section 4.2.1.1).
All price based measures together yield the following proportion of priced industry emissions in China in 2015: 19 percent of industry emissions are priced above EUR 0, 2 percent are priced at or above EUR 5, 2 percent are priced at or above EUR 30 and 1 percent is priced at or above EUR 60 (OECD, 2018).[22] These proportions of priced industry emissions add up to an average carbon price of EUR 0.28 for industrial consumers in China.[23] Compared to the other countries analysed in this report, China ranks 9th of 13.

5.4.2.1.1 Carbon Taxes and Specific Taxes on Energy use

There is a differentiated fee on electricity use, targeted at increasing energy efficiency. In 2004, the National Development Reform Commission (NDRC) established a fee with the goal of phasing out energy inefficient enterprises and encouraging more efficient ones. The policy differentiates electricity prices for industrial companies, grouping them into four categories based on their level of energy efficiency: "encouraged", "permitted", "restricted" and "eliminated" (Database, 2011). In 2013, companies in the "encouraged" and "permitted" categories paid the regular price applicable to their respective geographical area, which is highly regulated by the NDRC. Companies classified as "restricted" or "eliminated" pay this regular price plus an additional fee of EUR 0.013 per kWh (0.1 CNY/kWh) or EUR 0.039 per kWh (0.3 CNY/kWh) respectively. The cement industry is charged with a surcharge of EUR 0.05 per kWh (0.4 CNY/kWh). Further, different provinces have introduced price exceptions for the aluminium sector in particular. Reductions range between EUR 0.002 per kWh (0.017 CNY/kWh) and EUR 0.01 per kWh (0.1 CNY/kWh) (Fraunhofer ISI and Ecofys, 2015). Until today, no adjustments of this price have been reported.

The average electricity price for industrial consumers in 2014 was 91 EUR/MWh, 69% of what industrial consumers in the EU paid at the same time (Bloomberg New Energy Finance, 2016).

5.4.2.1.2 Emission Trading Schemes

5.4.2.1.2.1 National ETS

The Chinese government has been making plans for a national ETS for several years: in February 2013, its National Development and Reform Commission (NDRC) submitted a "Market Readiness Proposal" to the World Bank outlining considerations for such a programme (World Bank PMR Partnership Assembly, 2013). In 2015, president Xi announced at a US-China climate change event that the ETS would enter into force in late 2017. In December 2017, the government announced the "start" of the ETS by publishing an official guidance document (ICAP, 2020b).

[22] A detailed description of carbon pricing gaps is provided in section 3.

[23] A detailed description of the methodology used to calculate the effective carbon price is provided in section 3.

However, while elements of the ETS infrastructure (such as the registry or MRV rules) have been developed since, the programme has not actually started to operate – regulators require more time to work on its design.

All pilot ETS are to be incorporated into the national ETS so there are no plans for linking any of the pilots to each other. However, there has been logistical progress toward a unified national ETS based on the infrastructure established in the pilots. Concrete plans for the national allowance registry and exchange are in place, as confirmed by the fact that Hubei Emission Exchange (the provincial trading platform responsible for developing the national allowance registry) selected a provider for registry infrastructure with a clearing function in 2018 - unlike in other ETS, this transaction clearing function will be associated with the registry rather than with the national exchange. The Shanghai Environment and Energy Exchange is the entity responsible for developing the national trading platform.

A simulated trading scheme (similar to a trial run or pilot, but voluntary) involving only electricity generators is expected to begin in 2020, and once emissions monitoring procedures for that are seen as sufficiently established, the "real" market will be launched. Observers currently expect this to occur sometime in 2020, as the simulation phase was planned to run throughout 2019 (Carbon Pulse, 2018a). This timeline is likely to be pushed back further, given that China completely re-organised its government competencies for environment and climate in 2018: it moved climate change mitigation (and all related policies, including the ETS) from the purview of the powerful but thinly-spread NDRC to that of a newly created Ministry of Ecology and Environment (MEE). This change represents a massive shift in expertise that will take time to implement, and must be undertaken at the subnational level as well because provincial government departments largely mirror their national counterparts.

Meanwhile, the eight pilot ETS continue operating. As it is unclear when the national programme will begin, it also remains unclear whether and how the pilots will continue to operate, possibly with smaller sectoral coverage, and whether emitters will be able to carry over their allowances into the national ETS.

The Chinese government's original plans for the national ETS had involved eight economic sectors to be covered by the ETS: power, petrochemicals, chemicals, building materials,[24] iron and steel, non-ferrous metals, paper production, and domestic aviation. So-called new energy vehicles (electric and hybrids) are to be covered eventually as well. While the December 2017 "launch" only focused on electricity generators only, the government underlined their intent to include the remaining sectors eventually: the government requested companies above the scheme threshold in all the originally included sectors to submit emissions data for 2016, 2017 and 2018 (Carbon Pulse, 2019). If the eight original sectors are included, the ETS will eventually regulate CO_2 emissions from around 7,000-8,000 companies emitting around 4-5 billion tonnes of CO_2 annually (Qi and Cheng, 2018). The power sector only would already cover 1,700 companies and 3 to 3.3 billion tonnes of CO_2.

Draft regulations by the National Development and Reform Commission (NDRC) indicate that only CO_2 will be covered, that allocation will be free in early years but shift to a benchmarking system as better emissions data becomes available.

[24] As the definition of "building materials" remains unclear, the glass and ceramics manufacturing industry might be (partly) covered by the national ETS. China is the EU's main trading partner for both ceramics and glass. The name of this sector has also been translated as "non-metallic minerals" (Qi and Cheng, 2018) which would also include ceramics and glass.

Price

Given the uncertainties, forecasted allowance prices for the national ETS range widely. A survey conducted in July 2018 by the China Carbon Forum among 317 of stakeholders from Chinese industry and the Chinese carbon market expert community resulted in prospective allowance price estimates averaging CNY 51 (EUR 6.53) in 2020, rising to roughly CNY 86 (EUR 11.01) in 2025 (De Boer et al., 2015).

Percentage of industrial emissions covered within country

Since it remains unclear which industrial sectors will be included in the national ETS at what time, the share of total emissions covered over time is also uncertain. Greater clarity exists as to how much of China's total emissions the industrial sectors to be covered altogether account for: according to 2016 estimates, the total emissions of the eight sectors mentioned above make up 45–50% of China's total emissions (Qi and Cheng, 2018). Goulder et al cite the NDRC's May 2017 draft National Allocation Plan as indicating that the power, cement, and aluminum sectors alone account for approximately 40% of China's current CO_2 emissions (Goulder et al., 2017). Which share of the industry sectors' emission will subsequently be covered by the national ETS is still unknown.

Allocation of free allowances

As stated above, it is expected that allowances will be allocated for free, initially based on grandfathering and then shifting to a benchmarking system once emissions data availability is more profound.

Flexibility

The programme is expected to allow banking across compliance phases (which have not yet been determined) but not borrowing from future compliance phases.

Compliance and enforcement

Reporting is likely to be done on an annual basis. Enforcement will involve provincial governments requiring penalties up to five times the market price of permits for non-compliance.

Proposals for linking

There are no plans to link China's eventual national ETS with any other ETS.

5.4.2.1.2.2 Regional ETS

Eight regional pilot ETS are currently in force in China, with most having started between 2013 and 2014. Five cities (Beijing, Shanghai, Shenzhen, Tianjin and Chongqing) and three provinces (Hubei, Guangdong, and Fujian) operate these sub-national programmes. Taken together, these jurisdictions represent 31% of China's 2017 GDP according to its national statistics bureau.

Allowance prices in the seven ETS ranged from around EUR 1 per tonne CO_2 in Shanghai and Chongqing in 2016 to a peak of EUR 10.6 per tonne CO_2 in Shenzhen in 2013 (Wenbo and Noi, 2016). In the majority of pilot ETS, prices peaked shortly after establishment in 2013 and 2014 and then declined continuously. Current prices exceed EUR 6 in only one programme (Beijing), with Shanghai and Hubei featuring prices around EUR 4-5 and all others less than that (Refinitiv CMM November 2018).

Since all pilot ETS were designed locally and regional circumstances were taken into account, they differ in various design aspects. Compliance thresholds for industrial facilities range from 3,000 and 5,000 tCO_2 per year in Shenzhen and Beijing (respectively) to 60,000 tCO_2 per year in

Hubei. All other ETS set their thresholds for industrial facilities at 20,000 tCO_2 or 10,000 tonnes of coal equivalent (tce) per year. Carbon Offsets (China Certified Emission Reduction credits) are allowed in all pilots, but their share is limited to 5% in Beijing and Shanghai, to 8% in Chongqing and to 10% in all other pilots. Banking within the trading period is allowed in all pilots, while borrowing is not. Moreover, all pilot ETS oblige the covered entities to report their emissions annually and require third-party verification. Table 13 displays other key policy features, highlighting similarities and differences among the ETS.

Table 13: Regional ETS in China

	Beijing	Chongqing	Fujian	Guangdong	Hubei	Shanghai	Shenzhen	Tianjin
Reduction goal (intensity-based)	20.5% over 2015 levels; absolute cap: ~50 $MtCO_2eq$	19.5% over 2015 levels; absolute cap: ~100 $MtCO_2eq$	19.5% over 2015 levels; absolute cap of ~200MtCo2e	20.5% over 2015 levels; absolute cap: 422 $MtCO_2eq$ (excl. white cement)	19.5% over 2015 levels; absolute cap: 257 $MtCO_2eq$	20.5% over 2015 levels; absolute cap: 158$MtCO_2eq$	45% over 2005 levels; absolute cap: 31.45 $MtCO_2eq$ Peak GHG emissions by 2022	20.5% over 2015 levels; absolute cap: 160-170 MtCO2eq
Trading period	2013-2019[25]	2013-2019[33]	2016-2019[33]	2013-2019[33]	2014-2019[33]	2013-2015[33]; 2016-(no specific ending year)	2013-2019[33]	2013-2019[33]
GHG covered	CO2 (direct and indirect)[26]	CO2 (direct and indirect), CH4, N2O, HFCs, PFCs, SF6	CO2 (direct and indirect)	CO2 (direct and indirect)	CO2 (direct and indirect)	CO2 (direct and indirect)	CO2 (direct and indirect)	CO2 (direct and indirect)
Sectors covered	Power and heat, cement, petrochemicals, manufacturers, other industrial enterprises, the service sector	Power, electrolytic aluminum, ferroalloys, calcium carbide, cement, caustic soda, iron and steel.	Electricity, petrochemicals, chemicals, building materials, iron and steel, non-ferrous metals, pulp and paper,	Power, iron and steel, cement, petrochemicals, aviation, paper and white cement	Power and heat, iron and steel, non-ferrous metals, petrochemicals, chemicals, chemical fiber, cement, glass	Airports, aviation, chemical fiber, chemicals, commercial, power and heat, water suppliers, commercial,	Power, water, gas, manufacturing sectors, buildings, port and subway sectors, public buses and other	Heat and electricity production, iron and steel, petrochemicals, chemicals, exploration of oil and gas.

[25] Initially, the seven regional ETS were planned to transit into a national ETS in 2016. However, as the start of the national ETS was delayed, pilots continue operating until then and are expected to operate parallel to the Chinese carbon market. Over the medium to long term, it is expected that the regional ETS will be fully integrated into the national market.

[26] In contrast to the EU ETS, entities in the Chinese pilot ETS are liable not only at the point of emission, but also upstream in case the energy source they use is electricity or heat. For a more detailed explanation of this procedure see (Healy et al., 2016).

	Beijing	Chongqing	Fujian	Guangdong	Hubei	Shanghai	Shenzhen	Tianjin
	and public transport		power, aviation, ceramics		and other building materials, pulp and paper, ceramics, manufacturing, food, beverage and medicine producers	hotels, financial, iron and steel, petrochemicals, ports, shipping, non-ferrous metals, building materials, paper, railways, rubber, and textiles.	non-transport sectors	
Cap coverage (in percent of total emissions)	45%; 943 entities	50%; 195 entities	~60%; 255 entities	60%; 249 existing entities, 39 new entrant entities	~45%; 344 entities	57%: 298 entities	40%; 794 entities	55%; 109 entities
Allowance Allocation	Mainly free allocation through grandfathering; baseline years: 2009-2012 (stationary sources) or 2013-2016 (mobile sources) Benchmarking for entities with expanded capacity and new entrants	Free allocation through grandfathering; baseline years: 2008-2012. If sum of allocated emissions exceeds cap, reduction factor is applied. Ex-post adjustments possible	Benchmarking is applied to electricity, cement, aluminum, and plate glass sectors. The other sectors are allocated allowances based on historical intensity. Free allowances are also to be allocated to new entrants while they are only	Mainly free allocation (95% for power sector, 97% for remaining sectors) based on grandfathering, historical intensity. Benchmarking for coal or gas fired electricity generators (incl. heat and combined heat and power), certain cement	Free allocation (2016 vintage) through benchmarks for power, heat, co-generation and cement (except entities using outsourced clinker) Historical carbon intensity method for glass and other building material and ceramics sectors	Free allocation of 2017 vintage allowances through benchmarks for power, heat, co-generation, and cement (except the entities using outsourced clinker). Historical emissions intensity for glass and other building materials, pulp	Free allocation based on sector-specific benchmarks (power, heat, manufacturers), historic emissions intensity (industry, aviation, car glass, ports, shipping, and water suppliers, generally based on 2014-2016 data), or	Allowances are largely distributed for free. Benchmarking is applied to the water, power, and gas sectors based on sectoral historical emissions intensity. Grandparenting is applied to port and subway sectors,

	Beijing	Chongqing	Fujian	Guangdong	Hubei	Shanghai	Shenzhen	Tianjin
			covered after 12 or 24 months of operation.	and industrial iron and steel processes and relevant for new entrants	Grandfathering (baseline years: 2013-2015) for all other sectors Ex-post adjustments possible	and paper, and ceramics sectors; grandparenting based on previous three years' historic emissions for all other sectors. Ex-post allocation adjustments are possible.	historic emissions (buildings, commercial sector, industry with complex products or considerable change in emission boundary, and airports, generally based on 2014-2016 data). Ex-post allocation adjustments possible for those with historic intensity or benchmarking allocations.	public buses, and other nontransport sectors based on the entity's historical emissions intensity. Allowance allocation is adjusted ex-post based on output data.

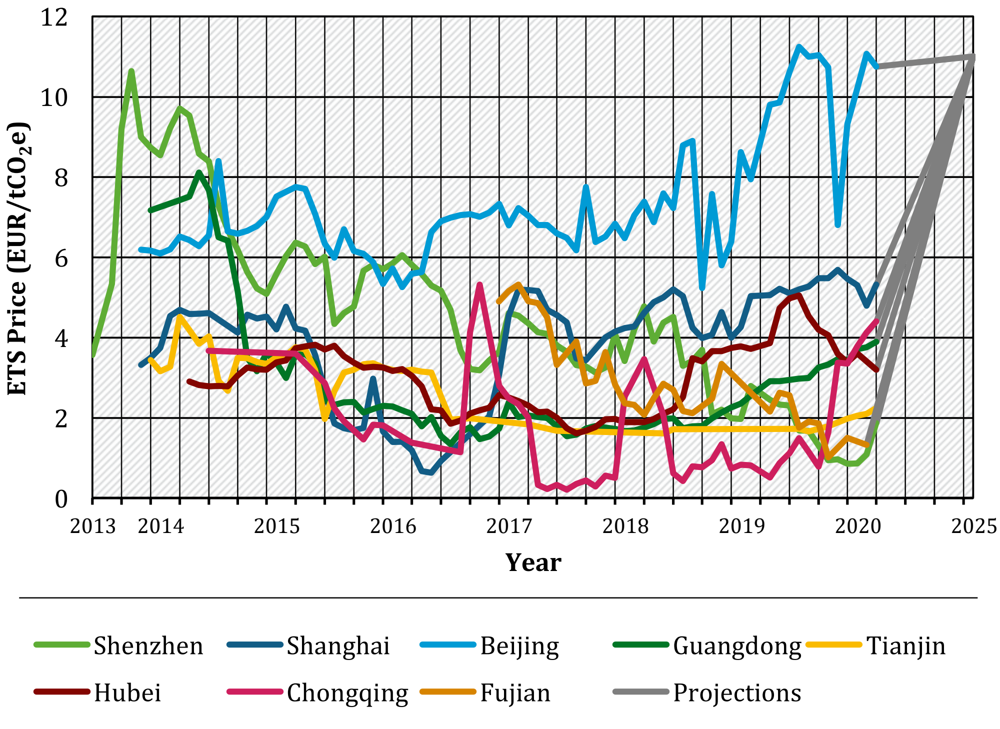
Source: based on (Swartz, 2016) and (ICAP, 2019a, 2020c, 2020d, 2020e, 2020f, 2020g, 2020h, 2020i, 2020j)

Prices

Shenzhen was the first jurisdiction to implement a regional ETS with a starting price of around 3.5 EUR per tonne CO_2. Shortly after the introduction the price increased to 10.6 EUR/tCO_2 in October 2013. Since then the price steadily decreased to around 1.9 EUR/tCO_2 in March of 2020. Shenzhen was followed by the two regional ETS of Shanghai and Beijing. Both trading systems were implemented in November 2013. While the allowance price in Shanghai started at 3.3 EUR/tCO_2, the price for one allowance in Beijing was 6.2 EUR/tCO_2. The ETS market in Beijing developed at relatively constant prices with few ups and downs. Today, the price is the highest among the different regional ETS in China with around 11 EUR/tCO_2. After a steady decrease, Shanghai's allowance price increased to 5.3 EUR/tCO_2 in the beginning of 2020. In Hubei allowance price increased from 2.9 EUR/tCO_2 in April 2014 to 3.2 EUR/tCO_2 in March 2020, in Chongqing from 3.6 EUR/tCO2 in June 2014 to 4.4 EUR/tCO2 in March 2020. All other regional trading scheme (Guangdong, Tianjin, Fujian) experienced a price decrease from their first implementation until today.

A recent survey conducted by the China Carbon Forum yields a projected allowance price of 6.53 EUR/tCO_2 in 2020 and 11 EUR/tCO_2 in 2025 for a national ETS, which still needs to be fully established.

Figure 6: Regional ETS Allowance Prices in China



Source: (ICAP, 2020k)

Percentage of industrial emissions covered within country

According to OECD (2018, p. 81) 10.2% of China's emissions from industrial production were covered by the (then seven) pilot ETS in 2015. In terms of emissions, combining all regional caps, the pilots cover a total of 1,383.45 MtCO_{2e}, which translates into 12.7% of China's overall greenhouse gas emissions (ICAP, 2019a; Muntean et al., 2018).

Allocation of free allowances

For existing covered entities, the Chinese pilots most commonly apply emission-based grandfathering – meaning allocations based on historical emissions data. However, these are typically subject to significant ex-post adjustments (based on e.g. current production levels) given that output can vary strongly in many of the covered sectors and the quality of historical emissions data is inconsistent across companies.

For new facilities built by existing covered entities, nearly all pilot ETS provide free allowances. For these, they use either production-based benchmarking applying a sector-wide intensity standard (Beijing, Tianjin, Shenzhen and Guangdong) or emission-based allocation applying changes to emission levels relative to initial allocations (Shanghai and Hubei). Whether new entities (i.e. new enterprises) are covered varies by pilot: Beijing, Guangdong, and Shenzhen have covered them and adopted the same free allocation methods as for new facilities - Shanghai, Chongqing, and Hubei have not included new enterprises in their coverage (Pang and Duan, 2016).

For details on individual pilots' allocation amounts and benchmarking methodologies, refer to the allocation row of Table 13 in this section.

Flexibility

All pilot ETS allow banking to some extent but do not allow borrowing.

Compliance and enforcement

Table 14: Compliance and Enforcement in regional ETS

Pilot	Compliance	Enforcement
Beijing	Annual reporting, third party verification required	Penalties for failing to submit emissions or verification reports on time can result in fines up to 50,000 CNY. Failing to surrender enough allowances to match emissions means fines three to five times the average market price over the past six months for each missing allowance
Chonqing	Annual reporting, third party verification required	No financial penalties for non-compliance. Punishments may include media reporting and public exposure of the non-compliance; disqualification from subsidies.
Fujian	Annual reporting of CO2 emissions before end of February. Third party verification required by end of April.	Companies failing to surrender enough allowances to match their emissions are fined between one to three times the average market price of the past 12 months, with the maximum limit of CNY 30,000. Twice the amount of the missing allowances can be withdrawn from the account of the company or deducted from next year's allocation.
Guangdong	Annual reporting, third party verification required	Penalties for failing to submit emissions or verification reports on time range from CNY 10,000 to CNY 50,000. Firms failing to surrender enough allowances to match their emissions are deducted twice the amount of allowances from the following year's allocation and are fined CNY 50,000.

Pilot	Compliance	Enforcement
Hubei	Annual reporting, third party verification required	Companies that fail to surrender enough allowances to match their emissions are deducted twice the amount of allowances from next year's allocation and are fined one to three times the average market price for every allowance, with a maximum limit of CNY 150,000
Shanghai	Annual reporting, third party verification required	Between CNY 50,000 – CNY 100,000 can be imposed for non-compliance, besides surrendering the adequate amount of allowances.
Shenzen	Annual reporting, third party verification required	Companies failing to surrender enough allowances to match their emissions are fined three times the average market price of the past six months. The missing allowances can be withdrawn from the account of the company or deducted from next year's allocation.
Tianjin	Annual reporting, third party verification required	There are no financial penalties for non-compliance. Companies are disqualified for subsidies and other financial support policies for three years.

Source: based on (Swartz, 2016) and (ICAP, 2019a, 2020c, 2020d, 2020e, 2020f, 2020g, 2020h, 2020i, 2020j)

Proposals for linking

As mentioned, the Chinese government plans on implementing a nationwide trading scheme. Since all regional pilot ETS are supposed to be transitioned into the national ETS, there is no intent and no perspective to link the regional trading schemes with other markets.

5.4.2.1.3 Proposals for pricing carbon

There are no carbon pricing proposals beyond the national ETS and the ETS pilots described above. There is movement, however, in Taiwan, which the Chinese government considers part of China. Taiwan intends to implement an ETS: a law on greenhouse gas reduction passed by Taiwan's government in 2015 foresees a domestic (Taiwanese) cap-and-trade programme to meet its long-term goal of cutting greenhouse gas emissions by 50 percent from 2005 levels by 2050. In November 2018, Taiwan's environmental administrators proposed draft reduction targets in five-year increments, starting with the 2016-2020 period. This would involve a two percent reduction from 2005 levels by 2020, a 10 percent reduction by 2025, and 20 percent by 2030. The targets would be reviewed two years ahead of the start of each period. Though it is implied that the targets will be reached with an ETS, officials have yet to indicate a start date for carbon trading. Given the lack of ETS infrastructure, a Taiwanese carbon market is unlikely to emerge within the next few years: the government has not finalized a legal framework for the ETS or decided on its design including allocation or offset eligibility. As of now, there is also no exchange on which carbon allowances could be traded.

5.4.2.2 Energy efficiency standards

China's energy consumption steadily increased in the last three decades. Especially since 2003 the country experienced significant annual growth rates in energy consumption (IEA, 2019a). At the same time, China's energy intensity remains relatively high compared to industrialized countries. In order to reduce energy consumption and increase energy efficiency, the Chinese government implemented various policies.

Energy Efficiency Policies

In its 13th five-year development plan (FYDP 2016-2020), China set a goal of increasing the share of non-fossil energy in total primary energy consumption by three percent between 2015 and 2020, leading to a total share of 15% in 2020 (The Central People's Government of the People's Republic of China, 2016). The plan also requires a reduction in energy consumption per unit of GDP by 15% and of CO_2 emissions per unit of GDP by 18% over this time period. The energy intensity of the Chinese economy still differs from that of industrialised economies: in 2014, the Chinese economy needed double the amount of energy to produce a unit of GDP as the EU did (World Bank, 2018a).

The 13th FYDP is the first to include an *absolute* limit on energy consumption: against a planned annual GDP growth rate of 6.5%, total Chinese energy consumption may not exceed 5 billion tonnes of coal equivalent (t_{ce}) in 2020, which translates to around 3,500 mt_{oe} (Hall, 2017). The EU's absolute target is 1,474 mt_{oe} - given that China's population is nearly 2.5 times that of the EU, the requirement implies lower per capita energy use in China than in the EU in 2020.

According to the IEA, China has achieved huge efficiency improvements since 2000. Increased economy activity in the last decade would have tripled China's primary energy demand without the impact of efficiency measures and structural change. Overall, China saved 12% of additional final energy use due to energy efficiency gains. About 80% of this impact happened in the industry and service sector (IEA, 2018c), where mandates for the largest industrial consumers have been instituted (Foster et al., 2018).

Still, the largest opportunities for energy savings remain in the industry (42%): the less intensive sectors – such as food, beverage and textile – have the biggest potential in reducing energy use between 2018 and 2040. In the iron and steel manufacturing, energy intensity could fall by 35% - particularly due to increased metals recycling. An improvement of motor-driven systems as well as the adoption of management systems is central for realizing efficiency gains (IEA, 2018c).

Energy Efficiency Rating

Mandatory energy efficiency policies cover 68 percent of industrial energy use (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and the completeness of its energy efficiency policy landscape (RISE indicators) (see Chapter 3). China receives 1 out of 8 possible points for its industrial energy efficiency (13%) and 1918 out of 2065 possible points for the energy efficiency policy landscape (93%). Thus, China ranks 10th out of 13 in industry energy efficiency performance and second of 13 for its energy efficiency policies. Table 15 provides an overview of the country's performance in each of the selected sub-indicators of the RISE indicator.[27]

Table 15: RISE Indicators Score of China

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	140/140	100%
EE Entities	75/75	100%
EE Incentives from Electricity Rate Structures	133/200	67%
Incentives & Mandates for Industrial and Commercial End Users	600/600	100%

[27] For a detailed description of the sub-indicators of the RISE indicator see section 3.

RISE Sub-Indicator	Absolute score	Relative score
Financing Mechanisms for EE	50/50	100%
Minimum EE Performance Indicators	520/600	87%
Energy Labelling Systems	400/400	100%
Overall	1918/2065	93%

Source: Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

5.4.2.3 Air quality standards

Air quality standards

China's Air Quality Standards are not uniform across the nation, but include dedicated standards and timelines for certain metropolitan areas to prioritize regions where pollution is worst. The standards are also divided into "Class 1" for special regions like national parks and "Class 2" for all other areas. Nationwide implementation of the current standard was completed in 2016. For the evaluation of China's ambition air quality standards, only the "Class 2" indicators were considered, which are more relevant for industrial production sites.

Table 16 provides and overview of China's air quality standards for the most relevant air pollutants.

Table 16: Air quality standards in China

Pollutant		Level of the standard (µg/m^3)	Scope of the standard
particulate matter (PM10)	Annual Daily	40 50	National Class 1
	Annual Daily	70 150	National Class 2
particulate matter (PM2.5)	Annual Daily	15 35	National Class 1
	Annual Daily	35 75	National Class 2
ozone (O3)	8-hr-daily Hourly	100 160	National Class 1
	8-hr-daily Hourly	160 200	National Class 2
sulphur dioxide (SO2)	Annual Daily Hourly	20 50 150	National Class 1
	Annual Daily Hourly	60 150 500	National, Class 2
nitrogen dioxide (NO2)	Annual Daily Hourly	40 80 200	National, classes 1 and 2

Pollutant		Level of the standard (µg/m³)	Scope of the standard
carbon monoxide (CO)	Daily	4	National, classes 1 and 2
	8-hr- daily	N/A	
	Hourly	10	

Source: (Kutlar Joss et al., 2017; TransportPolicy, n.d.)

5.4.3 Carbon constraints in the European Union (as of February 2020)

The EU has agreed on several short-, mid- and long-term energy and climate targets to guide the transformation towards an energy-efficient and low carbon economy. These strategies include (inter alia): legally binding targets to cut greenhouse gases by 20% in 2020 and by at least 40% in 2030, to put the EU in position to achieve a reduction of greenhouse gas emissions by 80 to 95% in 2050 (all from 1990 levels); a binding target of producing 20% of EU energy from renewables in 2020 and at least 27% in 2030; and to reduce energy consumption by 20% in 2020 and an indicative target to reduce energy efficiency by at least 27% in 2030. Moreover, the European Parliament, the Commission and the Council reached political agreement on 14. June 2018 to raise the 2030 renewable energy target to 32% and to raise the indicative 2030 energy efficiency target to 32.5%, and make it legally binding.

The EU's emission targets are divided into sub-targets for the sectors included in the EU Emissions Trading Scheme (EU ETS), and the (remaining) sectors, which are regulated by the "Effort Sharing Regulation" (ESR). EU industrial emissions are part of the EU ETS, which faces greenhouse gas reduction targets of 21% in 2020 and 43% in 2030 (from 2005 levels). The EU ETS is thus the main instrument for reducing industrial emissions in the EU.

5.4.3.1 Effective Carbon Prices

The EU has an emissions trading system in place since 2005. Moreover, the EU sets minimum rates for the taxation of EU energy products. In addition to that, different EU member states impose higher taxes on energy use that also apply to the industry sector, leading to different proportions of priced industry emissions in all member states. Therefore, the OECD's report on effective carbon rates has not calculated the proportions of emissions priced at or above specific benchmarks for the EU as a whole, but instead provides individual calculations for the 22 EU member states that are also OECD members.[28] On average, these individual calculations lead to the following results, which will in this analysis – due to a lack of information on the remaining member states – be treated as "EU average": 80 percent of industry emissions are priced above EUR 0, 75 percent are priced at or above EUR 5, 4 percent are priced at or above EUR 30 and 2 percent are priced at or above EUR 60 (OECD, 2018). These proportions of priced industry emissions add up to an average carbon price of EUR 15 for industrial consumers in the EU. Compared to the other countries analysed in this report, the EU ranks 3rd out of 13.

5.4.3.1.1 Carbon Taxes and Specific Taxes on Energy Use

The EU and its member states levy excise taxes on natural gas, electricity, steam coal, coking coal. Again, the EU average is based on results of the 22 EU Member States that are also OECD members. For these, the tax on natural gas increased by 100% between 2010 and 2017, from EUR 1.77 per MWh to EUR 3.54 per MWh. The tax on steam coal increased by 236% between 2010 and 2017, from EUR 18.43 per tonne to EUR 61.89 per tonne. The tax on coking coal increased by 948% between 2010 and 2017, from EUR 9.11 per tonne to EUR 95.51 per tonne. The tax on electricity increased by 119 % between 2010 and 2017, from EUR 7.17 per MWh to

[28] The EU member states not included are: Bulgaria, Croatia, Cyprus, Lithuania, Malta and Romania

EUR 15.72 per MWh. Table 17 provides an overview on the average excise tax amount in the 22 EU Member States that are also member of the OECD.

Table 17: Energy Excise Tax for Industry per Energy Source

Year	Natural Gas (EUR per Mwh GCV)	Steam coal (per tonne)[29]	Coking coal (per tonne)	Electricity (per Mwh)
2007	1.62	20.20	8.94	7.19
2008	1.53	21.17	10.10	4.86
2009	1.63	21.06	10.10	5.06
2010	1.77	18.43	9.11	7.17
2011	2.50	31.57	22.04	9.37
2012	2.96	38.02	44.12	11.35
2013	3.17	38.99	45.66	13.74
2014	3.33	39.19	45.66	15.24
2015	3.56	43.46	56.74	16.39
2016	3.61	50.89	65.97	17.30
2017	3.54	61.89	95.51	15.72

Source: (IEA, 2018d) , own calculations, numbers represent average values.

The EU Energy Taxation Directive (2003/96/EC) sets the framework for energy and carbon taxes levied in EU member states by defining minimum rates for the taxation of energy products. According to OECD (OECD, 2018c), the EU Energy Taxation Directive strongly shapes the energy taxes in EU member states, and leads to higher overall tax rates in comparison to other OECD member states.

However, the European Commission, considers that the directive is “outdated in that it does not address the EU’s higher ambitions in energy and climate change policies. It also needs to be revised to address problems that have emerged in the Internal Market. Finally, its current scope is incoherent with that of the EU Emission Trading System” (European Commission, 2011), Moreover, it taxes certain fossil fuels more favorably then sustainable substitutes. For these reasons, the EU intended to revise the directive in 2011. However, an agreement could not be reached, which is why several EU countries adopted more ambitious national rates for the taxation of energy products. In addition, some EU countries, including Denmark, Finland, France, Ireland, Portugal, Slovenia, Sweden and the UK, introduced national carbon taxes (OECD, 2018, Taxing energy use, p.49-50). In some of the countries, emitters that are covered by the EU ETS are exempt from these carbon taxes. Table 18 provides an overview on the treatment of the carbon tax in sectors covered by the EU ETS.

[29] According to the IEA (2020), “Steam coal is coal used for steam raising and space heating purposes and included all anthracite and bituminous coals not included under coking coal and for all countries; steam coal also includes sub-bituminous coal.”

Table 18: Treatment of the carbon tax in sectors also covered by the EU ETS

Country	Treatment of the carbon tax in sectors also covered by the EU ETS	Carbon tax amount in non-road sectors (in EUR/ tCO2)
Denmark	Fully exempted	4,64
Finland	Not exempted	9,44
France	Not exempted	4,22
Ireland	Fully exempted	7,49
Portugal	Fully exempted	0,36
Slovenia	Not exempted	4,58
Sweden	Fully exempted	5,68
United Kingdom	Not exempted	8,26

Source: OECD (2018) Taxing Energy Use 2018 Report, p.20 and OECD Taxing Energy Use 2018 online data bank: https://www1.compareyourcountry.org/taxing-energy. Please note that the OECD data specifies taxes in the non-road sectors – which may include certain industrial emitters but is broader than only industry.

In 2016, the EU-28 average environmental taxes as percent of GDP was at 2.4. The total EU environmental tax revenues amounted to 365 billion EUR. Values for individual Member States varied from 1.8 percent in Ireland, Spain, Luxembourg and Slovakia to 4 percent in Denmark (DG Taxation and Customs Union, 2019).

5.4.3.1.2 Emission Trading Schemes

5.4.3.1.2.1 The European ETS

The European Emissions Trading System (EU ETS) has operated since 2005. The third trading period started in 2013 and lasts until 2020. In this trading period, the EU ETS covers around 40% of all European CO_2, N_20 and PFC emissions. It covers industry as well as energy and aviation, with aviation limited to flights within the European Economic Area (EEA).

In February 2018, European lawmakers formally approved phase four (2021-2030) of the EU ETS, reforming the system in several substantial ways, including a tightening of the cap through a more ambitious linear reduction factor (from 1.74 percent per year to 2.2 percent), a one-off rule for cancellation of allowances held in the MSR, and an update of the allocation benchmarks.

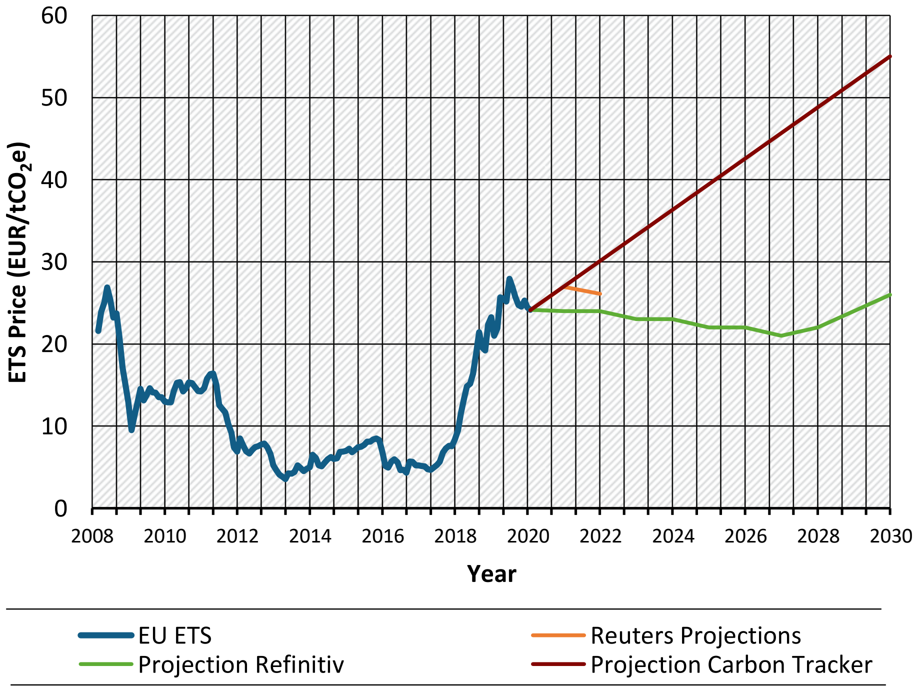
Price

Mostly due to an oversupply of allowances in the industry sector, the price of EU ETS allowances remained very low for most of the second commitment period. Starting at an average of EUR 24.07 in 2008, it fell to an average of EUR 4.46 in 2013. From 2013 to 2017, in the first half of the third commitment period, the average price remained in the single digits, reaching an intermediate high of EUR 7.69 in 2015 before declining again to EUR 5.84 in 2017. After rules for the fourth commitment period had been agreed, the price rose significantly. It reached an average of EUR 15.30 in 2018 and continued to rise in 2019, reaching EUR 29.46 on 25 July, 2019 (ICAP, 2019a). In February 2020, the average price was EUR 24.13 (ICAP, 2020k).The historic price development of EU ETS allowances is outlined in Figure 7.

Price projections from Reuters and Refinitiv expect the price to remain high, but do not expect the steady increases to continue. Eight analysts polled by Reuters expect average prices of EUR

32 in 2020 (Reuters, 2019). Projections from Refinitiv expect average prices to reach an average of EUR 25, and then decrease until 2027, to reach an average of EUR 21. After 2027, Refinitiv expects prices to rise again, reaching an average of EUR 26 in 2020 (Refinitiv, 2018). If the EU ETS was legislated to align with the EU's targets of the Paris agreement, which– according to Carbon Tracker – would imply a 60 percent emissions reduction target from 2005 levels by 2030 for the EU ETS, the average price of EU ETS allowances could rise to EUR 55 by 2030 (Carbon Tracker, 2018). Figure 7 gives a graphical overview of these price expectations.

Figure 7: ETS Allowance Price in EU



Source: (Carbon Tracker, 2018; ICAP, 2020k; Refinitiv, 2018)

Percentage of industrial emissions covered

In total, the EU ETS currently covers around 40 percent of EU CO_2, N_2O and PFC emissions (ICAP, 2019b). In 2018, verified emissions from industrial installations (excluding combustion of fuels) accounted for 587 of the 1,682 $MtCO_{2e}$ emitted by all stationary installations, or 34.9 percent (European Environment Agency, 2019).

Allocation of free allowances

The industrial sectors covered in this analysis all participate in the EU ETS, and are also found on the so-called carbon leakage list, as they qualify for the criteria defined in Article 10a of the EU ETS Directive 2003/87/EC, which means that they continue to receive for free the full allocation according to on an industry-wide benchmark. 2018 was the second year that industrial installations overall faced direct costs through the EU ETS because free allocation was below their emissions subject to emissions trading (Marcu et al., 2019). These direct costs for industry increased compared to the year 2017 due to two reasons: a) the steep increase in allowance prices and b) the decrease of coverage with free allocation for the industry as a whole. This coverage went down from 98.6% in 2017 to 96.5% in 2018 (Marcu et al., 2019).

Flexibility

Unlimited banking is allowed since 2008. Borrowing is also allowed. The option for borrowing between years is based on the circumstance that allowances for the current year are issued in February and surrendering for the previous year does not occur until April (Diekmann, 2012).

Compliance and enforcement

The Compliance period is from 1 January to 31 December. By 30 April of the following year, entities need to surrender allowances corresponding to their verified emissions. For each missing allowance, not surrendered, entities pay an "excess emissions penalty" of EUR 100 per allowance. The name of noncompliant operators are also published. For other forms of noncompliance, penalties on national level exist (ICAP, 2019b).

Proposals for linking

In 2017, Switzerland and the EU agreed to link their emissions trading systems. After final regulatory changes in the design of the Swiss ETS, both emission trading systems are linked since 1 January 2020 (ICAP, 2020l). Participants are allowed to use allowances from either of the two systems for compliance.[30]

5.4.3.1.2.2 Regional ETS

There are no regional ETS in the EU.

5.4.3.1.3 Proposals for pricing carbon

There are no relevant new proposals for pricing carbon at the EU. While there are lively debates on carbon pricing in several EU Member States, these tend to focus on the sectors that are not covered by the EU ETS, particularly on transport and buildings. For instance, Germany will introduce a national emission trading system (nETS) for the sectors heat and transport in 2021. The nETS will start with a fixed price of €25/tCO_2 which increases to €55/tCO_2 until 2025. After that, the allowance price can float between €55/tCO_2 and 65/tCO_2.

5.4.3.2 Energy efficiency standards

EU energy consumption fluctuated during the last decade. After decreasing gradually between 2007 and 2014, it increased from 2014 to 2017. These variations, however, cannot purely be attributed to changes in environmental policy. In fact, they depend largely on economic developments, fuel prices and atmospheric conditions (European Commission, 2019).

Energy Efficiency Policies

The Energy Efficiency Directive, the most relevant EU policy measure for energy efficiency, entered into force on 4 December 2012. At the time, EU member states agreed savings target to save 20% of their energy by 2020 (compared to BAU). To reach this shared target, individual EU countries set their own indicative national energy efficiency targets. Depending on country preferences defined in the National Energy Efficiency Action Plans (NEEAPs), these targets can be based on energy consumption (primary or final), energy savings (primary or final,) or energy intensity.

On 30 November 2016, the EU Commission proposed an update of the Energy Efficiency Directive (EED). This update included a 30% energy efficiency target for 2030. Another 18 month later, on 14 June 2018, the Commission, the Parliament and the Council reached political agreement to raise the energy efficiency target for the EU for 2030 by 2.5%, to 32.5 percent, with a clause for an upwards revision by 2023. This agreement is now to be translated into all EU

[30] https://ec.europa.eu/clima/news/eu-and-switzerland-sign-agreement-link-emissions-trading-systems_en.

languages and to be formally adopted by the European Parliament and the Council, and then published in the Official Journal of the EU (European Commission, 2019).

Accompanying the reduction targets mentioned, the EU has adopted a number of additional measures to improve energy efficiency in industry, including an annual reduction of 1.5% in national energy sales (EED, Art. 7) and large companies conducting energy audits at least every four years (EED, Art. 8) (European Commission, 2012).

Energy Efficiency Rating

Mandatory energy efficiency policies cover seven percent of industrial energy use in the EU (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE score). The EU receives 6 out of 8 points for its industrial energy efficiency (75%) and 1561 out of 2065 possible points for the policy landscape (76%). Thus, the EU ranks 3rd out of 13 in industry energy efficiency performance and 4th out of 13 for its energy efficiency policies. Table 19 provides an overview of the country's performance in each of the selected sub-indicators for the RISE indicator.[31]

Table 19: RISE Indicator Scores for the EU

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	132/140	94%
EE Entities	68/75	91%
EE Incentives from Electricity Rate Structures	155/200	78%
Incentives & Mandates for Industrial and Commercial End Users	512/600	85%
Financing Mechanisms for EE	36/50	72%
Minimum EE Performance Indicators	494/600	82%
Energy Labelling Systems	164/400	41%
Overall	1561/2065	76%

5.4.3.3 Air quality standards

Air quality standards

Air quality standards for industrial emissions are set by the directive on ambient air quality and cleaner air for Europe (2008/50/EC, or EU Air Quality Directive) and by the Industrial Emissions Directive (Directive 2010/75/EU, or IED) (European Commission, 2010, 2008). The IED includes several pillars, in particular an integrated approach, use of best available techniques (BAT), flexibility, inspections and public participation.[32] The EU Air Quality Directive defines the most important air quality standards for air pollutants in the EU, summarised in Table 20.

[31] For a detailed description of the sub-indicators of the RISE indicator see section 3.

[32] For more information on the IED, please see EC (2019),

Table 20: Air quality standards in the EU

Pollutant		Level of the standard (µg/m³)
Particulate matter (PM10)	Annual Daily	40 50
Particulate matter (PM2.5)	Annual Daily	25 N/A
Ozone (O3)	8-hr-daily Hourly	120 N/A
Sulphur dioxide (SO_2)	Annual Daily Hourly	N/A 125 350
Nitrogen dioxide (NO_2)	Annual Daily Hourly	40 other 200
Carbon monoxide (CO)	Daily 8-hr-daily Hourly	N/A 7 N/A

Source: (European Commission, 2008), (Kutlar Joss et al., 2017)

Table 21: Proportion of emissions priced in the industry sector per tonne of CO_2 per EU member state

Country	Proportion of emissions priced at or above in 2015 (%)	Proportion of emissions priced at or above in 2015 (%)	Proportion of emissions priced at or above in 2015 (%)	Proportion of emissions priced at or above in 2015 (%)	Change from 2012 to 2015, of emissions priced at or above (in percentage points)	Change from 2012 to 2015, of emissions priced at or above (in percentage points)	Change from 2012 to 2015, of emissions priced at or above (in percentage points)	Change from 2012 to 2015, of emissions priced at or above (in percentage points)
	EUR 0	EUR 5	EUR 30	EUR 60	EUR 0	EUR 5	EUR 30	EUR 60
Austria	54%	54%	11%	3%	1	1	-6	0
Belgium	59%	57%	0%	0%	-14	-10	0	0
Czech Republic	85%	50%	0%	0%	33	7	0	0
Germany	85%	82%	1%	0%	20	19	-2	0
Denmark	86%	86%	13%	10%	16	16	-52	-3
Spain	74%	68%	4%	0%	14	9	1	0
Estonia	63%	45%	4%	0%	-20	6	0	0
Finland	60%	60%	42%	17%	-2	-2	1	4

Country	Proportion of emissions priced at or above in 2015 (%)	Proportion of emissions priced at or above in 2015 (%)	Proportion of emissions priced at or above in 2015 (%)	Proportion of emissions priced at or above in 2015 (%)	Change from 2012 to 2015, of emissions priced at or above (in percentage points)	Change from 2012 to 2015, of emissions priced at or above (in percentage points)	Change from 2012 to 2015, of emissions priced at or above (in percentage points)	Change from 2012 to 2015, of emissions priced at or above (in percentage points)
France	79%	75%	2%	0%	1	4	-1	0
Great Britain	81%	79%	8%	4%	0	-2	-13	-3
Greece	91%	90%	16%	5%	-1	-2	-6	-2
Hungary	79%	67%	3%	3%	0	-8	1	1
Ireland	72%	72%	3%	0%	-3	-1	-14	-8
Italy	97%	96%	2%	2%	4	10	-19	-5
Luxembourg	89%	77%	0%	0%	11	19	0	0
Latvia	51%	29%	0%	0%	na	na	na	na
Poland	90%	89%	17%	2%	18	23	15	1
Portugal	91%	65%	1%	1%	8	-4	0	0
Slovakia	65%	60%	3%	0%	11	8	1	0
Slovenia	72%	56%	11%	0%	1	1	-5	0
Sweden	86%	86%	39%	38%	1	13	32	32
Austria	54%	54%	4%	3%	8	8	1	3
EU Average	**76%**	**68%**	**8%**	**4%**	**5,1**	**5,5**	**-3,1**	**1,0**

Source: (OECD, 2018a)

5.4.4 Carbon constraints in India (as of December 2019)

As a country, India is the world's third largest emitter of greenhouse gases (IEA, 2018e). However, at 1.6 tonnes CO_2, its per capita emissions in 2016 were well below those of other major emitters like the US (15), South Korea (11.5) or China (6.6) (IEA, 2019b). Under the Paris Agreement, India pledged a 33-35 percent reduction in the emissions intensity of its economy (emissions per unit of GDP) by 2030, compared to 2005 levels. It also has plans for 40 percent of its power generation to be carbon free (renewable or nuclear) by 2030.[33] To achieve these goals, India's climate policies feature carbon taxes as well as a market-based instrument called the perform, achieve and trade (PAT) scheme focused on energy efficiency in industry. The government is planning a voluntary domestic carbon market with the aid of the World Bank, under which companies could buy offsets called Marketable Carbon Units (MCUs) using a registry and offset project certification. In addition, India has air quality standards that pertain to emissions-intensive industries.

5.4.4.1 Effective Carbon Prices

India has neither a carbon tax, nor an emissions trading scheme in place. However, it implemented different taxes on energy use, some of which include elements of a carbon tax.

All price based measures together address the following proportion of industry emissions in India in 2015: 71 percent of industry emissions are priced above EUR 0, 25 percent are priced at or above EUR 5, one percent is priced at or above EUR 30; no installations are priced at or above EUR 60 (OECD, 2018).[34] These proportions of priced industry emissions add up to an average carbon price of EUR 4.12 for industrial consumers in India.[35] Compared to the other countries analysed in this report, India ranks 6th of 13 in this regard.

5.4.4.1.1 Carbon Taxes and specific taxes on energy use

In 2010, India introduced a "cess" tax on domestically produced and imported coal. A cess is a fee levied to raise funds for a specific purpose, in this case India's National Clean Energy and Environment Fund (NCEEF), which grants money to research and projects in clean energy. Since then, the coal cess increased several times from its initial INR 50 (EUR 0.65) per tonne. In March 2015, it was raised to INR 200 (EUR 2.59) per tonne and in March 2016 to INR 400 (EUR 5.18) per tonne. India refers to the cess as equivalent to a carbon tax in its NDC, with the 2016 increase translating to a carbon price of below EUR 2 per tonne CO_2 levied at the point of production. In July 2017, India introduced a new national Goods and Service Tax (GST) whose creation abolished the cess, but put in place a new coal production levy[36] at the same INR 400/tonne rate – the difference is that proceeds fill Indian states' budget deficits rather than flowing into the NCEEF for clean power research and development.

The GST aimed at simplifying and unifying taxation in India by applying the same rates to goods and services nationwide rather than having a patchwork of varying taxes by state (such as value added tax and excise levies) on similar products. However, the five major fuels petrol (gasoline), diesel, natural gas, crude oil, and aviation fuel are *not* under the GST (although their inclusion is intended in the longer term and has been recommended by e.g. the oil and transport ministries to combat price volatility) and are thus taxed at varying rates under individual state tax policies, with a particularly significant difference among the VAT charges (Business Today, 2018; The

[33] These targets come from India NDC, submitted in 2015 and available online at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/India%20First/INDIA%20INDC%20TO%20UNFCCC.pdf

[34] A detailed description of carbon pricing gaps is provided in section 3.

[35] A detailed description of the methodology used to calculate the effective carbon price is provided in section 3.

[36] the "GST Compensation Cess"

Economic Times, 2018). The Indian government considers the combined taxes on petrol and diesel an implicit carbon tax (Clean Technica, 2017; Shakti and EY, 2018).

Some fuels *are* covered by the GST, at the following rates:

Table 22: GST rates for fuels in India

Fuels	GST rates
LPG	5% (domestic) 18% (non-domestic)
Kerosene	5% (Fertilizer) 18% (Non-fertilizer)
Naptha	18%
Bitumen and Asphalt	18%
Coal	5%
Petroleum Coke	5%

Source: (Shakti and EY, 2018)

CO_2 combustion in India's industrial operations[37] accounted for 585 Mt CO_2e in 2016, which is roughly 16 percent of the country's total 3.6 billion tonnes CO2e emitted in that year.

5.4.4.1.2 Emission Trading Schemes

There is no ETS in place in India.

5.4.4.1.3 Proposals for pricing carbon

As part of India's membership in the World Bank's Partnership for Market Readiness (PMR) programme, which helps developing countries fund and design market-based mechanisms to combat climate change, India has been exploring establishing a domestic emissions registry and market-based programme to cut emissions in sectors not covered by its renewable energy programme since August 2017 (Reklev, 2017). In April 2019, a non-profit group involved in forest conservation that works with India's Ministry of New and Renewable Energy circulated draft rules for an Indian carbon standard and credit registry – these would form the foundation for a voluntary domestic carbon offset market. The registry would aggregate emission reductions from certified projects, e.g. in the forestry sector, and firms would purchase these to offset their emissions. The concept note developed so far does not suggest that this offsetting would be mandatory for industrial facilities, nor does it specify which types of businesses would be involved (Network for Certification and Conservation for Forest, n.d.). Projects already covered by the PAT scheme (described below) and renewable energy credit trading would not be eligible to generate offsets under this new programme (Reklev, 2019).

5.4.4.2 Energy efficiency standards

Various measures under India's Energy Conservation Act of 2001 aim to improve demand side energy efficiency, including labeling of equipment and appliances; energy conservation building

[37] This excludes industrial process emissions (non-combustion), which available breakdowns account for in a separate category together with non-combustion emissions from agriculture and waste. That grouping collectively emitted about 200 MtCO2e in 2016, so process emissions were no higher than that in that year. It also does not account for non-CO2 emissions from industry besides F gases, such as F nitrous oxide or methane. Data source = compilation of datasets via The Carbon Brief, combining energy consumption emissions of BP Statistical Review of World Energy 2018 and emissions data from the Potsdam Institute for Climate Impact Research (PIK). See data compilation details at (Carbon Brief, 2019) https://www.carbonbrief.org/the-carbon-brief-profile-india

codes for commercial buildings and energy consumption norms for energy intensive industries. In total, 19 appliances/types of equipment are under mandatory standards and labeling schemes (Ministry of Power, n.d.).

Energy Efficiency Policies

The hallmark of India's energy efficiency measures is its market-based energy efficiency instrument, whose elements incorporate tradable credits. The programme, called Perform Achieve and Trade (PAT) is mandatory and covers 478 industrial units (called designated consumers, DCs) in eight sectors: aluminum, cement, chlor-alkali, fertiliser, iron and steel, pulp and paper, thermal power generation, and textiles. In its first phases from 2012-2017, the target was to reduce specific energy consumption in these sectors by 4.1 percent from a base year of 2010 (Ministry of Power, n.d., IEA, 2018). During the current phase (2017-18 to 2019-20), targets for reduction in specific energy consumptions of different sectors vary, but range between four and ten percent from a base year of 2015-16 (Ministry of Power, 2017). Overall, the programme aims to save 6.6 million metric tonnes of oil equivalent (toe), which government estimates equate to a saving of 5,623 MWh of electricity over a period of three years.

Tradable energy saving certificates or ESCerts - these each equal 1 tonne of oil equivalent (toe) of energy *savings*, are issued to the covered industrial entities based on quantified energy savings verified by an accredited energy auditor. DCs are given specific energy consumption targets to meet over the programme's respective three-year period. If they achieve energy savings above the target benchmark, they earn the corresponding amount of ESCerts – which in turn can be sold to DCs that fall short of their efficiency targets. All entities that do not meet their targets must buy ESCerts or pay a penalty. The penalty for non-compliance is 1 million INR (~EUR 13,000) plus the value of the energy savings that have not been obtained by the DC.[38] As in most such markets, the penalty ends up constituting a "ceiling price" for the tradable units.

India's Central Electricity Regulatory Commission defines the regulatory framework for trading of the ESCerts, while the country's Power System Operation Corporation is responsible for the centralised ESCert registry. The Bureau of Energy Efficiency is the administrator of the platform managing actual ESCert trading – since 2017, the Indian Energy Exchange (IEX) and the Power Exchange of India (PXIL) have offered ESCert contracts among their energy-related commodity contracts (Indian Energy Exchange, 2018).

Whether this programme has affected covered industries' international competitiveness has not been examined directly. A critical review of the programme's results in 2017 conducted through ICF consulting found that the majority of the covered entities (67%) considered the targets for the 3-year compliance period stringent, and made investments in energy efficiency that otherwise would not have occurred (ICF, 2017). However, the report also found that 74 percent of the DCs exceeded their specific energy savings target, indicating that the demand for ESCerts (and hence their price) is low. The study did not break down investments or cost of energy efficiency increases by industry sector.

According to the IEA, India saved 6% of additional final energy use in 2017 compared to 2000 due to energy efficiency gains. About 83% of these energy savings happened in the industry and service sector mainly because economic activity moved from energy-intensive industries to less-intensive manufacturing (IEA, 2018f).

[38] The price of that non-attained toe is in turn determined by the Indian government based on then-current fuel prices. The government uses a combination of coal, fuel, gas and electricity prices. For instance, in 2011-2012 the cost of coal was based on the price of F-grade coal declared by India's Ministry of Coal multiplied by the amount of coal consumed by the 478 DCs and the total energy they consumed in that time period. For 2011-2012, the market value of 1 toe was thus 10154 INR (~EUR 131) and in 2014-2015 it was 10968 INR (~EUR 141). (IEA 2018)

Energy Efficiency Rating

Mandatory energy efficiency policies cover 38 percent of industrial energy use (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE indicators) (see Chapter 5.3). India receives 1.5 out of 8 possible points for its industrial energy efficiency (19%) and 1532 out of 2065 possible points for the policy landscape (74%). Thus, India ranks 8th out of 13 in industry energy efficiency performance and 6th out of 13 for its energy efficiency policies. Table 23 provides an overview of the country's performance in each of the selected sub-indicators for the RISE indicator.[39]

Table 23: RISE Indicator Scores for India

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	140/140	100%
EE Entities	75/75	100%
EE Incentives from Electricity Rate Structures	167/200	83%
Incentives & Mandates for Industrial and Commercial End Users	400/600	67%
Financing Mechanisms for EE	50/50	100%
Minimum EE Performance Indicators	300/600	50%
Energy Labelling Systems	400/400	100%
Overall	1532/2065	74%

Source: Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

5.4.4.3 Air quality standards

Air quality standards

India's Central Pollution Control Board is responsible for setting the country's ambient air quality standards.[40] Under the authority of the Air (Prevention and Control of Pollution) Act of 1981, it controls the national air quality and assists the government in enforcement of those standards (TransportPolicy, n.d.). Table 23 provides an overview of India's air quality standards for the most relevant air pollutants.

[39] For a detailed description of the sub-indicators of the RISE indicator see section 3.

[40] The board is in charge of India's National Air Monitoring Programme (NAMP), which monitors levels of SO_2, NO_2, and particulate matter from 731 operating stations in 312 cities across India. The NAMP publishes lists of cities that violate air quality standards but does not carry out enforcement (http://cpcb.nic.in/about-namp/).

Table 24: Air quality standards in India

Pollutant[41]		Level of the standard (Industrial, residential, rural and other areas) (µg/m³)	Level of the standard for Ecologically Sensitive Area (notified by Central Government) (µg/m³)
Particulate matter (PM10)	Annual Daily	50 80	20 80
Particulate matter (PM2.5) Annual	 Daily	40 60	40 60
Ozone (O_3)	8-hr-daily Hourly	100 180	100 180
Sulphur dioxide (SO_2)	Annual Daily Hourly	50 80 N/A	20 80 N/A
Nitrogen dioxide (NO_2)	Annual Daily Hourly	40 80 other	30 80 other
Carbon monoxide (CO)	Daily 8-hr-daily Hourly	N/A 2 4	N/A 2 4

Source: (TransportPolicy, n.d.), Kutlar Joss et al. (2017)

However, publicly available documentation from India's Central Pollution Control Board indicates that standards are only enforced when air quality conditions reach critical levels, i.e. during the times pollution levels exceed safe norms (Central Pollution Control Board, 2019). For instance, according to the Control Board's "Graded Response Action Plan" for Delhi and the national capital region, "stringently enforcing all pollution control regulations in brick kilns and industries" and "stringently enforcing or stopping garbage burning in landfills and other places and imposing heavy fines on those responsible" are measures to be taken when air quality levels are moderate to poor, implying that the regulations are *not* enforced otherwise, which in turn leads to poor air quality levels (Central Pollution Control Board, 2017). As a result, India ranked 178th of 180 countries in terms of air quality (Wendling et al., 2018).

In January 2019, the Indian government launched a five-year action plan to reduce air pollution, and build air quality monitoring networks. However, the initiative is not yet backed by a legal mandate that would ensure implementation of emission control measures in practice. With respect to air quality regulations as a competitiveness concern for industry, it is worth noting that much of India's air pollution problem comes from sources other than manufacturing industries, e.g. from biomass combustion for residential cooking and NOx emissions from transportation, as well as SO_2 emissions from power plants in coal-heavy states (Phys.org, 2019).

[41] Most pollutants are measured as µg/m³ except for CO which is measured in terms of mg/m3 while Benzopyrene, Arsenic and Nickel are measured as ng/m³

Pilot Emission Trading Programme (PETP)

The three Indian states with the most industrial production (Tamil Nadu, Gujarat and Maharashtra) have since 2011 been working toward implementation of a permit trading system for emissions of particulate matter, aimed at maintaining air quality as per India's National Ambient Air Quality Standard (IFMR Research and Abdul Latif Jameel Poverty Action Lab, 2011). Coordinated by India's Central Pollution Control Board (which monitors the pollutant levels and issues guidelines), the programme's permits are to be allocated by the states' pollution control boards – early estimates indicated that 1,000 facilities in the three states would receive permits to emit particulate matter and trade these. Like an ETS for greenhouse gases, regulators will check facilities' total emissions against permit holdings to verify compliance. The uptake of the programme, however, has been slow, which has been attributed to the requirement that covered installations need to install Continuous Emission Monitoring Systems (CEMS), which has delayed the roll-out.[42]

5.4.5 Carbon constraints in Japan (as of December 2019)

Japan is the fifth largest CO_2 emitter worldwide. At the same time the country is highly dependent on energy imports. Inter alia, this is one of the main reasons why the Japanese government has traditionally placed special emphasis on its industry's energy efficiency. Besides energy efficient measures, Japan prices the emission of CO_2 via taxes and two regional ETS.

5.4.5.1 Effective Carbon Prices

Japan has a carbon tax and two regional emissions trading systems in place, the first one having been introduced in 2010. Moreover, it implemented different taxes on energy use that also focus on the industry sector.

All price based measures together address the following proportion of industry emissions in Japan in 2015: 70 percent of industry emissions are priced above EUR 0, 34 percent are priced at or above EUR 5, 5 percent are priced at or above EUR 30 and 4 percent are priced at or above EUR 60 (OECD, 2018).[43] These proportions of priced industry emissions add up to an average carbon price of EUR 6.18 for industrial consumers in Japan.[44] Compared to the other countries analysed in this report, Japan ranks 5th of 13.

5.4.5.1.1 Carbon Taxes and specific taxes on energy use

Japan levies excise taxes on steam coal, coking coal and electricity. There is no excise tax on natural gas. The tax on both steam coal and coking coal increased by 80% between 2010 and 2017, from EUR 6.02 per tonne to EUR 10.81 per tonne. The tax on electricity decreased by 3% between 2010 and 2016, from EUR 3.23 per MWh to EUR 3.12 per MWh. Table 25 provides an overview on the excise taxes for industry in Japan.

[42] Other measures in India: India's Renewable Energy Certificate (REC) scheme was launched in 2010, with a vision to generate 175 GW electricity from renewable energy sources by 2022. So-called designated consumers and power distribution companies have renewable energy purchase obligations, and fulfill these with RECs - a REC is equivalent to 1 MWh renewably generated power. Power companies must be registered to participate in trading, registration is done by India's Central Electricity Regulatory Commission. RECs are verified by individual states' electricity regulatory commissions (Central Agency, National Load Despatch Centre, 2018). RECs are traded on the same platform as other environmental commodities including the PAT scheme's ESCerts, namely exchanges such as the Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL).

[43] A detailed description of carbon pricing gaps is provided in section 3.

[44] A detailed description of the methodology used to calculate the effective carbon price is provided in section 3.

Table 25: Energy Excise Tax for Industry per Energy Source in Japan

	Natural Gas (per MWh GCV)	Steam coal (per tonne)	Coking coal (per tonne)	Electricity (per MWh)
2007	..	3.97	3.97	2.33
2008	..	4.59	4.59	2.46
2009	..	5.37	5.37	2.88
2010	..	6.02	6.02	3.23
2011	..	6.31	6.31	3.38
2012	..	7.37	7.37	3.66
2013	..	7.10	7.10	2.89
2014	..	7.73	7.73	2.67
2015	..	8.49	8.49	2.79
2016	..	10.92	10.92	3.12
2017	..	10.81	10.81	..

Source: IEA (2018).

The Japanese Carbon Tax

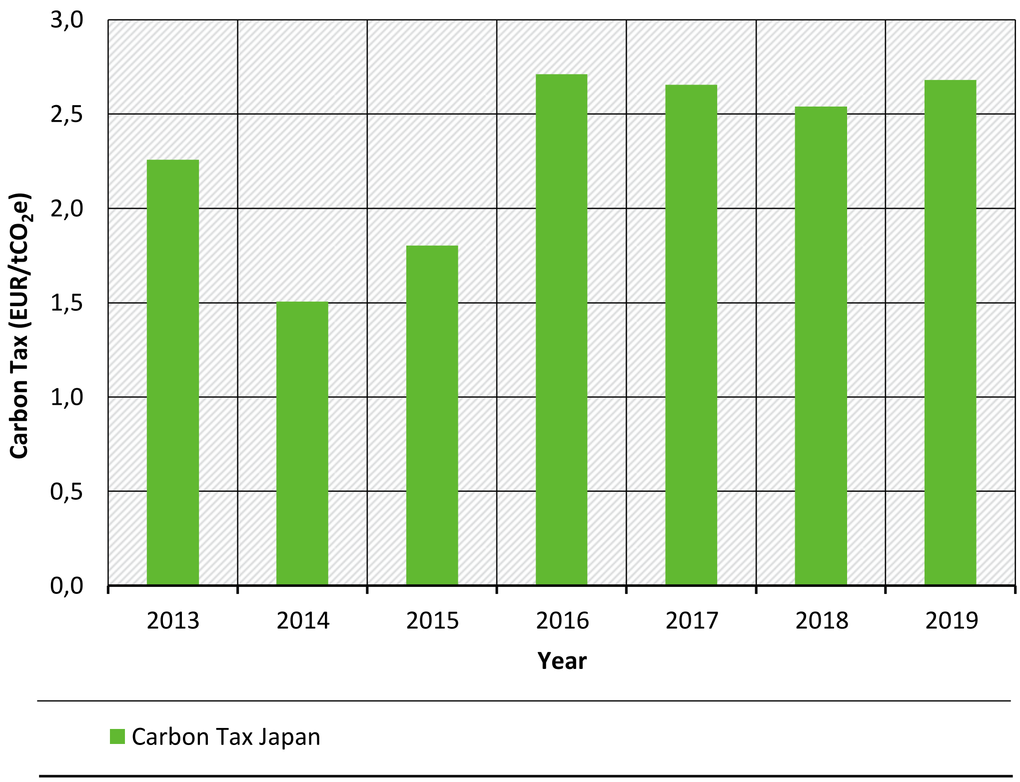
On 1 October 2012, the Japanese government introduced a nationwide carbon tax in order to reduce emissions from fossil fuels used in thermal generation, transport etc. The "Tax for Climate Change Mitigation" represents an additional tax on the usage of fossil fuels.

Price

The tax rate is set according to the emission factor of the taxed energy source, to equal JPY 289 (EUR 2.27)[45] per tonne of CO_2 emissions from 2016 onwards (Ministry of the Environment, Japan, n.d.). In order to keep the additional tax burden manageable for companies, the price increased gradually within three and a half years since its first implementation in 2012. For instance, the carbon tax on crude oil and oil products was first set at JPY 95 (EUR 0.74) per tonne CO_2 emissions in 2012 and then increased to JPY 190 (EUR 1.48) per tonne CO_2 emission in 2014 before reaching today's level, which exist since 2016. A further increase of the carbon tax was not planned at the time of writing (Mizuho Information and Research Institute, 2017).

[45] With an average exchange rate of 0.0078 JPY/EUR from 2007 to 2017, Source: (Eurostat, 2019).

Figure 8: Carbon Tax in Japan



Source: (World Bank et al., 2016; World Bank and Ecofys, 2018, 2017, 2015, 2014, 2013). Due to the respective yearly average exchange rate, the graph depicts decreasing instead of continuously increasing carbon tax rates until 2018.

The revenues gained by the tax are provided for further development of renewable energies and energy conservation measures in the country. It is estimated that the tax revenue will be JPY 262.3 billion (around EUR 2 billion) in the last stage of implementation. The carbon tax is estimated to reduce total energy-related emissions by 0.5% to 2.2% in 2020 compared to 1990 (between 6 and 24 million tonnes of CO_2). The price effect, i.e. the actual tax burden, is estimated to reduce emissions by approximately 0.2% (around 1.76 million tonnes of CO_2), whereas the budget effect, i.e. the invested tax revenues into renewable energy and conservation measures, accounts for 0.4% to 2.1% (approximately 3.9 to 21.6 million tonnes) of CO_2 emission reduction. Exemptions and refund measures apply to a variety of sectors, such as domestic flights, agriculture, forestry and fishery (Ministry of the Environment, Japan, n.d.).

Percentage of industrial emissions covered within country

Japan's carbon tax applies to all fossil fuels and covers around 65% of the country's GHG emissions. It is estimated that 2% of the GHG emissions priced by the carbon tax are also part of the two regional ETS (see below) (World Bank, 2019).

5.4.5.1.2 Emission Trading Schemes

5.4.5.1.2.1 National ETS

At current, there is no national ETS in Japan.

5.4.5.1.2.2 Regional ETS

Two regional trading schemes operate in Japan, in Tokyo and in Saitama. Combined, they account for approximately 1.4%[46] of the country's total GHG emissions (ICAP, 2020l). The two

[46] Own calculation.

systems cover around 1,900 entities consuming more than 1,500 kL of crude oil equivalent per year from both the commercial and the industrial sector.

The Tokyo cap-and-trade ETS was launched in 2010 as the first of its kind in Japan, and one of the first worldwide. Within the first period of implementation (2010-2014), large offices and factories were required to reduce their carbon footprint by 6% or 8% in comparison to the base period.[47] In the second period (2015-2019) the mandatory cut of emissions increased to 15% or 17%, respectively. The Tokyo ETS covers commercial and industrial facilities with an energy consumption above 1,500 kL of crude oil equivalent per year. This results in over 1,300 facilities covered by the trading scheme. All allowances were allocated for free. With the introduction of high efficiency heat sources and light fittings amongst other things, the emissions were reduced 26% below the base year in 2015 (ICAP, 2018a).

A year after the introduction of the Tokyo ETS, a similar carbon trading system was implemented in the city of Saitama, which is located close to the metropolitan area of Tokyo. Similar to the ETS in Tokyo, the first period (2011-2014) demanded a reduction of 6% or 8%, the second period (2015-2019) 13% or 15% below the base-year emissions. However, already in 2015, the installations covered by the Saitama ETS had reduced their emissions 27% below the base-year emissions. Overall, around 600 facilities from the commercial and industrial sectors, which each consume more than 1,500kL of crude oil equivalent per year, are part of the ETS (ICAP, 2018b).

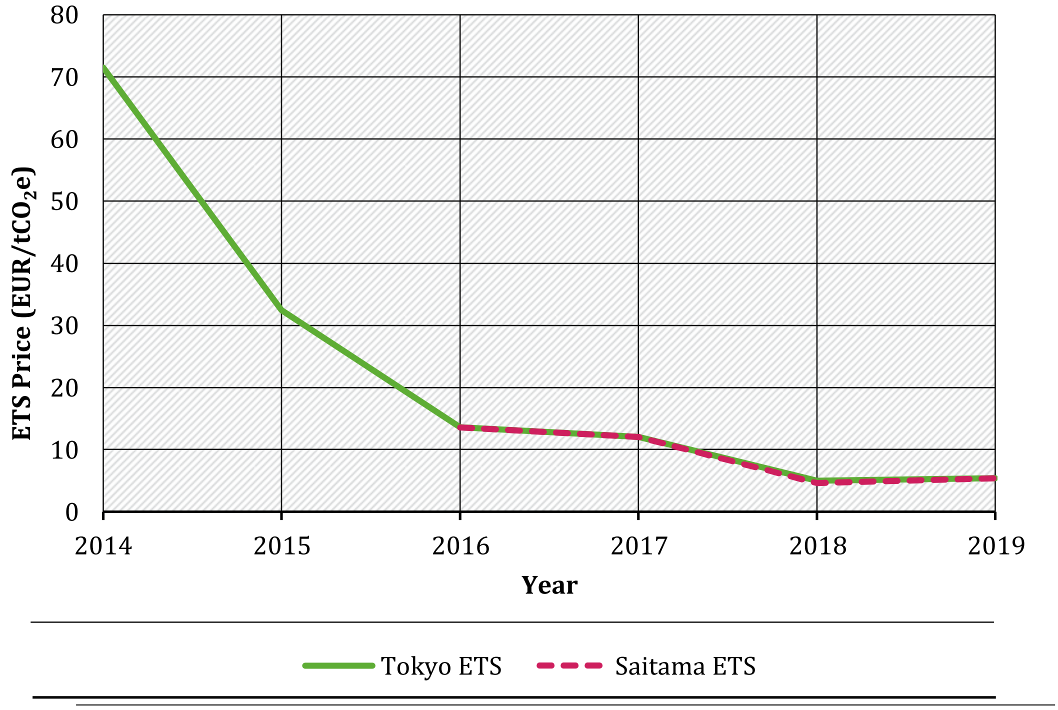
Price

Tokyo's ETS price was around 71 EUR/tCO_2e in 2014[48] and decreased significantly within the following two years. After the introduction in Saitama the ETS price developed equally to the Tokyo price. In 2018, the price for one allowance in Tokyo is almost 5 EUR/tCO_{2e}, in Saitama around 4.6 EUR/ tCO_{2e}.

[47] The base period is defined as the emission average of any three consecutive years between 2002 and 2007, selected by the business establishment. Further, office buildings as well as district and cooling plant facilities, which do not use a large amount of district heating and cooling themselves, have the higher compliance factor (8% and 17`%). On the other hand, office buildings, factories and facilities, which are heavy users of district and cooling plants, have the lower compliance factor (6% and 15%). Facilities with already tremendous efforts regarding energy efficiency measurements are subject to half or three-quarters of the compliance factor.

[48] Data availability only from 2014 onwards.

Figure 9: Regional ETS Allowance Price in Japan



Source: (World Bank, 2019; World Bank et al., 2016; World Bank and Ecofys, 2018, 2017, 2015, 2014)

Percentage of industrial emissions covered within country

Both systems only cover CO_2 emissions: The Tokyo ETS covers around 20% of Tokyo's total CO_2 emissions; Saitama ETS includes 18% off all CO_2 emissions in the municipality.

Overall, both regional ETS cover around 1.4% of Japan's total CO_2 emissions.[49] The industry emissions of the two prefectures account for 1.2%[50] of the country's total emissions (ICAP, 2020l).

Allocation of free allowances

Allocation is based on grandfathering on the ground of historical emissions. Allocation to new entrants is based on past emissions or on emissions intensity standards.

Flexibility

Banking is allowed between two compliance periods (e.g. banking from first to second, but not from first to third compliance period). Borrowing is not allowed. Also, compliance companies can use offsets and credits.

Compliance and enforcement

There is no information on how companies need to report on emissions

In case of non-compliance, the following measures may be taken in two stages:

1. The Governor orders the facility to reduce emissions by the amount of the reduction shortfall multiplied by 1.3.

[49] Only CO_2 emissions and excluding LULUCF.

[50] Own calculation.

2. Any facility that fails to carry out the order will be publicly named and subject to penalties (up to JPY 500,000 [USD 4,460]) and surcharges (1.3 times the shortfall).

Proposals for linking

A national ETS, which is still to be implemented, could potentially be linked to the Korean and the different Chinese ETS. The government supports regular exchange and meetings between these three countries, mostly at the level of academic experts.

5.4.5.1.3 Proposals for pricing carbon

The Japanese government currently considers developing a national ETS. For this, a detailed policy proposal has been developed and regular meetings to elaborate future carbon market links with academics from both China and South Korea are supported by the government (Carbon Pulse, 2018b). However, as of today, there are no concrete plans to develop a national ETS.

5.4.5.2 Energy efficiency standards

Japan is one of the biggest energy consuming countries worldwide. In order to meet the consumption needs the country is highly dependent on energy imports. Thus, energy efficiency measures are among the top-priorities of the Japanese government.

Energy Efficiency Policies

The core of Japan's energy efficiency policies and measures is the Act on the Rational Use of Energy (Energy Conservation Act), which was implemented in 1979 and has been revised several times since then. It covers over 60% of energy consumption in the main sectors, i.e. industry, transport, residential and commercial (IEA, 2018a). The Act requires companies in the industry sector with an energy consumption of at least 1.5 million litres of crude oil equivalent to 1) report annually on the amount of energy they actually consume, 2) submit a medium-term (3- to 5-year-) plan for a rational use of energy, and 3) assign a person responsible for energy management within the company. Together, these measures are expected to reduce energy intensities by at least 1% a year in the medium term. In addition, the Energy Conservation Act encourages energy-intensive companies[51] to meet certain energy efficiency benchmarks. The top 10% to 20% performers in each sector set the benchmarks for all other companies, which need to report annually on their progress towards meeting these benchmarks (IEA, 2016a).

Energy efficiency plays a significant role in the 2015 Long-term Energy Supply and Demand Outlook, which constitutes Japan's strategy to structure energy supply and demand by 2030. The implementation of energy efficiency and conservation measurements is expected to reduce energy demand by 13% (from 2013 to 2030) below the baseline scenario. This equals 50.3 billion litres of crude-oil equivalents (Ministry of Economy, Trade and Industry, Japan, 2015).

Energy Efficiency Rating

Mandatory energy efficiency policies cover 46 percent of industrial energy use (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE indicators) (see Chapter 5.3). Japan receives 6 out of 8 possible points for its industrial energy efficiency (75%) and 1559 out of 2065 possible points for the policy landscape (76%). Thus, Japan ranks 2nd among 13 in industry energy efficiency performance and 5th out of

[51] Companies from the following sectors: iron and steel, cement, pulp and paper, power generation, oil refining and chemicals.

13 for its energy efficiency policies. Table 23 provides an overview of the country's performance in each of the selected sub-indicators for the RISE indicator. [52]

Table 26: RISE Indicator Scores for Japan

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	140/140	100%
EE Entities	43/75	57%
EE Incentives from Electricity Rate Structures	167/200	83%
Incentives & Mandates for Industrial and Commercial End Users	200/600	33%
Financing Mechanisms for EE	50/50	100%
Minimum EE Performance Indicators	560/600	93%
Energy Labelling Systems	400/400	100%
Overall	1559/2065	76%

Source: Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

5.4.5.3 Air quality standards

Air quality standards

In 1968, the Japanese government implemented the Air Pollution Control Law, which has been revised several times since then. It aims to protect the health of the Japanese population and to conserve the human environment through 1) the regulation of smoke and soot as well as dust from factories and business establishments, 2) the implementation of countermeasures for hazardous air pollutants, and 3) stipulating allowable limit of automobile exhaust gas etc. Table 27 provides an overview of Japan's air quality standards for the most relevant air pollutants.

Table 27: National Air Pollution Standards in Japan

Pollutant		Level of the standard (µg/m³)
Particulate matter (PM10)	Annual Daily	other 100
Particulate matter (PM2.5)	Annual Daily	15 35
Ozone (O3)	8-hr-daily Hourly	other 118
Sulphur dioxide (SO2)	Annual Daily Hourly	N/A 105 250
Nitrogen dioxide (NO2)	Annual Daily Hourly	N/A 112 other

52 For a detailed description of the sub-indicators of the RISE indicator see section 3.

Pollutant		Level of the standard (µg/m³)
Carbon monoxide (CO)	Daily 8-hr-daily Hourly	12 25 12.5

Source: Ministry of the Environment (2018), Kutlar Joss et al. (2017)

The enforcing institution is usually the Ministry of the Environment. Any person or industry planning on developing a soot and smoke emitting facility must provide relevant information to the local government. Owners of existing facilities are obliged to measure and keep record of the volume and concentration of the soot and smoke generated according to the technical standards set by the Ministry of the Environment. Exceeding the regulation standards can entail improvement orders by the local authorities.

5.4.6 Carbon constraints in South Korea (as of March 2020)

Besides a national ETS operating since 2015, South Korea has a long tradition of energy efficiency policies and standards, an energy efficiency financing program and a variety of air quality standards. In the last decade, the focus of climate policy in South Korea shifted from a strong focus on energy efficiency to a more diverse and comprehensive approach.

5.4.6.1 Effective Carbon Prices

South Korea does not have a carbon tax but a national emissions trading scheme in place since 2015. Moreover, it implemented different taxes on energy use that also apply to industrial energy consumers. All price based measures together address the following proportion of industry emissions in South Korea in 2015: 98 percent of industry emissions are priced above EUR 0; 97 percent are priced at or above EUR 5, 2 percent are priced at or above EUR 30 and 2 percent are priced at or above EUR 60 (OECD, 2018a).[53] These proportions add up to an average carbon price of EUR 17.49 for industrial consumers in South Korea.[54] Compared to the other countries analyzed in this report, South Korea ranks 2nd of 13.

5.4.6.1.1 Carbon Taxes and Specific Taxes on Energy Use

South Korea implemented excise taxes on electricity for the industrial sector. Natural gas is not covered by specific excise taxes. Excise taxes on steam coal and coking coal are not applicable. The tax on electricity increased by 68% between 2010 and 2017, from EUR 1.85 per MWh to EUR 3.11 per MWh. Table 28 provides an overview of the electricity excise taxes for industry in South Korea.

Table 28: Energy Excise Tax for Industry per Energy Source in South Korea

Korea	Natural Gas (per mwh GCV)	Steam coal (per tonne)	Coking coal (per tonne)	Electricity (per mwh)
2007	0.00	..	..	1.88
2008	0.00	..	..	1.53
2009	0.00	..	..	1.54
2010	0.00	..	..	1.85

[53] A detailed description of carbon pricing gaps is provided in section 3

[54] A detailed description of the methodology used to calculate the effective carbon price is provided in section 3.

Korea	Natural Gas (per mwh GCV)	Steam coal (per tonne)	Coking coal (per tonne)	Electricity (per mwh)
2011	0.00	..	..	1.95
2012	0.00	..	..	2.37
2013	0.00	..	..	2.56
2014	0.00	..	..	2.83
2015	0.00	..	..	3.16
2016	0.00	..	..	3.09
2017	0.00	..	..	3.11

Source: (IEA, 2018d)

Besides the electricity tax, industries in South Korea need to pay a transport energy environment tax (TEET), which applies to gasoline used for road transport and to diesel. The TEET price is linked to the energy and carbon content of the respective fuel (OECD, 2018d).

5.4.6.1.2 Emission Trading Schemes

5.4.6.1.2.1 National ETS

Since 2015 Korea has a national ETS in place. Within the Phase I (2015-2017) only domestic credits, e.g. national Clean Development Mechanism (CDM) projects, could be used for compliance and allowance. In Phase II (2018-2020), international CDM projects by domestic companies are allowed. Entities must convert CDM credits to Korean Credit Use (KCU) in order to accepted. The rules for Phase II (2021-2025) are so far unclear (ICAP, 2019c).

Unlike the EU ETS or other similar programs, the point of regulation in the Korean ETS (KETS) is at the company level rather than by installation: the country's highest emitting companies are covered, meaning the program covers over 70 percent of the country's emissions. The sector with the highest coverage under the KETS is industry (91%) (OECD, 2015). In addition to multiple greenhouse gases (not just CO_2), the scope of the program includes both direct and indirect emissions, so that emissions related to companies' electricity consumption are also covered.

Companies are allowed to fulfill up to 10 percent of their compliance obligation using offset credits. Like the EU ETS, the program includes a market stability reserve managed by a central allocation authority, but its purpose is to increase liquidity rather than addressing an allowance surplus – the traded volume in the market has been low compared to mature ETS like those in the EU and North America.

Price

Figure 10: ETS Allowance Price in South Korea

Source: (ICAP, 2020k)

The average allowance price in the KETS was EUR 8.4/tCO_2eq in 2015[55] and increased significantly over the next years. In 2020, the price rose to little less than EUR 30/tCO_2eq on average (ICAP, 2020l).

Percentage of industrial emissions covered

In 2015, 91% of Korea's industrial emissions were covered by the ETS. 19% of emissions are covered both by the KETS and by carbon taxes (TEET or excise taxes). 8% of industrial emissions are not covered by either of both (OECD, 2016).

Allocation of free allowances

During Phase I (2015-2017), all allowances were handed out for free, with most sectors receiving their allocation based on average GHG emissions of the base year (2011-2013). Three sectors (grey cement clinker, oil refining, and aviation) received free allowances on the basis of benchmarks using data from the same base year. In phase I, the number of covered entities grew (from 524 in 2015 to 592 in 2017), resulting in additional free allocation beyond the initial cap including over 100 million additional KAUs from the program's new entrant reserve and early action reserve, plus over 15 million offsets. In Phase II (2018-2020), 97% of the allowances are distributed for free while 3% are auctioned. Of the freely allocated amount, some more sectors receive benchmark allocations. Toward the end of phase II, the share of sector-specific benchmarking is set to reach 50%. Auctions began in January 2019. Entities deemed to be at high risk of carbon leakage are exempt from the three percent auctioning rule.[56] During Phase III

[55] Data availability only from 2014 onwards.

[56] "Sub-sectors with >30% of trade intensity, >30% of additional cost rate or a combination of >10% of trade intensity and >5% of additional cost rate are granted auctioning exceptions." (ICAP, 2019a).

(2021-2025), the Korean government intends to increase the auctioning share to over 10 percent of the annual allowance pool (ICAP, 2019c).

Flexibility

Both banking and borrowing are allowed in KETS. There is no restriction on banking. Borrowing is allowed only within a trading phase, up to a limit of 10% of a company's obligation in 2015 and 20% in 2016 and 2017 (ICAP, 2019c).

Entities covered by the KETS can offset their emissions by canceling CERs, the emission reduction credits generated by projects under the Kyoto Protocol's offset mechanism CDM. In phase I, only domestic credits from external reduction activities implemented by non-ETS entities were allowed to use for compliance. With CERs being worth less a few cents on average (whereas Korean offsets trade at roughly the price of Korean allowances), Korean firms have taken advantage of the option to cancel CERs from Korean CDM projects and using them for compliance under the KETS. So far, the Korean government has issued over 24 million Korean Offset Credits (KOCs) that can be used by companies for ETS compliance – the vast majority of which are cancelled CERs from CDM projects. In May 2018, however, the Korean government finalized rules allowing CERs from non-Korean CDM projects to be converted to Korean offsets and used for compliance as well – for up to five percent of an entity's compliance obligation, and provided the project is owned by a Korean company. Overall, the offset use limit is 10 percent of compliance obligation per company in Phase II as it was in Phase I, with half of that being international offsets/credits. The same percentage is intended for Phase III (2021-2025) (ICAP, 2019c).

Compliance and enforcement

Entities must submit an annual report on GHG emissions, verified by a third-party verifier, within three months of the previous compliance year (ICAP, 2019c), which are then reviewed and certified by the Certification Committee of Korea's Ministry of Environment. In case of incorrect reporting on emissions, entities are penalised for each unit of additional emission at either three times the average market price of allowances of the given compliance year or KRW 100,000/tonne (USD 89) (ICAP, 2019c).

Proposals for linking

There are no concrete proposals for linking Korea's ETS to other existing carbon markets in the near future, though Korean officials report that there have been "several discussions" about the idea.[57] Opportunities for at least *indirect* linking present themselves given that the start of the KETS' next phase coincides with that of many other ETS. The EU ETS Phase 4, as well as that of the North American Western Climate Initiative (California and Quebec) begin in January 2021, as does Korea's Phase III. With international credits/offsets allowed in this period in Korea, there is a chance that emitters in all three of these schemes could draw from a common international offset pool. However, whether that pool will exist and to what extent entities covered by domestic ETS can make use of it will be decided at future climate summits (UNFCCC) and by the governments of the jurisdictions in charge of the respective ETS.

5.4.6.1.3 Proposals for pricing carbon

Beyond the KETS and the other existing tools, there are no further proposals for carbon pricing.

[57] "As there have been several discussions about linking with other markets, the question of linkage will be one of the matters considered in Phase III." Kim Jung-Hwan, Ministry of Environment of the Republic of Korea, in (ICAP, 2019a).

5.4.6.2 Energy Efficiency Standards

The energy efficiency objective of South Korea, an integral part of the country's 'National Energy Plan 2008-2030', is to reduce energy intensity by 46 percent between 2007 and 2030 (ABB, 2013a). The energy savings goal for 2030 is around 38 Mtoe, of which 44 percent, i.e. 17 Mtoe, is expected to be achieved in industry. Compared to the business-as-usual scenario, energy consumption of industry is required to fall by around 13%. The implementing agency of energy efficiency programs, the Korean Energy Management Corporation (KEMCO), promotes five-year voluntary agreements with industrial groups. Businesses that enter into voluntary agreements or invest in energy-saving technologies are entitled to receive financial and technical support and tax credits covering up to 20 percent of the investment cost. Large energy consumers (over 2 ktoe/year) are required to carry out mandatory energy audits every 5 years since 2007 (ABB, 2013a).

Energy Efficiency Policies

Most of Korea's energy efficiency measures find their legal basis in the country's Energy Use Rationalisation Act, last amended in 2011 (Ministry of Government Legislation, Korea, 2011). Programs include concessional loans for energy efficiency investments with a below market interest rate in addition to a tax credit, as well as mandatory energy auditing that targets over 3,000 facilities of energy-intensive companies consuming more than 20 ktoe per year (World Bank, 2018b). These can participate in the Energy Saving Partnership Program (ESP) that shares new energy saving technologies within the industrial branches. A total of 195 companies participated in this program, resulting in fuel savings of 285 ktoe and electricity savings of 393 GWh between 2000 and 2007 (ABB, 2013a).

Korea has various programs to increase the energy efficiency of appliances. The energy standards and labeling program, in force since 1992, ensures all manufacturers attach an energy efficiency label to energy-intensive appliances; appliances that fail to meet minimum energy performance standards (MEPS) can longer be sold (IEA, 2016b). This is relevant to the industry sector to the extent that, besides common household products, some industrial appliances (such as gas boilers) are also covered by the programme (MOTIE and Korea Energy Agency, 2015).

Energy Efficiency Rating

Mandatory energy efficiency policies cover 8 percent of industrial energy use (IEA, 2018d). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE indicators) (see Chapter 5.3). South Korea receives 4.5 out of 8 possible points for its industrial energy efficiency (56%) and 1759 out of 2065 possible points for the policy landscape (85%). Thus, South Korea ranks 4th out of 13 in industry energy efficiency performance and 3rd out of 13 for its energy efficiency policies. Table 29 provides an overview of the country's performance in each of the selected sub-indicators for the RISE indicator.[58]

Table 29: RISE Indicator Scores for South Korea

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	140/140	100%
EE Entities	75/75	100%
EE Incentives from Electricity Rate Structures	134/200	67%

[58] For a detailed description of the sub-indicators of the RISE indicator see section 3.

RISE Sub-Indicator	Absolute score	Relative score
Incentives & Mandates for Industrial and Commercial End Users	600/600	100%
Financing Mechanisms for EE	50/50	100%
Minimum EE Performance Indicators	600/600	100%
Energy Labelling Systems	200/400	50%
Overall	1759/2065	85%

Source: Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

5.4.6.3 Air quality standards

Air quality standards

The standards are part of Korea's national ambient air quality objectives regulated by the Ministry of Environment under the current Clean Air Conservation Act (Ministry of Environment, Korea, n.d.). In addition to a national policy, South Korea also regulates air quality in certain metropolitan regions, including Seoul. Table 30 provides an overview of South Korea's air quality standards for the most relevant air pollutants.

Table 30: National Air Quality Standards in South Korea

Pollutant		Level of the standard ($\mu g/m^3$)
Particulate matter (PM10)	Annual Daily	50 100
Particulate matter (PM2.5)	Annual Daily	25 50
Ozone (O_3)	8-hr-daily Hourly	120 200
Sulphur dioxide (SO_2)	Annual Daily Hourly	50 130 400
Nitrogen dioxide (NO_2)	Annual Daily Hourly	57 115 190
Carbon monoxide (CO)	Daily 8-hr-daily Hourly	N/A 11 31

Source: (TransportPolicy, n.d.), Kutlar Joss et al. (2017)

5.4.7 Carbon constraints in Norway (as of December 2019)

Norway is one of the largest oil and natural gas exporters worldwide, but also one of the leading countries in climate change mitigation. Next to various energy efficiency measures, the country has a history of pricing carbon emissions.

5.4.7.1 Effective Carbon Prices

Norway has a carbon tax and a national emissions trading scheme in place since 2005. Moreover, there are different taxes on energy use, some of which also apply to the industry sector.

All price based measures together address the following proportion of industry emissions in Norway in 2015: 80 percent of industry emissions are priced above EUR 0, 79 percent are priced at or above EUR 5, 46 percent are priced at or above EUR 30 and 46 percent are priced at or above EUR 60 (OECD, 2018a).[59] These proportions of priced industry emissions add up to an average carbon price of EUR 26.72 for industrial consumers in Norway.[60] With this, Norway ranks 1st among the 13 countries analysed in this report.

5.4.7.1.1 Carbon Taxes and Specific Taxes on Energy Use

Excises taxes on natural gas and coking coal are not applicable in Norway. Electricity is not covered by specific excise taxes. Data for the Norwegian excise tax on steam coal is not available.

Norwegian Carbon Tax

Norway has a carbon tax on mineral oil, petrol and emissions from petroleum extraction on its continental shelf since 1991. A CO_2 tax on natural gas and LPG was introduced in 2010.

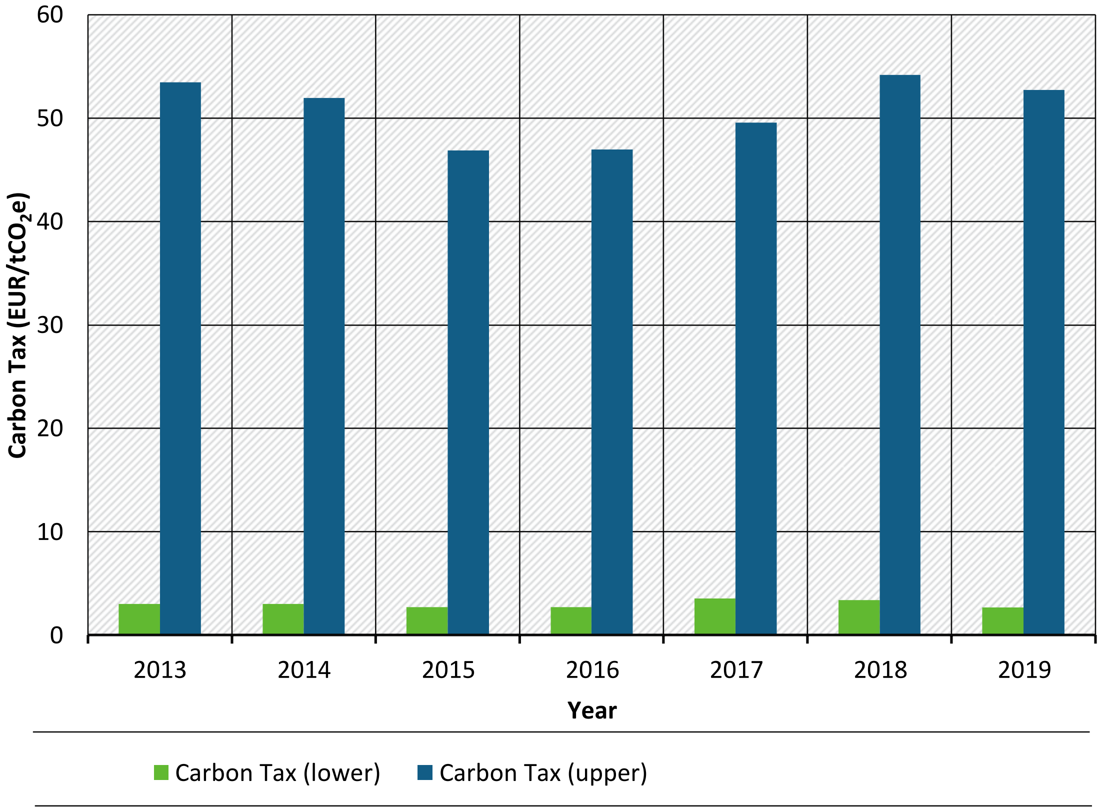
Price

Norway's carbon tax varies across sectors and sources. The price for emitting a tonne of CO_2 is highest in the petroleum sector and in domestic aviation. Both are also part of the EU ETS. Yet if natural gas and LPG used in the manufacturing process are subject to the EU ETS, the tax will be reduced or exempted. Fishery, freight and passenger transport in domestic shipping and offshore supply vessels can also be exempt from the carbon tax on natural gas and LPG.

[59] A detailed description of carbon pricing gaps is provided in section 3.

[60] A detailed description of the methodology used to calculate the effective carbon price is provided in section 3.

Figure 11: Carbon Tax Norway



Source: (World Bank et al., 2016; World Bank and Ecofys, 2018, 2017, 2015, 2014, 2013)

Companies that are active in the pulp and paper, the herring meal and fishmeal sectors that are not covered by the EU ETS, as well as fishery in inshore waters, pay a reduced carbon tax of around 11 Euros per tonne.[61] For the 2018 budget, the government excluded most instances where companies were exempt from the carbon tax or paid a reduced rate. Agriculture and fishery are temporarily excluded. However, it is being reviewed whether carbon taxes should be gradually increased in these sectors (Norwegian Ministry of Climate and Environment, 2017).

	Tax Rate NOK/tonne CO_2	Tax Rate EUR/tonne CO_2
Petrol	449	48.14
Mineral Oil		
- Standard rate, light fuel oil	451	48.35
- Standard rate, heavy fuel oil	383	41.06
- Domestic Aviation	431	46.21
- Pulp and paper industry and fishmeal industry, light fuel oil	120	12.87
- Pulp and paper industry and fishmeal industry, heavy fuel oil	102	10.94
- Fishing and catching inshore waters	109	11.69

[61] The average 2018 exchange rate was used for calculation. Source: (Eurostat, 2019).

	Tax Rate NOK/tonne CO_2	Tax Rate EUR/tonne CO_2
Domestic use of gas		
- Natural Gas[62]	452	48.46
- LGP	450	48.25
- Reduced tax natural gas	29	3.11
Petroleum activities on the continental shelf[72]		
Light fuel oil	398	42.67
Heavy fuel oil	338	36.24
Natural gas	453	48.57
- Natural gas emitted to air	444	47.6

Percentage of industrial emissions covered within country

Overall, 60% of total GHG emissions are covered by the tax. The Norwegian Government is considering to introduce a flat tax on all non-ETS emission as it lays out in its Whiter Paper on the 2030 Climate Strategy (Norwegian Ministry of Climate and Environment, 2017).

5.4.7.1.2 Emissions Trading Systems

In 2005 Norway implemented a national ETS. In 2007, along with Iceland and Lichtenstein, Nthe EU ETS. Full harmonization between the different ETS was established in 2008, with the beginning of the second trading phase (EU Business Ltd., 2007).

Price

As Norway joined the EU ETS, the carbon price of the EU ETS applies equally to Norwegian emitters, depicted in Figure 7 above.

Percentage of industrial emissions covered within country

In the current trading period, 83% of Norway's industrial emissions are covered by the EU ETS, as well as 50% of all the country's total GHG emissions (Norwegian Ministry of Climate and Environment, 2017; (OECD, 2018a).

Allocation of free allowances

Before the allocation of allowances was harmonized with the EU methodology in phase III, installations in sectors of carbon leakage risk obtained some or all of their allowances for free. In the current third phase, free allocation accounted for 75% of the Norwegian installations' 2012 emissions.

For the manufacturing industry, Norway has introduced a CO_2 compensation scheme, which is applicable from July 2013 to December 2020. Because Norway is member of the integrated Nordic electricity market together with the Netherlands and Germany, higher electricity prices due to emissions trading in those countries result in higher prices in Norway. In order to prevent carbon leakage, affected companies can apply to the Norwegian Environmental Agency to

[62] Most of these emissions are also covered by the EU ETS.

receive compensation for higher prices. Based on the EU list of sectors possibly exposed to carbon leakage risk, the scheme for instance covers aluminium, ferro alloys, chemicals and pulp and paper (Norwegian Ministry of Climate and Environment, 2017).

Flexibility

Refer to the description of the EU ETS in chapter 5.4.3 above.

Compliance and enforcement

Refer to the description of the EU ETS in chapter 5.4.3 above.

Proposals for linking

Refer to the description of the EU ETS in chapter 5.4.3 above.

5.4.7.1.3 Proposals for pricing carbon

Since Norway already has both a carbon tax and ETS in place, there are no proposals for further pricing carbon.

5.4.7.2 Energy efficiency standards

In general, stationary energy consumption in Norway is mostly based on electricity generated from hydropower. Thus, emissions from energy consumption and in turn incentives for increasing energy efficiency are relatively low compared to other countries (Norwegian Ministry of Climate and Environment, 2017).

Energy Efficiency Policies

For decades, Norway's energy efficiency policies for the country's industry has been based on voluntary agreements. For instance, the Programme for Energy Efficiency in Energy Intensive Industry entitles participants for electricity tax exemptions if they have invested in energy efficiency. Further, the state enterprise Enova supports inter alia the incorporation of energy management systems in industry and infrastructure, pre-project energy efficiency measures in industry, support for central heating systems and support for the use of new energy and climate innovations in industry (IFE, 2015).

Energy Efficiency Rating

Mandatory energy efficiency policies cover three percent of industrial energy use (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE indicators) (see Chapter 3). Since Norway is not part of the ACEEE analysis, the performance is not evaluated for Norway. Yet, Norway receives 1445 out of 2065 possible points for the policy landscape (70%), placing the country on rank 8 out of 13 for its energy efficiency policies. Table 31 provides an overview of the country's performance in each of the selected sub-indicators of the RISE indicators.[63]

Table 31: RISE Indicator Scores for Norway

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	140/140	100%
EE Entities	68/75	90%
EE Incentives from Electricity Rate Structures	167/200	83%

[63] For a detailed description of the sub-indicators of the RISE indicators see Chapter 3.

RISE Sub-Indicator	Absolute score	Relative score
Incentives & Mandates for Industrial and Commercial End Users	500/600	83%
Financing Mechanisms for EE	50/50	100%
Minimum EE Performance Indicators	520/600	87%
Energy Labelling Systems	0/400	0%
Overall	1445/2065	70%

5.4.7.3 Air quality standards

Air quality standards

As a party to the European Economic Area (EEA), statutory limits are established in the Norwegian Pollution Regulation (Ch. 7) for particulate matter, nitrogen dioxide, sulphur dioxide, benzene and carbon monoxide originating primarily from industry and transport. These are based on the EU air quality directive – Clean Air for Europe (CAFE) Directive (COM/2013/0918) and the Fourth Daughter Directive (2004/107/EC) – and also pursuant to Norway's Pollution Control Act of 1981. As of January 2016, Norway introduced tighter domestic controls on air pollution, making national standards stricter than those set forth by the EU. Table 32 provides an overview of Norway's air quality standards for the most relevant air pollutants.

Table 32: National air quality standards in Norway

Pollutant		Level of the standard (µg/m^3)
Particulate matter (PM10)	Annual Daily	25 50
Particulate matter (PM2.5)	Annual Daily	15 other
Ozone (O_3)	8-hr-daily Hourly	120 other
Sulphur dioxide (SO_2)	Annual Daily Hourly	20 125 350
Nitrogen dioxide (NO_2)	Annual Daily Hourly	40 Other 200
Carbon monoxide (CO)	Daily 8-hr-daily Hourly	N/A 10 N/A

Source: (Norwegian Environment Agency, 2012), Kutlar Joss et al. (2017)

5.4.8 Carbon constraints in Russia (as of December 2019)

Russia's Intended Nationally Determined Contribution (INDC) proposes to reduce emissions 25% – 30% below 1990 levels by 2030 (UNFCCC, 2015a). It was submitted in 2015, and while the Russian Federation officially signed the Paris Agreement in April 2016, ratification and thus the submission of the definitive Nationally Determined Contribution (NDC) were announced only in September 2019.[64]

There are few regulations that amount to an implicit carbon price for the industries relevant to this report - they include permitting procedures that are supposed to incorporate ambient air quality standards, and support for renewable electricity.

5.4.8.1 Effective Carbon Prices

Russia has neither a carbon tax, nor a national emissions trading scheme in place. However, it implemented different taxes on energy use that also apply to the industry sector.

These taxes address the following proportion of industry emissions in Russia in 2015: 44% of industry emissions are priced between zero and five Euro, no emissions are priced above this level.[65] These shares add up to an average carbon price of EUR 0.48 for industrial consumers in Russia.[66] Compared to the other countries analysed in this report, Russia ranks 8th out of 13.

5.4.8.1.1 Carbon Taxes and Specific Taxes on Energy Use

There is at current no carbon tax in place in Russia.

However, there are hydrocarbon taxes levied on the extraction and on the export of natural gas, crude oil and petroleum products. The two main hydrocarbon taxes are the minerals extraction tax (MET) and the export tax. Hydrocarbon taxes on petroleum products are lower than those for crude oil to incentivise investment in domestic refining capacity. Likewise, particular difficult-to-develop resources such as Arctic offshore or shale reservoirs have benefited from full or partial tax exemptions. Thus, the function of the hydrocarbon taxes is not to discourage the use of fossil hydrocarbons, but rather to direct investment toward particular fossil resources.

Next to the specific taxes on energy use, the Russian general law on environmental protection of 2002 (Federal Law 7-FZ on Environmental Protection, of 10 January 2002) authorizes the Russian government to charge fees for "negative impact on the environment" (including emissions of air pollutants exceeding allowed levels. However, there is evidence that such fines are not well enforced or collected (Bazenkova, 2015).

5.4.8.1.2 Emission Trading Schemes

5.4.8.1.2.1 National ETS

There is no national ETS in place in Russia.

5.4.8.1.2.2 Regional ETS

There is no regional ETS in place in Russia.

[64] Furthermore, the degree to which industrial emitters (or any stationary sources) would account for meeting these targets is "diffused" by the INDC's language on the role of emission reduction from land use. The wording of Russia's commitment explicitly state's the country's intent to calculate achievement of the emission reduction target through increased carbon sequestration (afforestation and other land use changes) to the maximum extent allowable under the agreement (the Russian INDC submission can be found in English and Russian as a word document in the UNFCCC's database under "Russia" at https://www4.unfccc.int/sites/submissions/indc/Submission%20Pages/submissions.aspx). This puts the minimum possible reduction "burden" on Russia's emitting sectors (including industry), as forest expansion in Russia is occurring without targeted measures as a byproduct of climate change, since more and more of the Russian Federation's land mass is forested under conditions of rising temperatures.

[65] A detailed description of carbon pricing gaps is provided in section 3

[66] A detailed description of the methodology used to calculate the effective carbon price is provided in section 3.

5.4.8.1.3 Proposals for pricing carbon

There are currently no proposals for pricing carbon in Russia. Russia is the only BRICS country that is not a member of the World Bank's Partnership for Market Readiness.

5.4.8.2 Energy efficiency standards

Russia is one of the largest energy consuming countries worldwide. The country has extensive oil and natural gas reserves. Energy efficiency measures are relatively marginal.

Energy Efficiency Policies

Following President Putin's Decree No. 730-p, which approved the Climate Doctrine of the Russian Federation in 2009, several target-oriented programmes addressing energy efficiency for industrial sectors were adopted (President of Russia, 2009). Decree No. 2446-r for energy saving and energy efficiency improvement is one of the programmes. It runs from 2010 to 2020 and aims to reduce energy intensity of industrial production per unit GDP by 40% from 2020 compared to 2007 levels. The programme covers 45-55% of total Russian energy consumption, 90% of industrial energy use and nearly all energy intensive sectors in Russia (IIP, 2012a). The programme is supported by Federal Law No. 261-FZ on energy conservation and energy efficiency. The law includes timeframes, responsibilities and specific implementation requirements, etc. (Government of the Russian Federation, 2009; IIP, 2012b). All participating industrial enterprises were obliged to have meters monitoring their energy consumption by 2012, obtain an energy performance certificate and have an energy manager. Further these entities needed to develop a reduction plan for their resource consumption by 2013. In addition, they were obliged to implement an energy management system and to reach the ISO 50001 energy system standard to undertake energy audits by 2013 (Gusev, 2013; IIP, 2012b).

Those firms not adhering the obligations face a relatively modest fine of max EUR 10,767 (RUR 710,000)[67] (IIP, 2012c). The IEA states that many enterprises delayed the implementation of energy audits. In addition, most of the submitted audits were of poor quality (IEA, 2014). However, the government tries to support energy efficiency measure in various ways: It con-finances the best regional energy efficiency programmes, guarantees loans for energy efficiency projects and applies an investment tax credit (IIP, 2012a, 2012b). On the other hand, many companies did not take advantage of these supporting measures due to a lack of information and poor incentives (IEA, 2014).

Energy Efficiency Rating

There are no mandatory energy efficiency policies for industrial energy use (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE indicators) (see Chapter 3). Russia receives 2 out of 8 possible points for its industrial energy efficiency (25%) and 607 out of 2065 possible points for the policy landscape (29%). Thus, Russia ranks 6th out of 13 in industry energy efficiency performance and 13th out of 13 for its energy efficiency policies. Table 33 provides an overview of the country's performance in each of the selected sub-indicators of the RISE indicators.[68]

[67] The average 2018 exchange rate was used for calculation. Source: (Eurostat, 2019).

[68] For a detailed description of the sub-indicators of the RISE indicators see Chapter 3.

Table 33: RISE Indicator Scores for Russia

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	140/140	100%
EE Entities	75/75	100%
EE Incentives from Electricity Rate Structures	167/200	83%
Incentives & Mandates for Industrial and Commercial End Users	200/600	33%
Financing Mechanisms for EE	25/50	50%
Minimum EE Performance Indicators	0/600	0%
Energy Labelling Systems	0/400	0%
Overall	607/2065	29%

Source: Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

5.4.8.3 Air quality standards

Air quality standards

Almost 100 years ago, Russia was the first country to implement environmental quality standards. They determine the limits of pollution in both industrial and residential areas. By 2003, 625 maximum allowable concentrations (MACs) and 1945 "tentatively safe exposure levels" (TSELs) existed for ambient air. Most of these standards were derived to ensure "zero risk for human health". Many of the MACs are much more ambitious than EU requirements or even WHO reference values. They are therefore often considered to be overly ambitious or even unachievable (OECD, 2006). However, compliance with the environmental standards has always been low, and as a result pollution continues to be a major problem in Russia (Digges, 2014; OECD, 2004). Table 34 provides an overview of Russia's air quality standards for the most relevant air pollutants.

Table 34: National Air quality standards in Russia

Pollutant		Level of the standard (µg/m³)
Particulate matter (PM10)	Annual Daily	40 60
Particulate matter (PM2.5)	Annual Daily	25 35
Ozone (O_3)	8-hr-daily Hourly	Other Other
Sulphur dioxide (SO_2)	Annual Daily Hourly	N/A 50 N/A
Nitrogen dioxide (NO_2)	Annual Daily Hourly	40 N/A other

Pollutant		Level of the standard (µg/m^3)
Carbon monoxide (CO)	Daily	3
	8-hr-daily	N/A
	Hourly	N/A

Soruce: Kutlar Joss et al. (2017)

Specifically, Russia's regulatory regime for air pollution is one of permitting (emission of pollutants requires a permit). Depending on the type of polluter, the permit is issued either by the Federal Service for Supervision of Natural Resource Usage or by a relevant regional environmental agency. The permit sets out the maximum allowable emission levels and other terms to ensure protection of the atmospheric air. Although the relevant agency must take safe ambient air quality levels into consideration when doing so (as per section 31.6 of the national law on environmental protection of 2002), there appears to be no defined national ambient air quality standard on which permitted levels are based. Instead, allowable levels of criteria pollutants vary on a case by case basis by permit. Experts point out that enforcement is inadequate under this system, as emissions levels granted in permits depend on the respective emitters' connections to relevant political entities (Yulkin, 2018).

Regulatory reform is expected in 2019, which may allow major industrial facilities to apply for an integrated permit for different types of emissions (as opposed to the current permitting system, which is separate for each pollutant and thus cumbersome and less well-enforced) (Bartholomy et al., 2019). Better enforcement of existing permitting requirements for criteria air pollutants (such as sulphur dioxide and particulate matter) would amount to a slightly tighter effective carbon constraint to the extent that the more adequately regulated facilities emit greenhouse gases.[69]

5.4.9 Carbon constraints in Saudi Arabia (as of December 2019)

Saudi Arabia's greenhouse gas emissions grew rapidly in recent years, increasing by 75% from 1990 to 2013. Today, the country has the second highest CO_2 per capita emissions globally. Future levels are expected to increase by 2030 up to 132% above 2010 levels and 600% up to 1990 levels (Climate Transparency and Climate Action Tracker, 2016).

Saudi Arabia's climate policy has been assessed as weak in several instances, e.g. as the country with the lowest climate protection performance worldwide (Germanwatch, 2019) or critical insufficient progress towards the Paris pledge (Climate Action Tracker, 2019b). While the kingdom ratified the Paris Agreement in 2016, Saudi Arabia's iNDC (intended Nationally Determined Contributions) contains a clause to adjust its target in case it poses "disproportionate or abnormal burden" to its economy (Climate Action Tracker, 2019b; UNFCCC, 2015b).

Still, there are some climate policies to recognize: according to its iNDC, the country aims to reduce its emissions by 130 Mt/CO_2 per year by 2030 – without specifying the baseline year (World Bank, 2016). Saudi Arabia's prominent "Vision 2030" mentions an initial target of 9.5 GW of renewable energy (Kingdom of Saudi Arabia, n.d.). In 2017, King Salman launched a Renewable Energy Initiative with the aim of generating 10% of the country's energy share from renewables (argaam, 2017). National energy saving policies include an energy efficiency plan

[69] Other measures in Russia: Russia has a sophisticated system to support renewable capacity expansion, which however fails to deliver at the scale necessary to achieve the set targets. The cost of the system is passed on to electricity consumers, including to large industry. Thus, indirect additional carbon prices for the Russian industry occur. However, a quantification to what extend that is the case is complicated since, inter alia, price differential is partially covered by public funds.

that targets the reduction of electricity intensity by 30% between 2005 and 2030. Moreover, the country determined mandatory air quality standards to reduce environmental pollution.

5.4.9.1 Effective Carbon Prices

Saudi Arabia has neither a carbon tax, nor an emission trading scheme (ETS) in place. However, the country implemented different taxes on energy use that also focus on the industry sector.

Besides Singapore and Russia, Saudi Arabia is the only country in this analysis, which is not an OECD member. As a result, there is no consistent data on pricing of industry emissions. Since there are no carbon prices levied in Saudia Arabia, it is rated 0 points in this section.

5.4.9.1.1 Carbon Taxes and specific taxes on energy use

Saudi Arabia does not have a carbon tax in place.

5.4.9.1.2 Emission Trading Schemes

There is no ETS in place in Saudi Arabia.

5.4.9.1.3 Proposals for pricing carbon

Saudi Arabia has not yet mentioned any intention to price carbon.[70]

5.4.9.2 Energy efficiency standards

Saudi Arabia's per capita energy consumption is 3.6 times higher than the global average. Today, around 15% of total energy consumption comes from the industrial sector. Petrochemicals, steel and cement represent about 85% of total energy consumption in industry (Saudi Energy Efficiency Center, 2018a).

Energy Efficiency Policies

In 2003, a National Energy Efficiency Program (NEEP) was introduced. The NEEP included energy audits for the industrial sector and the promotion of high-efficiency motors, as well as energy efficiency labels, standards for appliance constructions codes, technical management and training (ABB, 2012).

The NEEP formally ended in 2010 and was followed by the creation of the Saudi Energy Efficiency Center (SEEC) with the main tasks of developing Saudi Arabia's energy efficiency plans, policies and initiatives, monitoring implementation, promoting awareness and developing capacity in the energy efficiency market. For the commercial and industrial consumers, measures include the use of remote control for air conditioning during peak hours and curtailable load contracts (ABB, 2012).

In view of these, the SEEC created the 2012 Energy Efficiency Plan (EEP) as a follow-up to the NEEP. The EEP set out to establish a baseline for energy efficiency policy efforts (notably on energy efficiency in key sectors); to bring together key stakeholders from government and business that have important leverage over energy efficiency outcomes within their portfolios; to implement standards for measuring the highest impact; to agree and disseminate energy efficiency labels on appliances; to procure and demonstrate leadership on energy efficiency in government buildings; and to develop the basic infrastructure and capacity to begin monitoring and enforcing energy efficiency objectives (IEA, 2015a).

[70] Rathter than introducing a carbon price, the more imminent challenge that Saudi Arabia currently faces is to continue to phase out the still widespread subsidies for fossil fuels. Whereas Saudi-Arabia has taken first steps to scale back fossil fuel subsidies in recent years, Saudi Arabian consumers continue to benefit from some of the cheapest energy prices in the world (IEA, 2019c; IEA and OECD, 2019).

Moreover, the SEEC has developed an energy efficiency framework for industrial plants: in the first phase, it achieved an energy reduction of 1.7% in the steel manufacturing, 2.0% in cement and 2.8% for petrochemicals. The second phase will target the aluminum industry, and the third phase the remaining industrial sectors (Saudi Energy Efficiency Center, 2018b). Saudi Basic Industries Corporation (SABIC) has set formal energy efficiency targets to reduce energy intensity by 25% by 2025. In that regard, SABIC is working with the SEEC. In addition, Saudi Aramco, the world's largest oil company, is also keenly interested in energy efficiency improvements and has signed up to the corporate Energy Conservation Policy with the goal of reducing its energy intensity by 2% per year. Between 2012 and 2013 Saudi Aramco reduced its energy intensity by 4.6% (IEA, 2015b).

According to the iNDC, the National Energy Efficiency Program focuses on the sectors industry, transport and buildings – as these account for over 90% of the kingdom's energy demand.

Energy Efficiency Rating

There are no mandatory energy efficiency policies for industrial energy use (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE indicators) (see Chapter 3). Saudi Arabia receives 2 out of 8 possible points for its industrial energy efficiency (25%) and 847 out of 2065 possible points for the policy landscape (41%). Thus, Saudi Arabia ranks 6th out of 13 in industry energy efficiency performance and 12th out of 13 for its energy efficiency policies. Table 35 provides an overview of the country's performance in each of the selected sub-indicators for the RISE indicator.[71]

Table 35: RISE Indicator Scores for Saudi Arabia

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	140/140	100%
EE Entities	75/75	100%
EE Incentives from Electricity Rate Structures	167/200	83%
Incentives & Mandates for Industrial and Commercial End Users	200/600	33%
Financing Mechanisms for EE	25/50	50%
Minimum EE Performance Indicators	240/600	40%
Energy Labelling Systems	0/400	0%
Overall	847/2065	41%

Source: Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

5.4.9.3 Air quality standards

Vehicular and industrial emissions are the major drivers of air pollution in Saudi Arabia. The largest polluter of PM, NO_x and SO_2 is the national industry. According to UNEP, inter alia crude oil production, petroleum refining, basic petrochemicals industries, cement, fertilizer, plastics, metals and construction manufactures have the highest potential to improve air quality.

[71] For a detailed description of the sub-indicators of the RISE indicator see section 3.

Additionally, natural sources such as sandstorms significantly affect the pollution rates (UNEP, 2015).

Air quality standards

Since 2004, Saudi Arabia has mandatory Ambient Air Standards (Kingdom of Saudi Arabia, 2004). There has been an update in 2012. The standards prescribe limit values for companies, especially for the industrial sector. However, when a company performs “exempted activities”, the standards do not apply. Moreover, the policy exempts dispersion zones, indoor air and natural events from the limitations (New Climate Policy Database, 2012). As a result, air quality in Saudi Arabia’s cities and regions are critically unhealthy (air-quality.com, 2019). Table 36 provides an overview of Saudi Arabia’s air quality standards for the most relevant air pollutant.

Table 36: National Air Quality Standards in Saudi Arabia

Pollutant[72]		Level of the standard (ug/m3)[73]
Particulate matter (PM10)	Annual Daily	80 340
Particulate matter (PM2.5)	Annual Daily	15 35
Ozone (O_3)	8-hr-daily Hourly	157 235
Sulphur dioxide (SO_2)	Annual Daily Hourly	N/A 125 350
Nitrogen dioxide (NO_2)	Annual Daily Hourly	100 other 660
Carbon monoxide (CO)	Daily 8-hr-daily Hourly	N/A 10 40

Source: Kutlar Joss et al. (2017)

In May 2019, Saudi Arabia’s Ministry of Environment, Water and Agriculture and UN Environment signed a strategic cooperation for environmental protection. Among other, UN Environment will provide technical expertise for air quality management and support the Kingdom in achieving climate action targets and sustainable development goals (UN Environment, 2019).

5.4.10 Carbon constraints in Singapore (as of December 2019)

In its nationally determined contribution under the Paris Agreement (NDC), Singapore commits to reduce its emission intensity (emissions per GDP) by 36 percent from 2005 levels until 2030. It further envisions reducing absolute emissions, with the aim of peaking them around 2030. As one of the tools to achieve these targets, the country has implemented a carbon tax. Energy efficiency standards, especially for industrial installations, are mandatory and enforced through

[72] Limits for some of the pollutants must not exceed twice per months, for some not more than once per annum. PM exposures, if exceed due to abnormal natural background concentrations, it will not be considered as violation of standard.

[73] For industrial cities.

the country's comprehensive Energy Conservation Act. Air quality standards are also in place and enforced, as are mandatory compliance standards for households and energy management practices for existing industries.

5.4.10.1 Effective Carbon Prices

Singapore introduced a carbon tax in 2019. In addition, different taxes apply to energy use, including in the industry sector.

Besides Saudi Arabia and Russia, Singapore is the third country in this analysis that is not an OECD member. As a result, there is no consistent data on pricing of industry emissions. However, we since Singapore (unlike Saudia Arabia and Russia) has introduced a carbon tax, the corresponding price is reflected in the evaluation of effective carbon constraints. Yet, it was not possible to obtain data on how much of the country's industrial emissions are covered by the carbon tax. To prevent distortions, we therefore applied the average emission coverage for industry emissions of all countries that have a carbon price in place.[74] The results are found in section 5.

5.4.10.1.1 Carbon Taxes and Specific Taxes on Energy Use

Singapore's Carbon Pricing Act (CPA) and its accompanying regulations came into operation on 1 January, 2019. Installations who emit more than 25,000 tonnes CO_{2e} per year are subject to a tax of 5 Singapore dollars (EUR 3.30) per tonne, starting in January 2020 for the previous year's emissions. The tax rate is set through 2023, but will be revised based on the status of international climate change negotiations and other emission reduction policies. Singapore's finance minister announced in March 2018 that this revision would increase the per tonne charge to between S$10/t$CO_{2e}$ and S$15/t$CO_{2e}$ (EUR 6.61 to 9.91) by 2030 (Jindal, 2018).

Revenues from the tax (estimated at S$ 1 billion / EUR 660 million over the first 5 years) will fund two existing energy efficiency programmes called the Productivity Grant and the Energy Efficiency Fund (see energy efficiency measures section below) - these finance emission reduction efforts in the building sector, which accounts for roughly 16 percent of the country's emissions.

Though called a "carbon tax" the charge does not apply to CO_2 alone. Rather, it covers the six "Kyoto gases" – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

The tax applies to all sectors of Singapore's economy, and industry accounts for 60% of the country's overall GHG emissions (Ministry of the Environment and Water Resources, Singapore, 2018). Singapore's power plants are relatively low-emitting, having switched to gas in the 1990's: nearly all of them are combined cycle natural gas plants or cogeneration facilities (Energy Market Authority, 2018). Thus, industrial installations account larger portion of the tax than in other countries' economy-wide schemes. The 25,000 tonne/year threshold means the island's 30-40 largest emitters are covered. These are power plants, refineries, and manufacturing facilities - mainly of chemicals, pharmaceuticals, and semiconductors. Together, they account for 80% of Singapore's overall GHG emissions (The Straits Times, 2018).

Of the covered industrial installations, refineries are likely to be impacted the most in terms of competitive disadvantage given rising competition from their counterparts in China, India and the Middle East. Singapore's National Climate Change Secretariat estimated in 2017 that refineries' increase in operating cost from a S$10-20/tonne tax (the level under discussion at the

[74] These countries are China, the EU, Japan, South Korea, Norway, Switzerland and the United States.

time) is equivalent to the impact of an increase in crude oil prices of US$3.50-US$7 a barrel (National Climate Change Secretariat, 2017; Soh, 2017).

5.4.10.1.2 Emission Trading Schemes

Singapore does not have an ETS in place.

5.4.10.1.3 Proposals for pricing carbon

Given that the national carbon tax entered into force in January 2019, there are no further carbon pricing proposals under development/consideration in Singapore.

5.4.10.2 Energy efficiency standards

Energy Efficiency Policies

During 2000-2010, industrial energy intensity increased by around 2.5% per annum (ABB, 2013b). However, Singapore aims to *decrease* energy intensity 35% by 2030 compared to the 2005 level (Ministry of the Environment and Water Resources and Ministry of National Development, 2014).[75] The profile of Singapore's electricity consumption (which grew by 2 percent from 48.6 TWh in 2016 to 49.6 TWh in 2017) differs from most other industrialised nations in that industrial-related sectors account for over 43 percent of power use, surpassing commerce and services (36%) and households (15%). Energy efficiency measures (especially electricity) are thus relevant to the industry sector in particular.

The main national policy in this regard is Singapore's Energy Conservation Act, originally enacted in 2012 and revised in 2014: it requires minimum energy efficiency standards for all energy-consuming systems. Failure to comply with the standards is pursued as a criminal offense. Energy intensive entities are required to register with National Environment Agency if the entities used a threshold of 54 TJ energy in two of preceding three years and the entities are either manufacturing industries, energy supply companies or water supply companies. Within 30 days of registration, an entity is required to appoint an energy manager. New entities or those undergoing major expansion with projected energy consumption of more than 54 TJ/annum, and those that fall within the sectors included for existing entities, are required to conduct an energy efficiency opportunities assessments during the business permitting process. These entities are required to conduct energy performance monitoring once they come into operation. This monitoring includes metering to measure the overall energy consumption of the facility, and measuring consumption of the individual systems that account for at least 80% of the entity's total consumption (National Environment Agency, 2018a).

The Energy Efficiency Fund (into which proceeds from the carbon tax go) supports energy efficiency efforts of industrial facilities. Companies setting up new facilities in Singapore can receive up to S$600,000 to attend a design workshop on how to build the most efficient facility under this programme, which also pays up to S$200,000 for energy audits and co-funds up to 30% of the investment cost of energy efficient equipment or technologies in existing facilities.

Energy Efficiency Rating

Mandatory energy efficiency policies cover one percent of industrial energy use (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE indicators) (see Chapter 3). Since Singapore is not part of the ACEEE analysis, the performance is not covered in this analysis. Singapore receives 999 out of 2065 possible points for the policy landscape (48%). Thus, Singapore ranks 11th of 13 for its energy efficiency policies.

[75] Target is 22% compared to 2012 level

Table 37 provides an overview of the country's performance in each of the selected sub-indicators of the RISE indicators.[76]

Table 37: RISE Indicator Scores for Singapore

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	140/140	100%
EE Entities	75/75	100%
EE Incentives from Electricity Rate Structures	167/200	83%
Incentives & Mandates for Industrial and Commercial End Users	567/600	94%
Financing Mechanisms for EE	50/50	50%
Minimum EE Performance Indicators	0/600	0%
Energy Labelling Systems	0/400	0%
Overall	99/2065	48%

Source: Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

5.4.10.3 Air quality standards

Motor vehicles represent the main sources of air pollution in Singapore, so most of the regulations in this area apply to the transport sector rather than to industry (Land Transport Authority, 2017).

Air quality standards

Measures to contain air pollution include integrated urban and industrial planning, legislation with strict enforcement programmes, and air quality monitoring. International air quality benchmarks such as the World Health Organisation Air Quality Guidelines are constantly reviewed by an advisory committee established by the National Environment Agency (NEA) (National Environment Agency, 2018b).

In terms of enforcement, industries are required to conduct source emission tests on their own or through one of eight accredited consultants authorized by the NEA. This "Source Emission Test Scheme" aims to ensure that air emissions are monitored regularly by industries, meeting prescribed air emission standards. Table 38 provides an overview of Singapore's air quality standards for the most relevant air pollutants.

Table 38: National Air Quality Standards in Singapore[77]

Pollutant[78]		Level of the standard (ug/m3)
Particulate matter (PM10)	Annual Daily	other 150

[76] For a detailed description of the sub-indicators of the RISE indicators see Chapter 3.

[77] The values in the table are the current standards in Singapore. However, new and stricter standards are planned to be implemented by 2020 with further adjustments in the long term.

[78] Limits for some of the pollutants must not exceed twice per months, for some not more than once per annum. PM exposures, if exceed due to abnormal natural background concentrations, it will not be considered as violation of standard.

Pollutant[78]		Level of the standard (ug/m3)
Particulate matter (PM2.5)	Annual Daily	15 25
Ozone (O_3)	8-hr-daily Hourly	147 other
Sulphur dioxide (SO_2)	Annual Daily Hourly	80 365 N/A
Nitrogen dioxide (NO_2)	Annual Daily Hourly	100 N/A N/A
Carbon monoxide (CO)	Daily 8-hr-daily Hourly	N/A 10 40

Source: Kutlar Joss et al. (2017)

5.4.11 Carbon constraints in Switzerland (as of January 2020)

Switzerland is one of the few countries that has both a carbon tax and an ETS. The country further supports companies in matters of energy efficiency with guidance and consultancy. Air quality standards in Switzerland are among the strictest of the countries covered in this analysis.

5.4.11.1 Effective Carbon Prices

Switzerland has a carbon tax and a national emissions trading scheme in place since 2008. Moreover, it implemented a mineral oil duty that also covers industry. All price based measures together address the following proportion of industry emissions in Switzerland in 2015: 84 percent of industry emissions are priced above EUR 0, 49 percent are priced at or above EUR 5, 18 percent are priced at or above EUR 30 and 0 percent are priced at or above EUR 60 (OECD, 2018).[79] These proportions of priced industry emissions add up to an average carbon price of EUR 12.10 for industrial consumers in Switzerland.[80] Compared to the other countries analysed in this report, Switzerland ranks 3rd of 13.

5.4.11.1.1 Carbon Taxes and specific taxes on energy use

Switzerland implemented excise taxes on natural gas and electricity. Steam coal is not covered by specific excise taxes. Excise taxes on coking coal is not applicable. The tax on natural gas increased by 184% between 2010 and 2017, from EUR 4.92 per MWh gross calorific value (GCV) to EUR 13.97 per MWh GCV. The tax on electricity increased by 314% between 2010 and 2017, from EUR 3.26 per MWh to EUR 13.49 per MWh.

Table 39: Energy Excise Tax per Energy Source

	Natural Gas (per Mwh GCV)	Steam coal (per tonne)	Coking coal (per tonne)	Electricity (per mwh)
2007	0.28	0.00	x	0.00

[79] A detailed description of carbon pricing gaps is provided in section 3.

[80] A detailed description of the methodology used to calculate the effective carbon price is provided in section 3.

	Natural Gas (per Mwh GCV)	Steam coal (per tonne)	Coking coal (per tonne)	Electricity (per mwh)
2008	1.68	0.00	x	0.00
2009	1.74	0.00	x	2.98
2010	4.92	0.00	x	3.26
2011	5.52	0.00	x	3.65
2012	5.60	0.00	x	3.73
2013	5.47	0.00	x	3.66
2014	9.12	0.00	x	4.94
2015	10.38	0.00	x	10.30
2016	14.25	0.00	x	11.92
2017	13.97	0.00	x	13.49

Source: IEA (2018)

The Swiss Carbon Tax

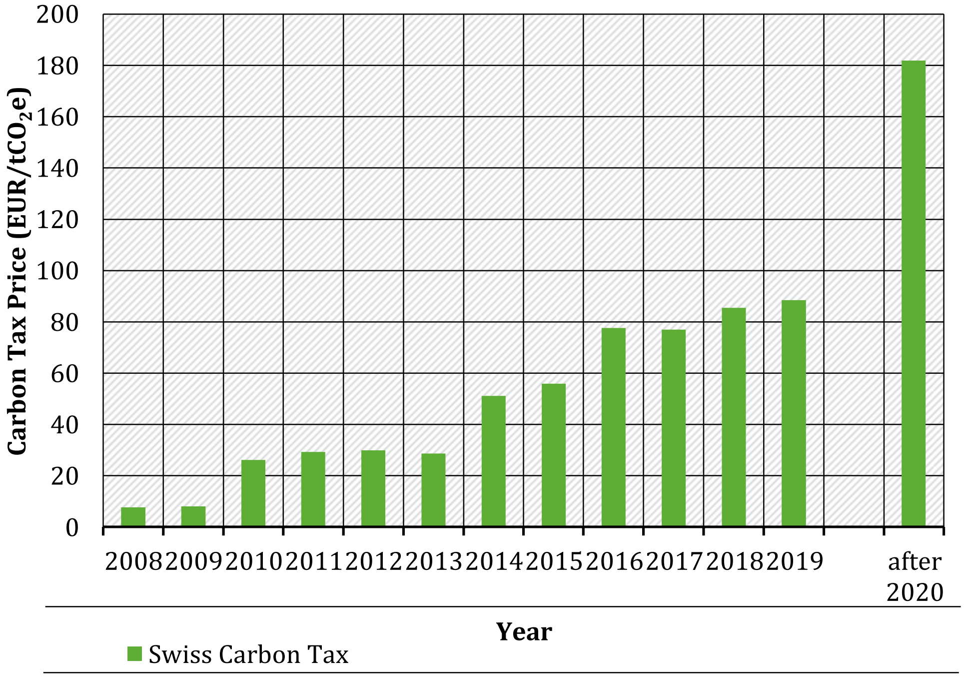
Price

Switzerland implemented a carbon tax in 2008 with a tax rate of 7.56 EUR/tCO_2[81] (Bundesamt für Umwelt BAFU, 2018a). Since then, the carbon tax increased gradually, reaching a price of 88 EUR/tCO_2 in 2019. Today, the Swiss carbon tax is in terms of price level the second globally after Sweden (114 EUR/tCO_2 in 2019) (Ministry of Finance, Sweden, 2018). In light of the Swiss carbon law's revision, the tax might increase to a maximum value of 210 CHF (181 EUR[82]) per tonne after 2020 (Bundesamt für Umwelt BAFU, 2018b).

[81] With an average exchange rate of 0.630 CHF/EUR in 2008. Source: (Eurostat, 2019).

[82] 2018 exchange rate is assumed. Source: (Eurostat, 2019).

Figure 12: Carbon Tax in Switzerland



Source: (Ecoplan, 2017; World Bank, 2019, 2012, 2011, 2010; World Bank et al., 2016; World Bank and Ecofys, 2018, 2017, 2015, 2014, 2013)

Percentage of industrial emissions covered within country

Since its implementation in 2008, the carbon tax imposes a price on the energetic use of fossil fuels. After its revision in 2013, it also includes CO_2 emissions from industrial processes that are unrelated to fuel combustion. Transport fuels are not affected by the carbon tax. Operators of fossil fuel-based combined heat and power plants with a rated thermal input of 0.5 to 20 MW are also exempt from the carbon tax. Other greenhouse gas intensive producers can be exempt from the tax if they commit to a company-specific reduction target. Furthermore, large companies that participate in the national ETS are excluded from the carbon tax (Federal Office for the Environment FOEN, 2018a); this applies to about 50-60 companies with around 5 million tonnes of emissions. All sectors obliged to participate in the ETS are listed in Annex 6 of the CO_2 Ordinance (The Federal Council, 2019). These companies usually have an installed total rated thermal input of more than 20 MW (ICAP, 2020l).

Overall, the carbon tax covers 33% of the national GHG emissions (World Bank and Ecofys, 2018). In combination, the general tax on fossil fuels and the carbon tax cover 40% of the country's industrial emissions. 19% of industry emissions are covered by taxes (excise taxes on energy and the carbon tax) and, at the same time, by the ETS (OECD, 2016).

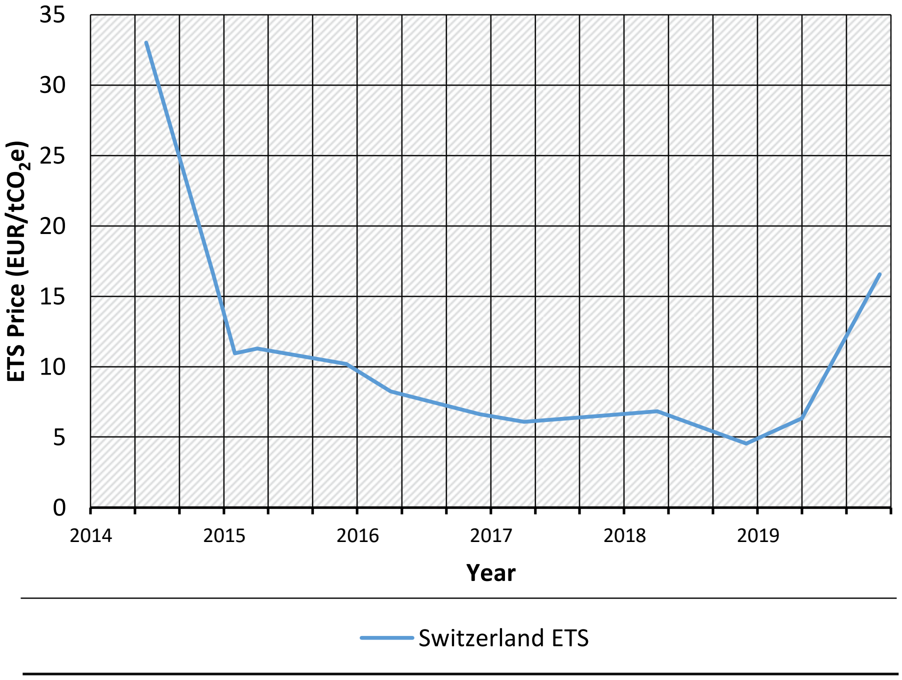
5.4.11.1.2 Emission Trading Systems

Since 2008, a national ETS operates in Switzerland. Following a testing period from 2008 to 2012, the national ETS has become mandatory since. As of January 1st, 2020 Switzerland is officially linked to the EU ETS.

Price

The first auction took place in May 2014, clearing at CHF 40.25 (EUR 33.03) per allowance. The price dropped significantly to around EUR 11 in January 2015 and continued to decrease, albeit at a slower rate. In November 2018, the allowance price was EUR 4.50. By November 2019, the price had increased to EUR 16.58/tCO_{2e}.

Figure 13: ETS Allowance Price in Switzerland



Source: (ICAP, 2020k)

Percentage of industrial emissions covered within country

The Swiss ETS covers 42% of all industrial production emissions (OECD, 2016).

Allocation of free allowances

Free allocation in the mandatory phase (2013-2020) of the Swiss ETS is based on industry benchmarks, using a similar approach to the EU ETS. For sectors not deemed to be exposed to carbon leakage, free allocation is phased out gradually, i.e. from 80% free allocation in 2013 to 30% in 2020. Allowances not allocated for free are auctioned two or three times a year. 5% of the cap is set aside for the New Entrants Reserve (NER).

In dependence of specific requirements, Annex 6 of the CO_2 Ordinance lists all sectors obliged to participate in the national ETS.[83] Although not required to do so, companies of the sectors listed in Annex 7 of the CO_2 Ordinance can voluntarily opt into the ETS and thereby avoid paying the carbon tax. Companies already participating in the ETS can apply to opt out if they emitted less than 25,000 tonnes of CO_{2e} in three consecutive years (Federal Office for the Environment FOEN, 2018b).

Table 40: Obligations for the sectors being evaluated

Industry sector	
Iron & Steel	Obliged to participate in the ETS Exempted from CO2 tax
Chemicals	Qualify for exemption from carbon tax if reduction target is adopted Can voluntarily participate in ETS and thereby being exempted from carbon tax

[83] For instance, production sights of paper or cardboard with an installed production capacity of over 20 tonnes per day are obliged to participate in the national ETS. Installations with less production capacity in the same sector can opt into the ETS and hence avoid paying the carbon tax (listed in Annex 7 of the CO2 ordinance).

Industry sector	
Non-Ferrous Metals	Obliged to participate in the ETS Exempted from carbon tax
Cement and Lime	Obliged to participate in the ETS Exempted from carbon tax
Glass	Qualify for exemption from carbon tax if reduction target is adopted Can voluntarily opt into ETS and thereby become exempt from carbon tax
Ceramics	Qualify for exemption from carbon tax if reduction target is adopted Can voluntarily opt into ETS and thereby become exempt from carbon tax
Pulp & Paper	Qualify for exemption from carbon tax if reduction target is adopted Can voluntarily opt into ETS and thereby become exempt from carbon tax
Refineries	Qualify for exemption from carbon tax if reduction target is adopted Can voluntarily opt into ETS and thereby become exempt from carbon tax

Source: (The Federal Council, 2019)

Flexibility

Banking is allowed within each compliance period. In addition, banking from one compliance period to the next is also possible without limitation. Offsets and credits are allowed.

Compliance and enforcement

Entities must report their emissions annually. Failure to deliver sufficient allowances will entail a penalty set at CHF 125/tCO_2 (around EUR 108/tCO_2). Further, companies are obliged to hand out missing allowances and/or international credits in the following year (ICAP, 2019d).

Proposals for linking

On 23. November 2017, Switzerland and the EU signed an agreement to link their emissions trading systems (European Commission, 2017). In order for the agreement to become effective, it must be ratified by the European Parliament and Council as well as by the Swiss Council of States.[84] In 2019, all requirements under the linking agreement were completed and ratified. The linked entered into force on 1 January 2020. Participants are allowed to use allowances from either one of the two systems for compliance.

5.4.11.1.3 Proposals for pricing carbon

Since Switzerland already has both a carbon tax and ETS in place, there are no proposals for further pricing carbon.

5.4.11.2 Energy efficiency standards

Energy Efficiency Policies

The Swiss Federal Office of Energy (SFOE) offers consultancy for companies in order to achieve better energy efficiency. Various activities are part of the support. For instance, the SFOE supports the development and promotion of process optimization methods as well as energy-efficient engines and equipment (Swiss Federal Office of Energy, 2014).

[84] On 3. December 2018, the Swiss National Council voted in favor of the agreement. According to (ICAP, 2018c), the draft bill passed with 118 votes out of 200.

Energy Efficiency Rating

Mandatory energy efficiency policies cover ten percent of industrial energy use (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE indicators) (see Chapter 3). Since Switzerland is not part of the ACEEE analysis, the performance aspect is not covered in the assessment of Swiss energy efficiency policies. Switzerland receives 1431 out of 2065 possible points for the policy landscape (69%). With this, Switzerland ranks 9th out of 13 for its energy efficiency policies. Table 41 provides an overview of the country's performance in each of the selected sub-indicators for the RISE indicator.[85]

Table 41: RISE Indicator Scores for Switzerland

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	100/140	71%
EE Entities	68/75	90%
EE Incentives from Electricity Rate Structures	200/200	100%
Incentives & Mandates for Industrial and Commercial End Users	567/600	94%
Financing Mechanisms for EE	50/50	100%
Minimum EE Performance Indicators	240/600	45%
Energy Labelling Systems	200/400	50%
Overall	1431/2065	69%

Source: Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

5.4.11.3 Air quality standards

Air quality standards

In 1983, the Federal Environmental Protection Act (EPA) was introduced. As a core part of Swiss air quality legislation, it defines the general standards for air quality in the country. The Ordinance on Air Pollution Control (OAPC) establishes specific benchmarks for emission sources such as stationary installations. Third, the Air Pollution Control Strategy describes standards for emissions sources and measures for accomplishing them. The latter two have been revised several times in order to keep pace with technological change (Amann and Cofala, 2015).

Air quality standards apply nationwide, while the cantons are responsible for their enforcement and monitoring. The cantons further are obliged to establish and regularly review action plans to control excessive ambient air pollution levels. The Swiss confederation shall enforce the provisions concerning market surveillance for construction machines, control of thermal and motor fuels on import and placing on the market (Library of Congress, 2019).

Table 42 provides an overview of Switzerland's air quality standards for the most relevant air pollutants.

[85] For a detailed description of the sub-indicators of the RISE indicator see section 3.

Table 42: Air quality standards in Switzerland

Pollutant		Level of the standard (µg/m³)
Particulate matter (PM10)	Annual Daily	20 50
Particulate matter (PM2.5)	Annual Daily	10 other
Ozone (O_3)	8-hr-daily Hourly	other 120
Sulphur dioxide (SO_2)	Annual Daily Hourly	30 100 N/A
Nitrogen dioxide (NO_2)	Annual Daily Hourly	30 80 other
Carbon monoxide (CO)	Daily 8-hr-daily Hourly	8 N/A N/A

Source: Kutlar Joss et al. (2017)

5.4.12 Carbon constraints in Turkey (as of December 2019)

As an emerging economy, Turkey's CO_2 emissions have been increasing rapidly in recent years. While there are taxes on industrial energy use, and while energy efficiency measures and air quality standards are in place, there is no price on CO_2 emissions.

5.4.12.1 Effective Carbon Prices

There is neither a carbon tax nor an emissions trading system in place. However, Turkey implemented different taxes on energy use that also apply to the industry sector. All price based measures together address the following proportion of industry emissions in Turkey in 2015: 41 percent of industry emissions are priced above EUR 0, 13 percent are priced at or above EUR 5, 4 percent are priced at or above EUR 30 and 0 percent are priced at or above EUR 60 (OECD, 2018a).[86] These proportions of priced industry emissions add up to an average carbon price of EUR 1.67 for industrial consumers in Turkey.[87] Compared to the other countries analysed in this report, Turkey ranks 7th of 13.

5.4.12.1.1 Carbon Taxes and specific taxes on energy use

Turkey levies excise taxes on natural gas and electricity. Steam coal and coking coal are not covered by specific excise taxes. The tax on natural gas decreased by 52% between 2010 and 2017, from EUR 1.08 per MWh to EUR 0.52 per MWh. The tax on electricity decreased by 32% between 2010 and 2017, from EUR 3.71 per MWh to EUR 2.52 per MWh.

[86] A detailed description of carbon pricing gaps is provided in section 3.

[87] A detailed description of the methodology used to calculate the effective carbon price is provided in section 3.

Table 43: Energy Excise Tax for Industry per Energy Source

	Natural Gas (per MWh GCV)	Steam coal (per tonne)	Coking coal (per tonne)	Electricity (per MWh)
2007	1.12	0.00	0.00	2.57
2008	1.13	0.00	0.00	3.09
2009	1.00	0.00	0.00	3.19
2010	1.08	0.00	0.00	3.71
2011	0.92	0.00	0.00	3.21
2012	0.93	0.00	0.00	3.76
2013	0.85	0.00	0.00	3.59
2014	0.74	0.00	0.00	3.20
2015	0.71	0.00	0.00	3.27
2016	0.65	0.00	0.00	3.11
2017	0.52	0.00	0.00	2.52

Source: (IEA, 2018d)

5.4.12.1.2 Emission Trading Schemes

Turkey does not have an ETS.

5.4.12.1.3 Proposals for pricing carbon

Turkey nominally still has the status of a candidate country to access the EU and thus works with the EU to complete the EU obligations in the field of climate and environment. This includes, inter alia, the requirements set by the EU ETS Directive. As stated in the EU position paper, Turkey was planning to complete the full transposition of the EU ETS in 2019. However, the accession negotiations between Turkey and the EU have been on hold for several years due to political disputes (Tournier, 2016), which also influences Turkey's aspirations and efforts to converge towards EU environmental regulations.

Turkey also explores national options to proceed in the area of carbon pricing in order to reach its 2030 climate mitigation target, to reduce GHG emissions up to 21% below the BAU level as pledged in the Turkish NDC (ICAP, 2017). The national climate action plan and the corresponding climate change strategy document describe Turkey's medium-term goal as developing "voluntary domestic carbon markets which provide financial assistance for reduction of GHG emissions" (TR Ministry of Environment and Urbanization, 2012, n.d.). In addition, Turkey is a member of the World Bank Partnership for Market Readiness and receives support for preparatory steps that may lead towards carbon pricing, particularly in the area of emission monitoring. Nevertheless, so far government has shown little politic will to introduce ambitious instruments or targets.

5.4.12.2 Energy efficiency standards

Energy Efficiency Policies

In order to increase energy efficiency and thus limit energy costs, the Turkish government implemented the Turkish Energy Efficiency Law (No. 5627) in May 2007, which was revised in 2011 (Turkish Government, 2007). This provides the legal basis for requirements for industry and businesses as well as for building above a certain threshold. Requirements include annual reporting of energy consumption to the Turkish General Directorate of Renewable Energy (CYGM, 2011) as well as the obligation of industrial facilities with an energy consumption of at least 5,000 toe annually to perform energy surveys every four years, beginning in 2015 (Turkish Government, 2011).

To reduce the energy intensity of its economy, Turkey published its Energy Efficiency Strategy in 2012, including a long-term energy intensity target of 20% reduction by 2023 compared to 2011 levels. The strategy also requires each industrial sub-sector to reduce energy consumption by at least 10% until 2023 (IIP, 2017; Ministry of Energy and Natural Resources, 2012). In more detail, the strategy's goals are described in the Energy Efficiency Action Plan published in 2014.

In light of an EU accession the Turkish government adapted most of the EU Ecodesign Framework Directive (2009/129/EC). The directive provides mandatory minimum requirements for the improvement of environmental performance of products in industry and in households. Further, it aims at harmonizing standards with the EU legislature for Turkish products to access EU appliances market (Coskun et al., 2011; IEA, 2016c). The Directive on Energy End-use Efficiency and Energy Services (2002/91/EC and recast as 2010/31/EU) was also transposed by the Turkish government. But the adoption of all EU energy efficiency measures is not complete, with the Directive on Energy End-Use Efficiency and Energy Services (2006/32/EC) and the Energy Efficiency Directive (2012/27/EC) still awaiting implementation (IEA, 2016c).

Energy Efficiency Rating

Mandatory energy efficiency policies cover ten percent of industrial energy usage (IEA, 2018). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE indicators) (see Chapter 3). Turkey receives 4 out of 8 possible points for its industrial energy efficiency (56%) and 1472 out of 2065 possible points for the policy landscape (71%). Thus, Turkey ranks 4th out of 13 in industry energy efficiency performance and 7th of 13 for its energy efficiency policies. Table 44 provides an overview of the country's performance in each of the selected sub-indicators of the RISE indicators.[88]

Table 44: RISE Indicator Scores for Turkey

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	100/140	71%
EE Entities	75/75	100%
EE Incentives from Electricity Rate Structures	200/200	100%
Incentives & Mandates for Industrial and Commercial End Users	567/600	94%
Financing Mechanisms for EE	50/50	100%

[88] For a detailed description of the sub-indicators of the RISE indicators see Chapter 3.

RISE Sub-Indicator	Absolute score	Relative score
Minimum EE Performance Indicators	240/600	40%
Energy Labelling Systems	200/400	50%
Overall	1472/2065	71%

Source: Regulatory Indicators for Sustainable Energy (RISE)" database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

5.4.12.3 Air quality standards

Air quality is a major concern in Turkey, as around 97% of its urban population is exposed to levels of particulate matter (PM10, PM2.5), which are the highest in Europe and which exceed the limits set by the European Union and the WHO (IEA, 2016c). According to OECD estimates, 28,924 people in Turkey died prematurely from ambient particulate matter and ozone exposure (OECD, 2014).

Air quality standards

The first Turkish air pollution regulation was established in 1986. The 'Protection of Air Quality' set standards for air quality and for emissions on plants that require an emission permit. A more detailed regulation entered into force in 2004 with the 'Industrial Air Pollution Regulation' for industrial and energy producing facilities. In 2009, it was replaced by the 'Regulation of Air Pollution Caused by Industry', which was subsequently amended in 2010, 2011 and 2012. It sets standards and establishes controlling measures for air pollutants including carbon monoxide, sulphur dioxide, nitrogen dioxide, volatile organic compounds and hazardous gases such as hydrogen fluoride, chlorine and inorganic chloride compounds. In addition, the regulation defines criteria and procedures for production, usage, storage and transportation of fuels and raw materials (FAO, 2017; Ministry of Environment and Forestry, 2009).

With its National Climate Action Plan, Turkey aims to transpose the EU Environmental Impact Assessment Directive and the EU Sulphur in Fuels Directive into national legislation. Further, power plants need to comply with both the EU Large Combustion Plant Directive (LCPD) and the Industrial Emission Directive (IEA, 2016c).

Table 45: Air quality standards in Turkey

Pollutant		Level of the standard (µg/m^3)
Particulate matter (PM10)	Annual Daily	60 100
Particulate matter (PM2.5)	Annual Daily	other other
Ozone (O_3)	8-hr-daily Hourly	N/A N/A
Sulphur dioxide (SO_2)	Annual Daily Hourly	150 250 500
Nitrogen dioxide (NO_2)	Annual Daily Hourly	N/A other 300

Pollutant		Level of the standard (µg/m³)
Carbon monoxide (CO)	Daily 8-hr-daily Hourly	N/A 10 N/A

Source: Kutlar Joss et al. (2017)

5.4.13 Carbon constraints in the United States (as of February 2020)

While several US states operate emissions trading systems, the US at national level has no direct carbon pricing and no law on climate change. Under the previous US administration (2009-2017) the country's Environmental Protection Agency (EPA) used a "social cost of carbon" reference (US$50/tonne CO_{2e} in 2020 / EUR 42/tonne) for calculating costs and benefits of climate change regulations. Although this is not an effective carbon price, it gives an indication of the government's theoretical understanding thereof. The current administration (as of 2018), has altered the calculation of the social cost of carbon in varous ways, which as a result now ranges from US$ 1 to 7/tonne (EUR 0.85 – 5.90/tonne) range.

Regardless of the lack of national level carbon pricing, many programmes to address climate change exist at the subnational level, some of which involve carbon pricing. To the extent that they apply to parts of the US economy exposed to international trade in the sectors relevant for this study, they constitute part of an effective carbon price for the US. Of particular note are North America's two active carbon markets (the Western Climate Initiative and the Regional Greenhouse Gas Initiative).

5.4.13.1 Effective Carbon Prices

The US does not have a carbon pricing at the federal level, however regional emissions trading systems have been in place since 2009. The US has not implemented federal taxes on energy use that apply to the industry sector.

The regional ETS address the following proportion of industry emissions in the US in 2015: 7 percent of industry emissions are priced between 5 and 30 Euro; none are priced above this level (OECD, 2018a).[89] These proportions of priced industry emissions add up to an average carbon price of EUR 0.09 for industrial consumer in the US. Compared to the other countries analysed in this report, the US ranks 11th of 13.

5.4.13.1.1 Carbon Taxes and Specific Taxes on Energy Use

US taxes on energy use are among the lowest in the world – the OECD ranked the US fourth lowest among 42 countries in this regard, with an average tax burden amounting to less than 2.50 Euro/tCO_{2e}. In relative terms, the sector that is taxed most in the US is road transport, i.e. even less of the already low taxes fall onto industry.

5.4.13.1.2 Emission Trading Systems

5.4.13.1.2.1 National ETS

The US does not have a national ETS in place.

5.4.13.1.2.2 Regional ETS

At the regional level, two emission trading systems operate in the US: The Western Climate Initiative, which since July 2018 includes California and the Canadian province of Quebec, and the Regional Greenhouse Gas Initiative (RGGI) on the US east coast, which covers nine North-

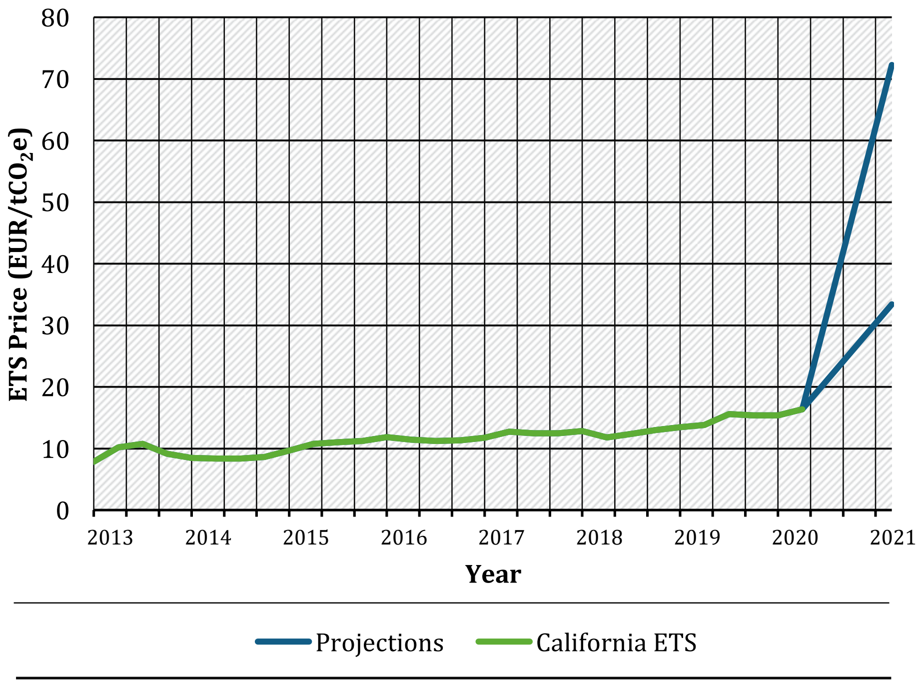
[89] A detailed description of carbon pricing gaps is provided in section 3.

eastern US States (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island and Vermont). RGGI, however, only covers CO_2 emissions from electricity generation. The Western Climate Initiative covers inter alia emissions from industrial operations; industrial emissions covered in the system amounted to 4.4% of US industrial GHG emissions in 2016.

Price

The annual average price for California carbon allowances ("CCAs," the emissions permits traded in the Western Climate Initiative programme) is shown in the figure below. The programme applied since January 2013.

Figure 14: ETS Allowance Price in California



Source:(Eurostat, 2019; ICAP, 2020k; Yang et al., 2017).[90]

In December 2017, a consulting firm published allowance price projections for California's cap-and-trade programme under various policy and fuel price scenarios through 2050, given that the programme will continue until at least 2030 as per a law passed by the state legislature in September 2017 (Yang et al., 2017). According to those projections, in 2030 allowances will sell at the system's price floor, which depends on the consumer price index but will range from $US\$_{2016}$ 37 to 80/tonne (EUR_{2018} 33 – 72/tonne). The results depend crucially on factors such as technical progress (not least in transport, which is also included in the Californian ETS via the transport fuel suppliers), complementary policies, and fuel prices especially for natural gas (ibid.).

Percentage of industrial emissions covered within country

Since the carbon price only applies at the sub-national level, it covers only a part of US industrial production – and therefore only a small proportion of US foreign trade in the respective sectors. In total, for the selected industrial sectors, the EU traded products worth EUR 56 billion with the USA in 2017 (see Table 8). About 5% of this trade took place between California and the EU, a

[90] The projected values are available only in US-$. For translation into EURO a constant exchange rate (2018) is assumed.

slight increase from 2016 to 2017 (see also Table 46). Thus, only a small share of US companies is exposed to similar carbon constraints as European competitors.

Table 46: Shares of Californian goods in total US trade with the EU for the selected industrial products

	2016			2017		
Product	**Imports**	**Exports**	**Total trade**	**Imports**	**Exports**	**Total Trade**
Pulp and paper	3.4%	1.6%	2.5%	3.3%	1.5%	2.4%
Refinery products	2.8%	1.8%	2.3%	2.7%	3.4%	3.0%
Chemicals	3.2%	5.6%	4.5%	4.0%	5.6%	4.7%
Ceramics	11.7%	4.3%	10.1%	11.5%	4.4%	10.0%
Glass	10.2%	4.0%	7.3%	10.1%	3.7%	7.0%
Cement and lime	2.5%	3.7%	2.6%	2.2%	4.2%	2.4%
Other non-metallic mineral products	12.6%	4.1%	10.4%	11.7%	4.2%	9.6%
Iron and steel	1.5%	3.7%	1.8%	1.8%	2.7%	1.9%
Non-ferrous metals	9.4%	6.0%	7.2%	14.0%	4.4%	7.8%
Total	**4.4%**	**4.4%**	**4.4%**	4.9%	4.4%	4.7%

Source: own calculations based on 2016 and 2017 trade data from U.S. Census Bureau, Economic Indicators Division. Selection of products based on NASIC 4-digit codes, which differ from NACE codes so that product categories according to NASIC can include additional

Allocation of free allowances

In the Californian ETS, the amount of free allocation to industrial entities is determined by their leakage risk (measured through emissions intensity and trade exposure, used to define "assistance factors"), sector-specific benchmarks and production volumes as well as a general cap-adjustment factor. From 2018, assistance factors were set to vary by sector based on leakage risk. For the post-2020 period, assistance factors for allocation will be part of a new rulemaking to reflect the requirement of the law extending the programme through 2030, which specifies an assistance factor of 100 percent. With the adjustment of the assistance factor for the forthcoming trading period, the current assistance factor is set in the same manner (ICAP, 2020l).

Flexibility

Banking is allowed, but emitters are subject to holding limits. Borrowing from future commitment periods is not allowed. Offsets are allowed for up to 8 percent of each company's compliance obligation,

Compliance and enforcement

Covered entities must report emissions annually and at the end of each 3-year compliance period, when a full "true up" (as opposed to partial true up of minimum 30 percent in the other two years) is required. The full true-up is in November of e.g. 2017 and 2020. Penalties for non-compliance can range from being considered a misdemeanor to fines to imprisonment as per California's health and safety code.

Proposals for linking

California and Quebec's ETS are already linked under the Western Climate Initiative, an international carbon market. Ontario was part of this programme, but its ETS was cancelled when the province came under new political leadership in July 2018. California is in talks with Mexico about linking that country's eventual ETS (to be launched in 2022) with California's, either indirectly via mutually recognized offset units or directly via allowance fungibility.

5.4.13.1.3 Proposals for pricing carbon

There are no plans for pricing carbon at the federal level in the US.

At the regional level, several states have proposed state-wide carbon taxes. Oregon passed a bill to investigate a cap-and-trade programme for greenhouse gases in March 2018, which includes a study of the state's energy intensive trade exposed industries to be published in late 2018. Differing proposed versions between the Senate and the House in terms of Oregon's potential carbon market would include different industrial sectors (different NAICS codes). However, both proposals include free allocation to industry based on an emissions efficiency benchmark of up to 90 percent of the average regional intensity per unit of output in each trade exposed industrial process (Lithgow, 2018). In January 2019, the House Bill 2020 was introduced with the proposition of establishing a state-wide cap-and-trade program, which would start in 2021. The design of the program is similar to the system of California and Québec including similar sectoral coverage as well as national offset programs and the use of auction price floors. Further, linking with other marked-based compliance mechanisms is stated in the legislation (ICAP, 2020l).

Two states are close to joining the eastern states' regional carbon market (RGGI), which would increase the amount of emissions it covers by quite a lot, given that the states in question are relatively large emitters: Virginia and New Jersey. However, since RGGI only covers participating states' power sectors, the average carbon price for Virginia and New Jersey industrial facilities is again only affected to the extent their facilities buy power. The latter was part of RGGI from 2009-2012 but its then-governor removed it from the program. The former is a comparatively coal-heavy state whose electricity generation emissions will follow a much lower trajectory through 2030 under its proposed RGGI caps than in a business-as-usual scenario. Further, in October 2019 Pennsylvania's Governor signed an executive order for the Environmental Quality Board to develop a proposal for an ETS, which covers CO2 emissions from the power sector. In addition, a potential linkage with the RGGI shall be investigated. A final proposal should not be expected before the third quarter of 2021. Therefore, the earliest date for a start of a Pennsylvanian ETS with its linkage to RGGI would be 2022 (ICAP, 2020l).

5.4.13.2 Energy efficiency standards

The US has no national energy efficiency target. Yet the country has some energy efficiency standards and measures.

Energy Efficiency Policies

Energy efficiency standards apply to newly manufactured or imported electric motors (Energy Independence and Security Act, Section 313) and for boilers and furnaces (Energy Policy Act). Other programmes support industrial energy efficiency increases through voluntary participation in a certification programme (Superior Energy Performance Programme) or in a partnership programme that encourages the companies to set their own efficiency targets or to introduce energy management systems including monitoring (Better Buildings/Better Plants Programme; Energy Star for Industry Programme) (IIP, 2016).

At the subnational level, there are energy efficiency targets enacted by states - these incentivize energy efficiency in the power sector and do not set targets for industrial sectors. As of January 2017, 26 US states were implementing an energy efficiency resource standard (EERS), which is a binding energy savings target for utilities or third-party program administrators that applies for at least three years. Savings are achieved through energy efficiency programs for electricity customers. The EERS requires that they achieve a certain amount of energy savings from energy efficiency measures. The strongest EERS requirements are in Massachusetts and Rhode Island, which require more than 2.5% new savings annually (American Council for an Energy-Efficient Economy (ACEEE), 2017). Like other measures designed for the power sector, EERS are relevant to industries' effective carbon constraint only to the extent those industries' facilities are electricity customers.

Energy Efficiency Rating

Mandatory energy efficiency policies cover 14 percent of industrial energy use (IEA, 2018a). This study assesses the energy efficiency policies for industry based on energy efficiency performance of industry (ACEEE industry performance score) and existence of energy efficiency policies (RISE indicators) (see Chapter 3). The US receives 6.5 out of 10 possible points for its industrial energy efficiency (70%) and 2025 out of 2065 possible points for the policy landscape (98%). Thus, the US ranks 1st out of 13 in industry energy efficiency performance and 1st for its energy efficiency policies. Table 47 provides an overview of the country's performance in each of the selected sub-indicators of the RISE indicators.[91]

Table 47: RISE Indicator Scores for the US

RISE Sub-Indicator	Absolute score	Relative score
National EE Planning	140/140	100%
EE Entities	75/75	100%
EE Incentives from Electricity Rate Structures	200/200	100%
Incentives & Mandates for Industrial and Commercial End Users	600/600	100%
Financing Mechanisms for EE	50/50	100%
Minimum EE Performance Indicators	560/600	93%
Energy Labelling Systems	400/400	100%
Overall	2025/2065	98%

Source: Regulatory Indicators for Sustainable Energy (RISE) database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

5.4.13.3 Air quality standards

Air quality standards

The main federal air pollution law in the US, the Clean Air Act (passed in the 1970's and amended in 1990) gives the US Environmental Protection Agency (EPA) authority to set air quality standards in the United States. The EPA establishes and periodically revises National Ambient Air Quality Standards (NAAQS) for each of six major pollutant categories: particulate matter, photochemical oxidants (including ozone), carbon monoxide, sulfur oxides, nitrogen oxides and lead. As the Clean Air Act is federal, it applies throughout the country - however, each

[91] For a detailed description of the sub-indicators of the RISE indicators see Chapter 3.

state must write its own State Implementation Plan (SIP) on how to monitor air pollution in that state and to stay in compliance with the standards. If the plan for reducing air pollution is in compliance with the EPA's requirements, it is approved; if not, the EPA may impose sanctions on the state in question. States are free to set standards higher than the EPA's NAAQs and enforce these at the subnational level. Table 48 provides an overview of US air quality standards for the most relevant pollutants.

Table 48: Air Quality Standards in the US

Pollutant		Level of the standard (µg/m3)
Particulate matter (PM10)	Annual Daily	other 150
Particulate matter (PM2.5)	Annual Daily	12 35
Ozone (O3)	8-hr-daily Hourly	140 other
Sulphur dioxide (SO2)	Annual Daily Hourly	N/A N/A 196
Nitrogen dioxide (NO2)	Annual Daily Hourly	100 other 188
Carbon monoxide (CO)	Daily 8-hr-daily Hourly	N/A 11 43

Source: Kutlar Joss et al. (2017)

5.5 Assessment of effective leakage risks in a world of converging carbon constraints

The following section presents the results of the analysis based on the methodology explained in section 5.3.1. Following the results of each category, the countries' ambition level is assessed overall.

5.5.1 Individual assessment of carbon prices, energy efficiency and air quality regulations

5.5.1.1 Average carbon prices for industrial emitters

Table 49: Effective Carbon Prices

Country	Rank	Norm'sd Score	OECD - percentage of industrial emissions being priced				
			0 €	5 €	30 €	60 €	EC P in €
Brazil	11	0,04	0,16	0,02	0,00	0,00	0,11
China	10	0,10	0,19	0,02	0,02	0,01	0,28
EU	4	4,50	0,80	0,75	0,05	0,02	12,03

India	6	1,54	0,71	0,25	0,01	0,00	4,12
Japan	5	2,31	0,70	0,34	0,05	0,04	6,18
Korea	2	6,55	0,98	0,97	0,02	0,02	17,49
Norway	1	10,00	0,80	0,79	0,46	0,46	26,72
Russia	9	0,18	0,44	0,00	0,00	0,00	0,48
Saudi Arabia	13	0,00	0,00	0,00	0,00	0,00	0,00
Singapore	8	0,33	0,59	0,00	0,00	0,00	0,87
Switzerland	3	4,53	0,84	0,49	0,18	0,00	12,10
Turkey	7	0,63	0,41	0,13	0,04	0,00	1,67
USA	12	0,03	0,07	0,07	0,00	0,00	0,09

Source: own calculations based on OECD (2018a)

Table 49 depicts each country's average carbon price (effective carbon price) for industrial emitters. As described in section 3, the OECD data shows the share of industrial carbon emissions priced within a certain price range for all countries except for Saudi Arabia, which is not covered in the OECD survey of effective carbon rates. However, as laid out in chapter 5.4.9.1, there is currently no carbon pricing system in place in Saudi Arabia, hence this category was evaluated with zero. In the case of Singapore, the country is not part of the OECD survey either, but in contrast to Saudi Arabia does have a carbon price in place. As described in chapter 5.4.10.1, the Singapore carbon tax was therefore included in the analysis – based on the current rates of taxation, and assuming coverage of industrial emissions corresponded to the average of all other countries in the analyses, that have a carbon price in place, and apply this to industry.

Overall, Norway comes out as the country with the highest price on industrial carbon emissions with an average carbon price of around EUR 27 per tonne of CO_2. The country with the second highest average carbon price is South Korea. Because 95% of Korea's industrial emissions are priced between EUR 5 and 30 and 2% above EUR 60, the country's average carbon price is around EUR 17.50. Overall, 98% of Korea's industrial emissions are covered by a carbon price. After Switzerland, which has an average carbon price of EUR 12.10 per tonne of industrial CO_2 emissions, the EU ranks fourth among the analyzed countries with an average carbon price of EUR 12 per tonne CO_2. It not should be noted, that the latest OECD data for effective carbon prices is from 2015. Since the beginning of 2018, the price has increased significantly and has reached around EUR 25/tonne CO_2 in January 2020.[92] At the other end of the spectrum, the United States rank 11th among the analyzed countries with only 7% of its industrial emissions priced between EUR 5 and 30 – resulting in an average carbon price of EUR 0.09/tonne CO_2.

5.5.1.2 Energy efficiency measures

The next chapter combines the results of three different energy efficiency indicators: the RISE score, the ACEEE score and the IEA energy efficiency policy coverage indicator. These three are shortly discussed and the rankings of the covered countries presented. In a final step, the overall energy efficiency performance of each country is derived as a combination of all three indicators.

RISE Score

In contrast to the selected sub-indicators of the ACEEE score, the RISE score assesses countries in terms of the policies they have implemented. Sub-categories like national energy efficiency planning or energy efficiency mandates for large consumers are the indicator's main focus.

[92] See Sandbag Carbon Price Viewer for most recent EU allowance price: https://sandbag.be/index.php/carbon-price-viewer/

Table 50 shows the results for all analyzed countries based on the RISE score. The United States rank first, scoring 1305 of 1345 possible points (97%). With a score of 1198 (89%), China ranks second. The EU, i.e. the average of those EU-countries for which data is available, comes fifth with a score of 1029 (77%). Saudi Arabia (627/1345, 47%) and Russia (487/1345, 36%) rank at the bottom of the list.

Table 50: RISE Score (World Bank)

Country	Rank	Scored points total	% of max. points
Brazil	10	845	63%
China	2	1198	89%
EU	5	1029	77%
India	6	1012	75%
Japan	4	1039	77%
Korea	3	1159	86%
Norway	7	975	72%
Russia	13	487	36%
Saudi Arabia	12	627	47%
Singapore	11	695	52%
Switzerland	9	964	72%
Turkey	8	968	72%
USA	1	1305	97%

Source: Regulatory Indicators for Sustainable Energy (RISE) database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

Table 51 shows the RISE score results, with adaptations as described in the methodology chapter. The overall rank with the adaptations does not differ strongly from the original World Bank RISE score, except for some instances of countries switching places (Turkey and Norway, Japan and the EU). However, the percentage rate of achieving the maximum points possible differs. Compared to the original RISE score, all countries have a lower percentage rate in the adapted version except China (+4%-points) and the United States (+1%-point). One reason is that the indicator "Incentives & Mandates: Industrial and Commercial End Users" is valued stronger in the adapted methodology, in which both China and the United States score 600/600 points (see Appendix D.2.4 for further details). Further, both countries have minimum performance standards as well as energy efficiency labeling schemes for industrial electric motors and other industrial equipment. At the other end of the spectrum, Russia and Saudi Arabia display the biggest difference between the original and the adapted RISE score, with a difference of -7 to -6 percentage points, respectively.

As indicated in section 5.3.1.2, the RISE score measures only whether certain types of energy efficiency policies are in place – not how ambitious they are, how well they are implemented, whether regulated entities comply, or what the policies achieve. Hence, China and the United States receive a relatively high score since they both have a relatively broad and sophisticated set of energy efficiency policies in place.

Table 51: RISE Score (Ecologic)

Country	Rank	Total scored points	% of max. Points
Brazil	10	1245	60%

China	2	1918	93%
EU	4	1561	76%
India	6	1532	74%
Japan	5	1559	76%
Korea	3	1759	85%
Norway	8	1445	70%
Russia	13	607	29%
Saudi Arabia	12	847	41%
Singapore	11	999	48%
Switzerland	9	1431	69%
Turkey	7	1472	71%
USA	1	2025	98%

Source: own calculations based on the Regulatory Indicators for Sustainable Energy (RISE) database from the World Bank Group (Energy Sector Management Assistance Program, 2018)

ACEEE Industry Performance Score

Table 52 shows the country results for the two indicators as well as the overall ACEEE score. The United States rank first with maximum point score considering the energy intensity in its industrial sector and 0.5 points for its share of combined heat and power (CHP) in total installed capacity. Slightly behind the United States, Japan ranks second in the ACEEE score with 6/6 points for its energy intensity in the industrial sector and 0/2 points for its share of CHP in the total installed capacity. The EU also ranks second with an overall score of 6 points. At the other end, China ranks last with 0/6 points for energy intensity of the country's industrial sector and 1/2 points for the share of CHP in total installed capacity. The score illustrates China's poor energy efficiency performance, which is in contrast to the country's comprehensive number of energy efficiency policies. The United States, by contrast, scores well on both in the policy and the performance score.

Table 52: ACEEE Industry Performance Score

Country / Indicator	Rank	Sum	Energy intensity of the industrial sector	Share of combined heat and power (CHP) in total installed capacity
max. points possible		8	6	2
Brazil	8.0	1.5	1.0	0.5
China	10.0	1.0	0.0	1.0
EU	2.0	6.0	5.0	1.0
India	8.0	1.5	1.0	0.5
Japan	2.0	6.0	6.0	0.0
Korea	4.0	4.5	4.0	0.5
Russia	6.0	2.0	0.0	2.0
Saudi Arabia	6.0	2.0	2.0	0.0
Turkey	4.0	4.5	4.0	0.5
USA	1.0	6.5	6.0	0.5

CHP = combined power and heat. Norway, Singapore and Switzerland are not displayed since these countries were not part of the ACEEE scoring evaluation.

Overall Energy Efficiency Rating

Table 53: Overall Energy Efficiency Rating

Country	Rank	Norm'sd Score	Score	ACEEE Industry Performance Score (2018)	RISE Score (2017)	IEA - industrial energy efficiency policy coverage (2017)
Brazil	9	5,02	0,366	1,50	1245	7%
China	3	9,14	0,666	1,00	1918	68%
EU	5	8,00	0,583	6,00	1561	7%
India	7	7,04	0,513	1,50	1532	38%
Japan	2	9,34	0,680	6,00	1559	46%
Korea	4	8,05	0,586	4,50	1759	8%
Norway	10	4,91	0,357	0,00	1445	3%
Russia	13	2,88	0,209	2,00	607	0%
Saudi Arabia	11	3,67	0,268	2,00	847	0%
Singapore	12	3,35	0,244	0,00	999	1%
Switzerland	8	5,10	0,372	0,00	1431	10%
Turkey	6	7,17	0,522	4,50	1472	10%
USA	1	10,00	0,728	6,50	2025	14%

Table 53 summarizes the results of the RISE and ACEEE score and adds a third indicator, the industrial energy efficiency policy coverage (IEA, 2017), as described in section 3. The indicator measures the industrial emissions that are covered by energy efficiency related policies, ranging from 0% (Russia and Saudi Arabia) to 68% (China).

Applying the underlying methodology of this analysis with its different weights for each indicator, the United States rank 1st in the overall energy efficiency score with 0.728 points and therefore 10 points in the normalised score. The country ranks 1st in the ACEEE performance indicator and in the RISE score and 4th in the policy coverage indicator.

The United States are followed by the Japan. The country ranks 2nd in the ACEEE score after the United States and 5th in the RISE score with 1559 total points. In addition. 46% of the country's industrial emissions are covered by energy efficiency policies. This means, that Japan does not only have a relatively high degree on financial incentives and mandatory measures but also a relatively energy efficient industry sector. At the same time, a relatively high share of industrial emissions are covered by energy efficiency policies.

The EU ranks 5th in the overall score with 0.583 total points and 8.00 points in the normalised score. Together with Japan, the EU comes in closely behind the top-performer in the ACEEE score and 4th in the RISE score. As mentioned before, the EU – on average – scores 36/50 points (72%) in the sub-indicator "Financing Mechanisms for Energy Efficiency" with only Russia and Saudi Arabia scoring fewer points. Further, in comparison to United States and China, which both score 400/400 points considering energy labeling systems and 600/600 points in the sub-indicator "Incentives and Mandates", the EU scores 164/400 points (41%) and 512/600 points (85%), respectively. 7% of the EU's industrial emissions are covered by energy efficiency policies.

Again, it should be noted, that the RISE score only covers the existence of energy efficiency policies but does not measure the country's performance nor the degree of compliance.

Singapore and Russia rank at the other end of the overall energy efficiency scoring table. Both countries score less than 0.3 total points. While none of the industrial emissions are covered by energy efficiency policies in Russia, 1% are covered in Singapore. Both countries score less than 1000 points in the RISE score, indicating a lack of consistent energy efficiency policies. Performance-wise, Russia scores 2/8 points, while no data is available for Singapore.

5.5.1.3 Air quality standards and other measures

Before discussing the overall assessment results, the following table provides an overview of the countries' air quality standards rating.

Table 54: Air Quality Standards Rating

Country	Rank	Norm'sd Score	Score
Brazil	6	6.27	4.57
China	7	6.15	4.48
EU	10	5.71	4.15
India	3	7.35	5.35
Japan	4	6.85	4.99
Korea	5	6.30	4.59
Norway	2	9.07	6.60
Russia	9	5.99	4.36
Saudi Arabia	12	4.66	3.39
Singapore	11	4.85	3.53
Switzerland	1	10.00	7.28
Turkey	13	2.59	1.89
USA	8	6.13	4.46

Table 54 depicts the overall score of the countries' air quality standards (AQS). Having the strictest emission limits per pollutant, Switzerland ranks first with a score of 7.28 points (10 points in the normalised score), followed by Norway (6.6 points, 9.07 points in the normalised score). The EU ranks 10th in the overall AQS rating, followed by Singapore, Saudi Arabia and Turkey. In particular, relatively to the country with the highest restriction in that category, the EU limits for sulphur dioxide (SO_2) and carbon monoxide (CO) are less ambitious.

5.5.2 Overall assessment of climate-related regulations applicable to industrial emitters

The three pre-defined categories discussed in the previous section can be combined to arrive at an overall assessment score for each country. As elaborated in section 5.3.2, this raises the question which weights should be assigned to the different dimensions. The analysis presents the following alternatives:

- As the first option, the three categories are weighted based on the estimated cost of compliance for the EU. When applying this metric, the effective carbon price receives a weight of 80%, whereas the energy efficiency and air quality component are each weighted with a factor of 10%. The results of this step are presented in section 0.
- Second, as an alternative approach, the three categories are aggregated with equal weight attached to each of them. This allows for a comparison of how the choice of

weights in the aggregation affects the relative performance of countries in the ranking. The results of this step are presented in section 5.5.2.2.

- In a third, step, the weights remain as in the first option (i.e. based on estimated EU compliance costs), but instead the results in all three categories are combined with a correction factor, which is supposed to control for differences in the enforcement of the respective regulations. As a correction factor, the country-specific enforcement indicator introduced in section 5.3.2 is applied. The results of this step are presented in section 0.

5.5.2.1 Aggregation based on compliance cost estimates

This section presents the results of aggregating the three categories. It uses the results presented in Renda et al., 2013 as a basis to derive the relative weights of the three categories (see also section 5.3.2). Based on their finding that the costs associated with the carbon price exceed the compliance cost of other environmental regulations by a factor of four, the effective carbon price enters the aggregation with a weight of 80%, whereas the two other categories are weighted with 10%.

When applying this score to aggregate the three categories, Norway comes out first with an overall score of 9.4. It has the highest average carbon price of all evaluated countries and is closely behind Switzerland in the category of air quality standards. As the country with the highest aggregated score, Norway sets the benchmark and receives 10 points in the normalised score.

The EU on average receives 4.97 points in total. While the EU ranks 4th in the average carbon price and the energy efficiency score, it comes in 10th in terms of air quality standards. As it can be observed in Table 69 in the Appendix D.2.3, this is due to the lack of air quality standards set in the EU in terms of hourly, daily or yearly maxima in comparison to the other jurisdictions. This corresponds to 5.29 points in the normalised score and positions the EU on the 4th position in the overall assessment score.

Saudi Arabia ranks at the bottom of the table with an overall score of 0.83. As the country does not have a carbon price on industry emissions, it receive zero points in the category of effective carbon pricing. Saudi Arabia, further, has unambitious air quality standards (12th place) and does not perform well in terms of industrial energy efficiency (11th place).

With China, India and the US, some of the largest emitters, and also large trading partners of the EU, occupy middle ranks in this ranking. Not surprisingly, in view of the aggregation weights, the top places in the ranking are occupied by countries that currently have some form of carbon pricing in place.

Table 55: Overall Assessment Score (weighted 80-10-10), without enforcement factor

Scores	Effective Carbon Prices		Energy Efficiency		Air Quality		Overall Score without Enforcement		
Country	Norm'sd Score	Price	Norm'sd Score	Score	Norm'sd Score	Score	Rank	Norm'sd Score	Score
Norway	10	26.72	4.91	0.36	9.07	6.6	1	10	9.4
Korea	6.55	17.49	8.05	0.59	6.3	4.59	2	7.1	6.67
Switzerland	4.53	12.1	5.1	0.37	10	7.28	3	5.46	5.13
EU	4.5	12.03	8	0.58	5.71	4.15	4	5.29	4.97

Japan	2.31	6.18	9.34	0.68	6.81	4.96	5	3.69	3.46
India	1.54	4.12	7.04	0.51	7.35	5.35	6	2.84	2.67
USA	0.03	0.09	10	0.73	6.13	4.46	7	1.74	1.64
China	0.1	0.28	9.14	0.67	6.15	4.48	8	1.72	1.61
Turkey	0.63	1.67	7.17	0.52	2.59	1.89	9	1.57	1.48
Brazil	0.04	0.11	5.02	0.37	6.27	4.57	10	1.24	1.16
Singapore	0.33	0.87	3.35	0.24	4.85	3.53	11	1.15	1.08
Russia	0.18	0.48	2.88	0.21	5.99	4.36	12	1.1	1.03
Saudi Arabia	0	0	3.67	0.27	4.66	3.39	13	0.89	0.83

5.5.2.2 Aggregation based on equal weights

As an alternative approach, the following section presents the results if the three categories (effective carbon price, energy efficiency and air quality) are instead included with equal weights.

Changing the weights to an even distribution changes the scores of the countries and the differences between them, but affects the ranking of the countries only to a limited extent. At the top of the table, Norway, Korea and Switzerland continue to occupy the top three spots. Behind them, the EU and Japan switch positions, as do India and the US. The first is due to Japan's relatively better performance in terms of air quality standards and energy efficiency, which pushes the country past the EU when applying equal weights. In the latter case, the US switches positions with India because of its better energy efficiency score. However, in contrast to the 80-10-10 weights distribution distances between the scores of the EU and Japan as well as India and the US become smaller. At the bottom of the table Saudi Arabia remains the worst performing country. Turkey and Brazil switch positions, as do Russia and Singapore. China keeps its place and ranks 8th when weights are equal among categories.

Table 56: Overall Assessment Score (weighted $^1/_3$-$^1/_3$-$^1/_3$), without enforcement factor

Scores	**Effective Carbon Prices**		**Energy Efficiency**		**Air Quality**		**Overall Score**		
Country	Norm'sd Score	Score	Norm'sd Score	Score	Norm'sd Score	Score	Rank	Norm'sd Scores	Scores
Norway	10	26.72	4.91	0.36	9.07	6.6	1	10	7.99
Korea	6.55	17.49	8.05	0.59	6.3	4.59	2	8.72	6.97
Switzerland	4.53	12.1	5.1	0.37	10	7.28	3	8.19	6.54
Japan	2.31	6.18	9.34	0.68	6.81	4.96	4	7.7	6.15
EU	4.5	12.03	8	0.58	5.71	4.15	5	7.6	6.07
USA	0.03	0.09	10	0.73	6.13	4.46	6	6.74	5.39
India	1.54	4.12	7.04	0.51	7.35	5.35	7	6.64	5.31
China	0.1	0.28	9.14	0.67	6.15	4.48	8	6.42	5.13
Brazil	0.04	0.11	5.02	0.37	6.27	4.57	9	4.73	3.78
Turkey	0.63	1.67	7.17	0.52	2.59	1.89	10	4.33	3.46
Russia	0.18	0.48	2.88	0.21	5.99	4.36	11	3.77	3.02
Singapore	0.33	0.87	3.35	0.24	4.85	3.53	12	3.56	2.84
Saudi Arabia	0	0	3.67	0.27	4.66	3.39	13	3.48	2.78

Overall, thus, applying the same weights to all categories changes the ranking of the different countries only to a limited extent. What does change significantly is the distance between overall and normalised scores. The distances between the top-performing countries and those at the end of the table narrow, as does the difference between the leading countries and their followers. For instance, applying the 80-10-10 weights, Norway's distance from Saudi Arabia in terms of the ranked overall score is 9.11 points, whereas the distance in the equal weights distribution is only 6.52 between these two countries. This comes down to the metric used: in the carbon price, as some countries apply a high carbon price and others none at all; whereas for air quality and energy efficiency, all countries apply some form of regulation.

5.5.2.3 Aggregation based on compliance cost estimates, corrected for enforcement

As described in section 3, the enforcement factor is included in the overall assessment as an additional sensitivity factor. As explained in section 5.3.2, this factor aims to correct for the fact that, while the assessment of the three categories mostly evaluates the officially announced policies, it does not (and cannot) reflect to what extent the policies are actually enforced. Since published assessments of the actual enforcement of environmental regulation are few and far between, and do not allow for a systematic comparison across countries, this study uses a combination of the Corruption Perception Index (CPI) by Transparency International and the Doing Business Indicator (DBI) by the World Bank to yield an aggregated measure of the quality of enforcement.

The enforcement factor is then applied to the ranking in all three categories – resting on the assumption that the quality of enforcement is comparable across different policy domains, i.e. if a government has difficulty enforcing regulations related to air quality, the performance for energy efficiency standards is unlikely to be much different.

Table 57: Overall Assessment Score (weighted 80-10-10), including enforcement factor

Scores	Effective Carbon Prices		Energy Efficiency		Air Quality		Enforce-ment	Overall Score (80/10/10)			Overall Score (80/10/10) with Enforcement		
Country	Norm'sd Score	Price	Norm'sd Score	Score	Norm'sd Score	Score	Score	Rank	Norm'sd Score	Score	Rank	Norm'sd Score	Score
Norway	10	26.72	4.91	0.36	9.07	6.6	83.08	1	10	9,40	1	10	7.81
Korea	6.55	17.49	8.05	0.59	6.3	4.59	70.46	2	7,10	6,67	2	6.02	4.7
Switzerland	4.53	12.1	5.1	0.37	10	7.28	80.46	3	5,46	5,13	3	5.29	4.13
EU	4.5	12.03	8	0.58	5.71	4.15	70.22	4	5,29	4,97	4	4.47	3.49
Japan	2.31	6.18	9.34	0.68	6.81	4.96	74.34	5	3,69	3,46	5	3.3	2.58
India	1.54	4.12	7.04	0.51	7.35	5.35	50.88	6	2,84	2,67	6	1.74	1.36
USA	0.03	0.09	10	0.73	6.13	4.46	76.77	7	1,74	1,64	7	1.61	1.26
Singapore	0.33	0.87	3.35	0.24	4.85	3.53	84.79	11	1,15	1,08	8	1.17	0.92
China	0.1	0.28	9.14	0.67	6.15	4.48	52.15	8	1,72	1,61	9	1.08	0.84
Turkey	0.63	1.67	7.17	0.52	2.59	1.89	55.07	9	1,57	1,48	10	1.04	0.81
Russia	0.18	0.48	2.88	0.21	5.99	4.36	51.75	12	1,10	1,03	11	0.68	0.53

Brazil	0.04	0.11	5.02	0.37	6.27	4.57	45.73	10	1,24	1,16	12	0.68	0.53
Saudi Arabia	0	0	3.67	0.27	4.66	3.39	55.75	13	0,89	0,83	13	0.59	0.46

When including the enforcement factor into the analysis, however, the ranking of countries changes little – with two exceptions, Singapore and Russia. The top seven ranks remain unchanged, even in the case of India (ranked 6th) vs. USA (ranked 7th) – despite the fact that the US score much higher in terms of their enforcement, this is not enough to offset the difference in terms of the calculated stringency of climate-related policies, where India scores higher. Merely Russia, bv virtue of its slightly more beneficial enforcement factor, overtakes Brazil as the country that has the lowest enforcement score among the countries investigated. The one striking case is Singapore, which has the strongest enforcement factor across all countries. By virtue of its stricter enforcement capabilities, Singapore advances from 11th to 8th position in the ranking, bypassing China, Turkey and Brazil.

Compared to the aggregation without correcting for enforcement differences, the distances between countries' normalised scores tend to grow – as those countries closer to the top in terms of their climate ambition, by and large (and with exceptions like Singapore) also tend to score better in terms of their enforcement capabilities.

5.5.2.4 Discussion of the Results

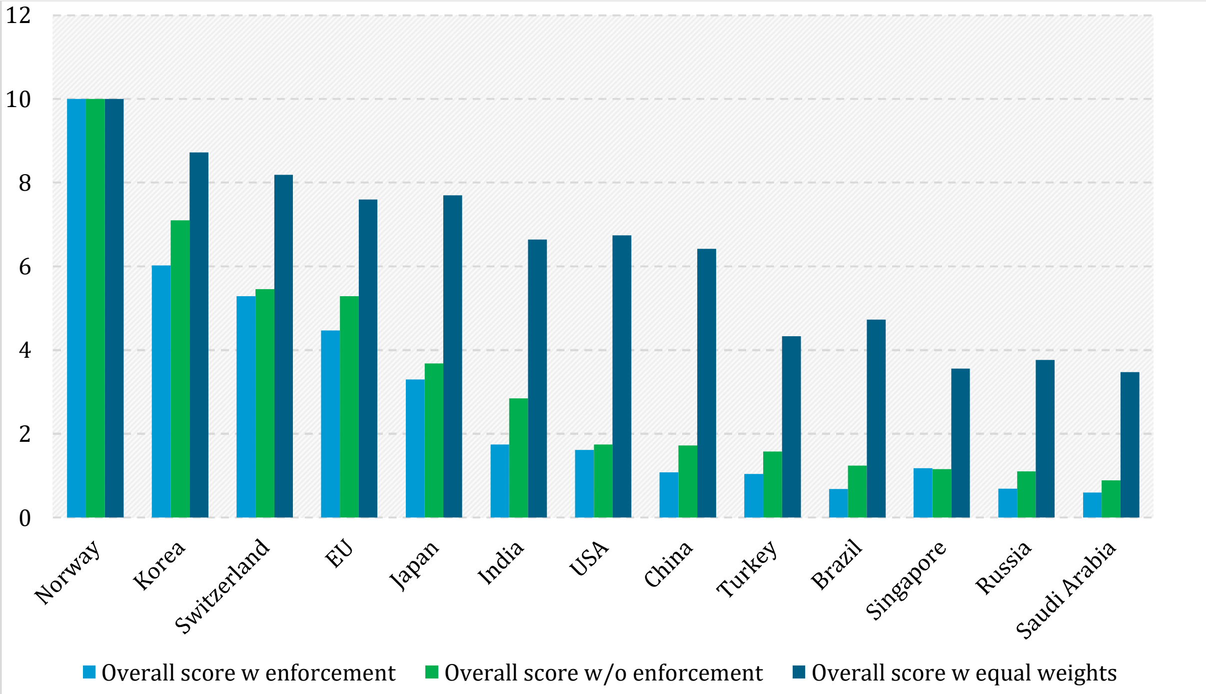
In general, both the different choice of weights and the inclusion of an enforcement factor do not change the ranking of the countries significantly, as compared to the initial option with 80-10-10 weights and without correcting for differences in enforcement. In all instances, countries' positions do not change much, with the exception of Singapore in the case of the enforcement correction. In this sense, the results are robust to changes of key assumptions.

What does change markedly, however, are the distances between the countries, as Figure 15 below illustrates. The weighting of the criteria in the first option places a particularly high emphasis on the effective carbon price. Therefore, a large number of countries that have no or only a very low carbon price in place also receive a low overall score. This also means that there is hardly any middle section: Norway is lonely at the top, followed by Korea, Switzerland and the EU. Japan (and India, unless the enforcement correction factor applies) are still relatively close. The rest of the world – including the economic heavyweights China and the US – are far behind, and score less than a third of the EU value.

This picture changes markedly if the three categories are weighted equally in the aggregation process. In this instance, there is a distinct middle section of countries (India, the USA and China) that are rated as only moderately less ambitious than the EU, with a score corresponding to 84-89% of the EU value. And even the laggards (with Turkey, Brazil, Singapore, Russia and Saudi Arabia) perform considerably better if the categories are weighted equally.

The reason for this divergence is, quite simply, that most of the countries that do not apply a carbon price do score relatively well in terms of air quality standards, but particularly in terms of energy efficiency regulations (where the USA, China, Turkey and India all score relatively high marks). In the first option case with an 80-10-10 weighting, however, these results hardly affect the overall score.

Figure 15: Overview of overall scores of countries analysed, using different aggregation methods



Source: own elaboration by the authors (Ecologic Institute)

This leads back to the question raised in the methodology: what is the "right" weighting factor for the aggregation of the different scores? To assess to what extent climate-related regulations affect the profitability of businesses, and hence the competitiveness of EU-based installations, the obvious metric would be the compliance cost associated with different types of regulations in the respective countries. However, the evidence for this is patchy. Since there are no international comparisons of compliance costs of different types of regulation, this study used the results by Renda et al., 2013 to derive a proxy, which was then applied across the entire subset of countries and sectors. There are clear constraints to this approach: not only does it extrapolate the results from one study, conducted for one sector (aluminium) in one location (the EU). What is more, the results from Renda et al. were derived for one particular constellation of policy instruments: if the ETS does indeed account for the lion's share of compliance costs in the EU, this does not mean that the same is true in other locations where the carbon price plays a much smaller role – or does not exist in the first place.

At the same time, an argument in defense of the weighting based on Renda et al. is that the strong emphasis on the carbon price is also warranted since the carbon price is undoubtedly an instrument whose primary purpose is climate protection. Considering other objectives will inevitably blur the analysis, and creates problems of delineating the boundary of the analysis: if air quality is included in the analysis, then why not water quality, then why not noise, then why not workplace health and safety, etc.

However, there are also good arguments in favour of an equal weighting. While the decision to assign identical weights may seem arbitrary to some extent, it does reflect the situation that different countries chose different approaches to regulation, and hold different views about the desirability of carbon pricing. And even where the carbon price exists, it may take on different functions in the climate policy mix of the respective countries. Also, broadening the analysis to air quality and energy efficiency better reflects the situation that climate protection is one among several interlinked objectives that regulators pursue. In political reality, however, it is not always specified which goal is the overriding policy objective, and which is rather seen as a co-benefit.

5.5.2.5 Implications for the assessment of the Carbon Leakage Risk

For the assessment of the carbon leakage risk, one clear result is that there is a subset of EU trading partners for whom a carbon leakage risk is clearly not given. Based on the methodology applied in this study, and irrespective of the assumptions chosen for weighting or correcting for enforcement – the finding is robust that the ambition levels of Norway, Switzerland and Korea exceeds that of the EU.

It is also clear that the ambition embodied in the climate-related regulations of Turkey, Brazil, Singapore, Russia and Saudi-Arabia is clearly below that of the EU – depending on the metric applied and the assumptions chosen, the ambition of climate-related regulations is at most half the score of the EU, and in other cases lower.

What is more difficult to ascertain is the middle section of EU trading partners, for which it matters how the different categories are weighted in the aggregation process. If the carbon price receives a higher weight, the overall ambition of climate-related regulations in the USA, India and China is significantly lower than that of the EU. Depending on whether results are corrected for enforcement, the scores are only between 24% and 54% of the EU value. However, if the categories are weighted equally, this difference shrinks markedly – and the three countries achieve scores of 84% to 89% of the EU value. This shows that different countries rely on different tools as part of their domestic policy mix, and that a comparison that is only or primarily based on carbon pricing may not provide an adequate picture. The numerical comparison must be taken with a grain of salt, bearing in mind the limitations of the different metrics, some of which measure the presence of policies rather their ambition. Still, and acknowledging these caveats, the numbers suggest that differences in the effective constraints are much less than they are made out to be. .

Finally, Japan is a special case in this regard: with equal weights, the ambition level of Japan's climate-related regulation is equivalent to that of the EU (at 101%); with carbon prices receiving a higher weight, it is markedly lower at 70% (or 74% if the enforcement correction factor is applied).

This evaluation of the middle section is particularly relevant since it comprises the heavyweights among the EU's external trading partners. As shown in the following table, the countries in the middle section - USA, India and China – account for between 13.5% and 43.7% of the EU's EU-external trade. By contrast, the share of the three leading countries – Norway, Switzerland and Korea – ranges from 6% to 15.8% of EU-external trade.

Table 58: Share of EU's external trade with trading partners

	Iron & steel	Chemicals	Non-ferrous metals	Cement & lime	Glass	Ceramics	Pulp & paper	Refinery products
Leaders (NOR/CHE/KOR)	13,1%	13,7%	15,8%	13,4%	9,1%	7,9%	8,2%	6,0%
Middle section (USA/IND/CHN)	25,2%	37,2%	21,2%	17,2%	43,7%	36,3%	28,5%	13,5%

Source: own calculations based on (Eurostat, 2017a)

5.6 Conclusion

The European economy is closely integrated through trade, both within the EU and with non-EU countries. Of the eight industrial sectors addressed in this report, refinery products and chemicals both have annual trading volumes of close to EUR 300 billion. In all of the sectors, the inner-EU trade far outweighs the external trade. In five of the eight sectors, the internal trade accounts for over 70% of the overall trading volume. In its external trade, the EU is both an exporter and importer. In three sectors, the value of EU imports exceeds that of exports: iron and steel (58% imports), chemicals (51%) as well as non-ferrous metals (65%). In all other sectors the EU is a net exporter.

Based on the overall trade volumes in the respective countries, the United States are the main trading partner for the EU with a trading volume of almost 56 EUR billion, followed by Russia (40 EUR billion) and China (29 EUR billion). For three of the eight sectors considered, the United States are the main trading partner.

Regarding the competitive situation of European industries vis-à-vis their main trading partners, the following can be concluded:

- By far the biggest trading partner of European industries are other EU countries. EU-internal trade accounts for 68% of the total trading volume in the eight sectors covered in this report. With the EU Emissions Trading System, emitters in all these countries pay the same carbon price. Many other climate-related regulation, including energy efficiency and air quality regulations, are identical across Europe. There are only few differences – e.g. where the Member States use existing flexibilities to a different extent, as is the case for the compensation of indirect costs under the EU ETS, or where Member States apply additional national carbon taxes on top of the EU ETS price. As a result, there are only few and relatively marginal competitive distortions between the EU countries, hence the carbon leakage risk for this part of European trade can be considered as irrelevant.

- Three of the main trading partners, Norway, Switzerland and Korea, have climate policies that are in fact more ambitious than those of the EU. Based on the three assessment categories, the three countries occupy the three top spots in the overall score irrespective of the assumptions made in the aggregation of the different categories. Further, Norway is a member of the EU ETS and Switzerland is linked to the EU ETS since January 2020. In terms of carbon leakage risk, it is fair to say that there is none between the EU and these three countries – if anything, Norwegian, Swiss and Korean producers might be worried about leakage risks from their countries to the EU.

- Considering the top three trading partners for the EU in the respective sectors, namely the United States, China and India, the picture is more nuanced. In the US, while the climate policy ambition level at the federal level is weak under the current administration, certain states in the US are key drivers for climate policies. For instance, California implemented a state-wide ETS with coverage and ambition that is at least comparable to that of the European ETS. California by itself accounts for almost 5% of the US trade with the EU in the eight sectors. Whether other states follow California's lead remains to be seen. Overall, a US induced carbon leakage risk is a possibility to consider, despite only 4.8% of the overall trading volume in those sectors accounts for the trade with the United States.

- At the same time, the EU's third biggest trading partner, China, with 29 EUR billion of trade volume in the respective sectors, has seen a rapid evolution of its policy landscape and performance towards a more climate-friendly model of economic development. The country has implemented seven pilot ETS since 2013, which together cover about a third of the Chinese economy. These are planned to be fully integrated into a nation-wide ETS, for which preparations have begun in 2016, and which is scheduled to start in 2020. While the national ETS will initially focus on the power sector, it is envisaged to expand to also include energy-intensive industries. Allowance prices in the pilots have initially been modest, but are expected to increase in the future. What remains unclear is whether / when allowance prices will approach those in the EU-ETS. In terms of energy efficiency policies, China's set of policies is already fairly comprehensive, but a detailed assessment of its ambition and the quality of implementation is still outstanding. Thus, while China's climate-related regulation is not yet comparable to that of countries like the EU, Switzerland or Norway, its policies and regulations have been advancing rapidly in recent years. If these trends continue, and if the announced policies are in fact enforced and lead to tangible change on the ground, they could well lead to a substantially decreasing carbon leakage risk for European industries in the years ahead.
- Finally, India performs relatively well in terms of air quality standards and energy efficiency, but has enforcement deficits.
- Contrary to that, Singapore has a high enforcement level but lacks ambitious tools for energy efficiency and air quality standards. Next to Russia, Turkey, Brazil and Saudi Arabia have the least substantial climate strategy in all categories. Absent a significant shift in the political constellations in these countries, a more meaningful carbon constraint is unlikely to emerge in those countries in the foreseeable future.
- In terms of the overall effects on the carbon leakage risk, a mixed picture emerges. While there is a group of ambitious countries for which the leakage risk would seem non-existent (i.e. Norway, Switzerland and Korea), these only account for a modest share of EU-external trade, ranging from 6 to 16% in the eight sectors considered in this study. By contrast, the bulk of the trade up to 44% - is conducted with the US, China (and less so India), as countries that found themselves in the middle of the ranking. Assessing the leakage risk for these countries is tricky: depending on the assumptions made in the aggregation process, the assessment of their climate ambition ranges from significantly below that of the EU, to roughly comparable.
- For a comparative assessment of the EU ambition level vis-à-vis its trading partners, it is obviously necessary to bear in mind not only the status and trends in the trading partners, but also the expected developments at EU level. Future ambition increases in the EU, unless they are matched by ambition increases elsewhere, will of course widen the gaps that are described in this analysis, and exacerbate the carbon leakage risk.

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C Annex

C.1 Trade volumes and partners in the selected industrial sectors

C.1.1 Trade volumes and partners in the iron and steel sector

In 2017, the EU exports of iron and steel products (CPA code 2410: iron and steel) amounted to EUR 96 billion. Imports in the same year came to EUR 104 billion, resulting in an overall trade volume of EUR 200 billion. Of this, the vast majority was inner-EU trade, accounting for 77% of total trade.

Table 59 lists the trade volumes with the 10 most important external trading partners in 2017. For the selection, countries were ranked by overall trade volume. It shows that the six largest trade partners account for 12% of overall EU trade (or 52% of all EU trade to non-EU countries). If this is extended to include the 10 largest trading partners, the shares increase to 16% for overall EU trade and 71% for EU trade with non-EU countries.

Table 59: Top 10 trading partners of the EU and respective trade volumes and shares for the iron steel sector

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
1	Turkey	5,026	2,127	2,899	2.5%	10.8%
2	Russia	4,535	3,731	805	2.3%	9.8%
3	China	4,275	2,803	1,472	2.1%	9.2%
4	United States	4,244	703	3,541	2.1%	9.1%
5	India	3,196	2,699	497	1.6%	6.9%
6	Ukraine	3,115	2,902	213	1.6%	6.7%
7	South Korea	2,703	2,368	335	1.3%	5.8%
8	Brazil	2,316	1,899	417	1.2%	5.0%
9	Switzerland	1,996	510	1,485	1.0%	4.3%
10	Norway	1,369	932	438	0.7%	2.9%
	Total	**32,775**	**20,674**	**12,101**	**16%**	**71%**

Total EU trade includes import and exports within the EU and to external partners

Source: Eurostat (2018)

C.1.2 Trade volumes and partners in the chemicals sector

In 2017, the EU exports of chemical products (CPA code 2013, 2014, 2015: inorganic and organic chemicals and fertilisers) amounted to EUR 141 billion. Imports in the same year came to EUR

150 billion, resulting in an overall trade volume of EUR 291 billion. Of this, the vast majority was inner-EU trade, accounting for 66% of total trade.

Table 60 lists the trade volumes with the 10 most important external trading partners in 2017. For the selection, countries were ranked by overall trade volume. It shows that the six largest trade partners account for 20% of overall EU trade (or 58% of all EU trade to non-EU countries). If this is extended to include the 10 largest trading partners, the shares increase to 24% for overall EU trade and 71% for EU trade with non-EU countries.

Table 60: Top 10 trading partners of the EU and respective trade volumes and shares for the chemicals sector

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
1	United States	20,778	7,845	12,933	7.1%	20.7%
2	China	12,378	6,966	5,412	4.2%	12.3%
3	Switzerland	7,878	4,421	3,458	2.7%	7.9%
4	Russia	6,534	5,333	1,201	2.2%	6.5%
5	Singapore	5,909	2,885	3,024	2.0%	5.9%
6	India	4,182	2,784	1,398	1.4%	4.2%
7	Japan	4,175	2,028	2,147	1.4%	4.2%
8	South Korea	3,094	1,356	1,738	1.1%	3.1%
9	Turkey	3,094	875	2,219	1.1%	3.1%
10	Norway	2,721	1,990	731	0.9%	2.7%
	Total	**70,744**	**36,483**	**34,261**	**24%**	**71%**

Total EU trade includes import and exports within the EU and to external partners
Source: Eurostat (2018)

C.1.3 Trade volumes and partners in the non-ferrous metals sector

In 2017, the EU exports of non-ferrous metals products (CPA code 2442, 2443, 2444, 2445: copper, aluminium, lead, zinc and tin and others) amounted to EUR 86 billion. Imports in the same year came to EUR 100 billion, resulting in an overall trade volume of EUR 186 billion. Of this, the vast majority was inner-EU trade, accounting for 70% of total trade.

Table 61 lists the trade volumes with the 10 most important external trading partners in 2017. For the selection, countries were ranked by overall trade volume. It shows that the six largest trade partners account for 14% of overall EU trade (or 49% of all EU trade to non-EU countries). If this is extended to include the 10 largest trading partners, the shares increase to 19% for overall EU trade and 64% for EU trade with non-EU countries.

Table 61: Top 10 trading partners of the EU and respective trade volumes and shares for the non-ferrous metals sector

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
1	Russia	6,440	6,011	429	3.4%	11.6%
2	United States	6,187	2,903	3,283	3.3%	11.2%
3	China	5,553	2,710	2,844	3.0%	10.0%
4	Norway	4,998	4,383	616	2.7%	9.0%
5	Switzerland	3,781	1,653	2,129	2.0%	6.8%
6	Turkey	3,242	1,637	1,605	1.7%	5.9%
7	Chile	1,704	1,661	44	0.9%	3.1%
8	United Arab Emirates	1,446	1,213	233	0.8%	2.6%
9	Canada	1,140	806	334	0.6%	2.1%
10	Mozambique	969	965	4	0.5%	1.7%
	Total	**35,460**	**23,940**	**11,520**	**19%**	**64%**

Total EU trade includes import and exports within the EU and to external partners

Source: Eurostat (2018)

C.1.4 Trade volumes and partners in the cement and lime sector

In 2017, the EU exports of cement and lime products (CPA code 2351, 2352: cement, lime and plaster) amounted to EUR 3 billion. Imports in the same year came to EUR 3 billion, resulting in an overall trade volume of EUR 6 billion. Of this, the vast majority was inner-EU trade, accounting for 78% of total trade.

Table 61 lists the trade volumes with the 10 most important external trading partners in 2017. For the selection, countries were ranked by overall trade volume. It shows that the six largest trade partners account for 10% of overall EU trade (or 45% of all EU trade to non-EU countries). If this is extended to include the 10 largest trading partners, the shares increase to 10% for overall EU trade and 45% for EU trade with non-EU countries.

Table 62: Top 10 trading partners of the EU and respective trade volumes and shares for the cement and lime sector

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
1	United States	219	14	204	3.8%	17.2%

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
2	Switzerland	104	14	90	1.8%	8.2%
3	Turkey	79	73	6	1.4%	6.2%
4	Norway	67	33	34	1.2%	5.2%
5	Israel	52	0	52	0.9%	4.1%
6	Cote D'Ivore	49	0	49	0.9%	3.9%
7	Ghana	49	0	49	0.9%	3.9%
8	Cameroon	48	0	48	0.8%	3.8%
9	Bosnia and Herzegovina	38	7	31	0.7%	3.0%
10	Colombia	28	16	12	0.5%	2.2%
	Total	**734**	**158**	**576**	**13%**	**58%**

Total EU trade includes import and exports within the EU and to external partners
Source: Eurostat (2018)

C.1.5 Trade volumes and partners in the glass sector

In 2017, the EU exports of glass products (CPA code 2311, 2313, 2314, 2319: glass and glassware) amounted to EUR 16 billion. Imports in the same year came to EUR 15 billion, resulting in an overall trade volume of EUR 31 billion. Of this, the vast majority was inner-EU trade, accounting for 72% of total trade.

Table 63 lists the trade volumes with the 10 most important external trading partners in 2017. For the selection, countries were ranked by overall trade volume. It shows that the six largest trade partners account for 17% of overall EU trade (or 61% of all EU trade to non-EU countries). If this is extended to include the 10 largest trading partners, the shares increase to 19% for overall EU trade and 70% for EU trade with non-EU countries.

Table 63: Top 10 trading partners of the EU and respective trade volumes and shares for the glass sector

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
1	China	1,904	1,391	513	6.2%	22.3%
2	United States	1,637	486	1,151	5.3%	19.2%
3	Switzerland	549	141	40	1.8%	6.4%
4	Turkey	452	260	192	1.5%	5.3%

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
5	Russia	359	140	219	1.2%	4.2%
6	Japan	331	158	173	1.1%	3.9%
7	Norway	226	57	169	0.7%	2.6%
8	India	193	109	85	0.6%	2.3%
9	Malaysia	160	126	34	0.5%	1.9%
10	Serbia	158	59	99	0.5%	1.8%
	Total	**5,970**	**2,926**	**3,045**	**19%**	**70%**

Total EU trade includes import and exports within the EU and to external partners
Source: Eurostat (2018)

C.1.6 Trade volumes and partners in the ceramics sector

In 2017, the EU exports of ceramics (CPA code 2331, 2341-2344, 2349: Ceramic products) amounted to EUR 15 billion. Imports in the same year came to EUR 11 billion, resulting in an overall trade volume of EUR 26 billion. Of this, the vast majority was inner-EU trade, accounting for 62% of total trade.

Table 64 lists the trade volumes with the 10 most important external trading partners in 2017. For the selection, countries were ranked by overall trade volume. It shows that the six largest trade partners account for 20% of overall EU trade (or 54% of all EU trade to non-EU countries). If this is extended to include the 10 largest trading partners, the shares increase to 24% for overall EU trade and 64% for EU trade with non-EU countries.

Table 64: Top 10 trading partners of the EU and respective trade volumes and shares for the ceramics sector

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
1	China	1,962	1,740	223	7.4%	19.7%
2	United States	1,662	305	1,358	6.3%	16.7%
3	Turkey	527	470	57	2.0%	5.3%
4	Switzerland	518	78	441	2.0%	5.2%
5	Japan	378	240	138	1.4%	3.8%
6	Russia	365	25	339	1.4%	3.7%
7	South Korea	272	76	196	1.0%	2.7%

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
8	Former Yugoslav Republic of Macedonia	260	0	259	1.0%	2.6%
9	United Arab Emirates	243	82	161	0.9%	2.4%
10	Israel	208	3	205	0.8%	2.1%
	Total	**6,395**	**3,020**	**3,376**	**24%**	**64%**

Total EU trade includes import and exports within the EU and to external partners
Source: Eurostat (2018)

C.1.7 Trade volumes and partners in the pulp and paper sector

In 2017, the EU exports of pulp and paper products (CPA 1711, 1712, 1724: pulp, paper and paperboard, wallpaper) amounted to EUR 60 billion. Imports in the same year came to EUR 52 billion, resulting in an overall trade volume of EUR 112 billion. Of this, the vast majority was inner-EU trade, accounting for 75% of total trade.

Table 65 lists the trade volumes with the 10 most important external trading partners in 2017. For the selection, countries were ranked by overall trade volume. It shows that the six largest trade partners account for 13% of overall EU trade (or 53% of all EU trade to non-EU countries). If this is extended to include the 10 largest trading partners, the shares increase to 16% for overall EU trade and 64% for EU trade with non-EU countries.

Table 65: Top 10 trading partners of the EU and respective trade volumes and shares for the pulp and paper sector

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
1	United States	4,376	2,187	2,189	3.9%	15.9%
2	China	2,727	425	2,302	2.4%	9.9%
3	Brazil	2,486	2,187	299	2.2%	9.0%
4	Turkey	1,914	294	1,620	1.7%	6.9%
5	Russia	1,766	498	1,268	1.6%	6.4%
6	Switzerland	1,340	563	777	1.2%	4.9%
7	Norway	908	568	340	0.8%	3.3%
8	India	750	28	721	0.7%	2.7%
9	Chile	663	475	187	0.6%	2.4%
10	Uruguay	661	644	17	0.6%	2.4%

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
	Total	**17,590**	**7,870**	**9,720**	**16%**	**64%**

Total EU trade includes import and exports within the EU and to external partners
Source: Eurostat (2018)

C.1.8 Trade volumes and partners in the refineries sector

In 2017, the EU exports of refineries (CPA code 1920: refined petroleum products) amounted to EUR 160 billion. Imports in the same year came to EUR 138 billion, resulting in an overall trade volume of EUR 298 billion. Of this, the vast majority was inner-EU trade, accounting for 59% of total trade.

Table 65 lists the trade volumes with the 10 most important external trading partners in 2017. For the selection, countries were ranked by overall trade volume. It shows that the six largest trade partners account for 19% of overall EU trade (or 46% of all EU trade to non-EU countries). If this is extended to include the 10 largest trading partners, the shares increase to 24% for overall EU trade and 58% for EU trade with non-EU countries.

Table 66: Top 10 trading partners of the EU and respective trade volumes and shares for the refineries sector

	Largest Trading Partners	Overall trade volume (EUR million)	Total imports (EUR million)	Total exports (EUR million)	Share of total EU trade volume within sector	Share of EU external trade within sector
1	Russia	20,075	19,496	579	6.8%	16.3%
2	United States	16,709	6,507	10,202	5.6%	13.5%
3	Saudi Arabia	7,211	5,636	1,575	2.4%	5.8%
4	Nigeria	4,660	157	4,502	1.6%	3.8%
5	United Arab Emirates	4,267	3,016	1,251	1.4%	3.5%
6	Gibraltar	4,010	115	3,895	1.3%	3.3%
7	Switzerland	3,895	106	3,789	1.3%	3.2%
8	Norway	3,553	1,729	1,824	1.2%	2.9%
9	Singapore	3,476	1,418	2,058	1.2%	2.8%
10	Turkey	3,115	292	2,822	1.0%	2.5%
	Total	**70,970**	**38,472**	**32,497**	**24%**	**58%**

Total EU trade includes import and exports within the EU and to external partners
Source: Eurostat (2018)

C.2 Methodology for the assessment

C.2.1 Industrial Emissions for EU Member Countries

Table 67: Industrial Emissions of EU Member Countries

Country	Industrial Emissions	% of EU Industry Emissions
Austria	123.003	4.15%
Belgium	149.993	5.06%
Bulgaria	31.255	1.05%
Croatia	28.655	0.97%
Cyprus	8.047	0.27%
Czech Republic	72.122	2.43%
Denmark	18.944	0.64%
Estonia	11.333	0.38%
Finland	72	2.43%
France	246.711	8.33%
Germany	618.587	20.87%
Greece	76.65	2.59%
Hungary	29.401	0.99%
Ireland	16.89	0.57%
Italy	335.108	11.31%
Latvia	4.643	0.16%
Lithuania	31.246	1.05%
Luxembourg	7.607	0.26%
Malta	0	0.00%
Netherlands	163.688	5.52%
Poland	187.784	6.34%
Portugal	59.739	2.02%
Romania	70.909	2.39%
Slovakia	31.182	1.05%
Slovenia	8.312	0.28%
Spain	299.243	10.10%
Sweden	62.042	2.09%
Great Britain	198.21	6.69%

Country	Industrial Emissions	% of EU Industry Emissions
EU28	**2963.304**	**100%**

Source: EEA ETS data viewer

C.2.2 Sub-Indicators of the RISE Score

Table 68: Sub-Indicators of the RISE Score

Sub-categories marked with green are weighted 2/3 (catergory a), sub-categories marked with yellow are weighted 1/3 (category b)

Indicator 1. National Energy Efficiency Planning	Indicator 2. Energy Efficiency Entities	Indicator 4. EE Incentives from Electricity Rate Structures
1. National energy efficiency legislation/action planning	**4. Human Capital and Institutions**	**9. Electricity rate structure**
1.1 Is there legislation or a national action plan that aims to increase EE?	4.1 Are there governmental and/or independent bodies that carry out formulation and implementation of EE strategy, policy and regulation for each of the roles listed below	9.1 What types of electricity rate structure do the residential, commercial services, and industrial customers face?
1.2 Is there an energy efficiency goal or target at the national level?	Setting EE strategy	Industrial Sector
	Setting EE standards	Flat fee (per connection)
2. Sub-sectoral targets	Regulating EE activities of energy suppliers	Constant (uniform) block rates
2.1 Are there targets defined for any of the following sectors?	Regulating EE activities of energy consumers	Declining block rates
Industrial sector	Certifying compliance with equipment EE standards	Increasing block rates
	Certifying compliance with building EE standards	
	Selecting and/or approving third party auditors tasked with certifying EE standards	**10 Demand charges (large customers)**
		10.1 Which of the following charges do electricity customers pay in the commercial services sector and industrial sector?
	4.3 Are there professional certification/accreditation programs mandated for any of the following energy efficiency activities	Industrial Sector
	Energy auditing/energy management	Energy (kWh)
	Energy efficiency financing	Demand (kW)
	Monitoring and verification of energy consumption/savings	Reactive power (kVAr)
	Building energy efficiency construction/design	

Indicator 5. Incentives & Mandates: Industrial and Commercial End Users

12 Mandates for large consumers

12.1 Are there any of the following energy-efficiency mandates for large energy users?

Targets (e.g. kWh savings or lower energy intensity or carbon dioxide reductions, etc.)

Mandatory audits

Progress/tracking reports

Energy-management system (computer technologies to optimize energy use)

12.2 Are there penalties in place for non-compliance with regulatory obligations for EE?

12.3 Is there a requirement for periodic reporting of energy consumption in order to enforce and/or track progress of energy efficiency in large consumers' facilities?

12.4 Is there a measurement and verification program in place?

13 Incentives for large consumers

13.1 Are energy efficiency incentives in place for large-scale users?

14 Small-medium size enterprises (SMEs)

14.1 Is there an energy efficiency mandate or incentive program for SMEs?

Indicator 8. Financing Mechanisms for Energy Efficiency

22. Financing mechanisms available in each sector

22.1 Are any of the following financing mechanisms for energy efficiency activities available in the (R) residential sector, (C) commercial services sector, and (I) industrial sector?

Industrial Sector

Tax incentives

Discounted "green" mortgages

On-bill financing

Credit lines and/or revolving funds with banks for energy efficiency activities

Green or energy efficiency bonds

Energy services agreements (pay-for-performance contracts)

Vendor credit and/or leasing for energy efficiency activities

Partial risk guarantees

Indicator 10. Energy Labeling Systems

25. Have energy efficiency labeling schemes been adopted for?

25.4 Industrial electric motors

Indicator 9. Minimum Energy Efficiency Performance Standards

23. Have minimum energy performance standards been adopted for the following product categories?

23.4 Industrial electric motors

23.5 Other industrial equipment

24. Verification and penalties for non-compliance

Industrial electric motors

24.1 Are the standards mandatory?

24.2 Is there a requirement for periodic reporting to verify compliance with standards?

24.3 Is the verification of standards compliance carried out by a third party?

24.4 Is there a penalty for non-compliance with energy efficiency standards?

24.5 Is there a periodic update of standards to reflect technological advances and changes in best practices for energy efficiency standards?

Other industrial equipment

24.1 Are the standards mandatory?

24.2 Is there a requirement for periodic reporting to verify compliance with standards?

24.3 Is the verification of standards compliance carried out by a third party?

24.4 Is there a penalty for non-compliance with energy efficiency standards?

25.5 Other industrial equipment	24.5 Is there a periodic update of standards to reflect technological advances and changes in best practices for energy efficiency standards?

C.2.3 Air Quality Standards

Table 69: Air Quality Standards per Pollutant and Analyzed Country

	PM10		PM2.5		O3		SO2				NO2			CO				Year set, revised or published
Country	1 year	24 hours	1 year	24 hours	1 hour	8 hour	10 minutes	1 hour	24 hours	1 year	1 hour	24 hours	1 year	15 min	1 hour	8 hour	24 hours	
Brazil	40	120	20	60	160	140	other	80	125	40	260	N/A	60	N/A	N/A	9	N/A	2013, 2018
China	70	150	35	75	200	160	other	500	150	60	200	80	40	N/A	10	N/A	4	2014
EU	40	50	25	N/A	N/A	120	other	350	125	N/A	200	other	40	N/A	N/A	7	N/A	2008
India	60	100	40	60	180	100	N/A	N/A	80	50	other	80	40	N/A	4	2	N/A	2009
Japan	other	100	15	35	118	other	other	250	105	N/A	other	112	N/A	N/A	12.5	25	12	-
Korea	50	100	25	50	200	120	other	400	130	50	190	115	57	N/A	31.25	11.25	N/A	2013
Norway	25	50	15	other	other	120	other	350	125	20	200	other	30	N/A	N/A	10	N/A	2007
Russia	40	60	25	35	other	other	N/A	N/A	50	N/A	other	N/A	40	other	N/A	N/A	3	-
Saudi Arabia	80	340	15	35	235	157	other	350	125	N/A	660	other	100	N/A	40	10	N/A	-
Singapore	other	150	15	25	other	147	N/A	N/A	365	80	N/A	N/A	100	N/A	40	10	N/A	2014

	PM10		PM2.5		O3		SO2				NO2			CO				Year set, revised or published
Switzerland	20	50	10	other	120	other	N/A	N/A	100	30	other	80	30	N/A	N/A	N/A	8	2015, 2018
Turkey	60	100	other	other	N/A	N/A	other	500	250	150	300	other	N/A	N/A	N/A	10	N/A	2008
USA	other	150	12	35	other	140	other	196	N/A	N/A	188	other	100	N/A	43	11	N/A	2016

Source: Kutlar Joss et al. (2017) and MMA (2018). Assessment of effective leakage risk

C.2.4 RISE Score

Table 70: RISE Score with World Bank Methodology

		Brazil	China	EU	India	Japan	Korea	Norway	Russia	Saudi Arabia	Singapore	Switzerland	Turkey	USA
	Rank	10	2	5	6	4	3	7	13	12	11	9	8	1
	Scored points total	845	1198	1029	1012	1039	1159	975	487	627	695	964	968	1305
Total max points	1345	63%	89%	77%	75%	77%	86%	72%	36%	47%	52%	72%	72%	97%
Indicator 1. National Energy Efficiency Planning	120	100 83%	120 100%	116 97%	120 100%	120 100%	100 83%	120 100%	120 100%	120 100%	120 100%	100 83%	120 100%	120 100%
1. National energy efficiency legislation/action planning														
1.1 Is there legislation or a national action plan that aims to increase EE?	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
1.2 Is there an energy efficiency goal or target at the national level?	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
2. Sub-sectoral targets														

2.1 Are there targets defined for any of the following sectors?														
Industrial sector	o = 20 / x = 0	x	o		o	o	x	o	o	o	o	x	o	o
Indicator 2. Energy Efficiency Entitites	75	75 100%	75 100%	68 91%	75 100%	43 57%	75 100%	68 90%	75 100%	75 100%	75 100%	68 90%	75 100%	75 100%
4. Human Capital and Institutions														
4.1 Are there governmental and/or independent bodies that carry out formulation and implementation of EE strategy, policy and regulation for each of the roles listed below	sum/7													
Setting EE strategy	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Setting EE standards	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Regulating EE activities of energy suppliers	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Regulating EE activities of energy consumers	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Certifying compliance with equipment EE standards	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Certifying compliance with building EE standards	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Selecting and/or approving third party auditors tasked with certifying EE standards	o = 50 / x = 0	o	o		o	x	o	x	o	o	o	x	o	o
4.3 Are there professional certification/accreditation programs mandated for any of the following energy efficiency activities														
Energy auditing/energy management	o to at least 1 = 25 / x to all = 0	x	o		o	x	o	o	o	o	o	o	o	o
Energy efficiency financing		x	o		o	x	x	x	x	x	o	x	x	x

Monitoring and verification of energy consumption/savings		x	x		o	x	o	x	o	o	o	o	o	o
Building energy efficiency construction/design		o	o		o	x	o	o	o	x	o	o	x	o
other		x	x		x	x	x	x	x	x	x	x	x	x
Indicator 4. EE Incentives from Electricity Rate Structures	200	100 50%	133 67%	155 78%	167 83%	167 83%	134 67%	167 83%	167 83%	167 83%	167 83%	200 100%	200 100%	200 100%
9. Electricity rate structure														
9.1 What types of electricity rate structure do the residential, commercial services, and industrial customers face?	if more then one option, highest score selected													
Industrial Sector														
Flat fee (per connection)	o = 33.3 / x = 0	o	o		x	o	x	x	o	x	x	x	x	x
Constant (uniform) block rates	o = 67 / x = 0	x	x		x	o	o	o	o	o	o	o	o	o
Declining block rates	o = 0 / x = 0	x	x		x	x	x	x	x	x	x	x	o	o
Increasing block rates	o = 100 / x = 0	x	x		o	o	x	x	x	x	x	o	o	o
10 Demand charges (large customers)														
10.1 Which of the following charges do electricity customers pay in the commercial services sector and industrial sector?														
Industrial Sector														
Energy (kWh)	o = 33.3 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Demand (kW)	o = 33.3 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Reactive power (kVAr)	o = 33.3 / x = 0	x	o		x	x	x	o	o	o	o	o	o	o
Indicator 5. Incentives & Mandates: Industrial and Commercial End Users	300	0 0%	300 100%	256 85%	200 67%	100 33%	300 100%	250 83%	100 33%	100 33%	283.3 94%	266.7 89%	283.3 94%	300 100%

12 Mandates for large consumers														
12.1 Are there any of the following energy-efficiency mandates for large energy users?	o to 1 or more = 33.3 / x to all = 0													
Targets (e.g. kWh savings or lower energy intensity or carbon dioxide reductions, etc.)		x	o		o	o	o	x	o	o	x	o	x	x
Mandatory audits		x	o		o	x	o	o	o	o	x	o	o	o
Progress/tracking reports		x	o		o	o	o	x	o	o	o	o	x	o
Energy-management system (computer technologies to optimize energy use)		x	o		x	c	x	x	o	x	x	x	o	o
12.2 Are there penalties in place for non-compliance with regulatory obligations for EE?	o = 33.3 / x = 0	x	o		o	o	o	x	o	o	o	x	o	o
12.3 Is there a requirement for periodic reporting of energy consumption in order to enforce and/or track progress of energy efficiency in large consumers' facilities?	o = 16.7 / x = 0	x	o		o	o	o	o	o	o	o	o	o	o
12.4 Is there a measurement and verification program in place?	o = 16.7 / x = 0	x	o		o	o	o	x	o	o	x	o	x	o
13 Incentives for large consumers														
13.1 Are energy efficiency incentives in place for large-scale users?	o = 100 / x = 0	x	o		x	x	o	o	x	x	o	o	o	o
14 Small-medium size enterprises (SMEs)														
14.1 Is there an energy efficiency mandate or incentive program for SMEs?	o = 100 / x = 0	x	o		o	x	o	o	x	x	o	o	o	o
Indicator 8. Financing Mechanisms for Energy Efficiency	50	50 100%	50 100%	36 72%	50 100%	50 100%	50 100%	50 100%	25 50%	25 50%	50 100%	50 100%	50 100%	50 100%

22. Financing mechanisms available in each sector														
22.1 Are any of the following financing mechanisms for energy efficiency activities available in the (R) residential sector, (C) commercial services sector, and (I) industrial sector?														
Industrial Sector														
Tax incentives		o	o		o	o	o	o	x	x	o	o	x	o
Discounted “green” mortgages	o to 3 or more = 50 / o to 1 or 2 = 25 / x to all = 0	x	o		x	x	x	x	x	x	x	o	x	o
On-bill financing		x	x		x	x	x	o	x	x	x	x	x	o
Credit lines and/or revolving funds with banks for energy efficiency activities		o	x		x	x	o	o	o	x	o	x	o	o
Green or energy efficiency bonds		o	o		o	x	x	o	x	x	o	x	x	x
Energy services agreements (pay-for-performance contracts)		o	o		o	o	o	x	x	x	o	o	o	o
Vendor credit and/or leasing for energy efficiency activities		x	x		x	o	x	o	o	o	o	x	o	o
Partial risk guarantees		x	o		o	x	x	x	x	x	x	o	x	o
Indicator 9. Minimum Energy Efficiency Performance Standards	400	320 80%	320 80%	316 79%	200 50%	360 90%	400 100%	320 80%	0 0%	140 35%	0 0%	180 45%	140 35%	360 90%
23. Have minimum energy performance standards been adopted for the following product categories?														
23.4 Industrial electric motors	o = 100 / x = 0	o	o		x	o	o	o	x	o	x	o	x	o
23.5 Other industrial equipment	o = 100 / x = 0	o	o		o	o	o	o	x	x	x	x	o	o
24. Verification and penalties for non-compliance														

Industrial electric motors														
24.1 Are the standards mandatory?	o = 20 / x = 0	o	o		x	o	o	o	x	o	x	o	o	o
24.2 Is there a requirement for periodic reporting to verify compliance with standards?	o = 20 / x = 0	x	x		x	o	o	o	x	x	x	o	x	o
24.3 Is the verification of standards compliance carried out by a third party?	o = 20 / x = 0	x	o		x	x	o	o	x	o	x	o	x	x
24.4 Is there a penalty for non-compliance with energy efficiency standards?	o = 20 / x = 0	o	o		x	o	o	x	x	x	x	o	x	o
24.5 Is there a periodic update of standards to reflect technological advances and changes in best practices for energy efficiency standards?	o = 20 / x = 0	o	x		x	o	o	o	x	x	x	x	x	o
Other industrial equipment														
24.1 Are the standards mandatory?	o = 20 / x = 0	o	o		o	o	o	o	x	x	x	x	o	o
24.2 Is there a requirement for periodic reporting to verify compliance with standards?	o = 20 / x = 0	x	x		o	o	o	x	x	x	x	x	x	o
24.3 Is the verification of standards compliance carried out by a third party?	o = 20 / x = 0	x	o		o	x	o	o	x	x	x	x	x	x
24.4 Is there a penalty for non-compliance with energy efficiency standards?	o = 20 / x = 0	o	o		o	o	o	x	x	x	x	x	x	o
24.5 Is there a periodic update of standards to reflect technological advances and changes in best practices for energy efficiency standards?	o = 20 / x = 0	o	x		o	o	o	x	x	x	x	x	x	o
Indicator 10. Energy Labeling Systems	200	200 100%	200 100%	82 41%	200 100%	200 100%	100 50%	0 0%	0 0%	0 0%	0 0%	100 50%	100 50%	200 100%

25. Have energy efficiency labeling schemes been adopted for?														
25.4 Industrial electric motors	o = 100 / x = 0	o	o		o	o	x	x	x	x	x	o	x	o
25.5 Other industrial equipment	o = 100 / x = 0	o	o		o	o	o	x	x	x	x	x	o	o

Source: World Bank (2018). Own calculation. “o” means a “yes”, “x” means a “no”.

Table 71: RISE Score with Ecologic Institute Methodology

	Ecologic	Brazil	China	EU	India	Japan	Korea	Norway	Russia	Saudi Arabia	Singapore	Switzerland	Turkey	USA
Rank		10	2	4	6	5	3	8	13	12	11	9	7	1
Total max points	2065	1245	1918	1561	1532	1559	1759	1445	607	847	999	1431	1472	2025
		60%	93%	76%	74%	76%	85%	70%	29%	41%	48%	69%	71%	98%
Indicator 1. National Energy Efficiency Planning	140	100	140	132	140	140	100	140	140	140	140	100	140	140
		71%	100%	94%	100%	100%	71%	100%	100%	100%	100%	71%	100%	100%
1. National energy efficiency legislation/action planning														
1.1 Is there legislation or a national action plan that aims to increase EE?	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
1.2 Is there an energy efficiency goal or target at the national level?	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
2. Sub-sectoral targets														
2.1 Are there targets defined for any of the following sectors?														
Industrial sector	o = 40 / x = 0	x	o		o	o	x	o	o	o	o	x	o	o
Indicator 2. Energy Efficiency Entitites	75	75	75	68	75	43	75	68	75	75	75	68	75	75
		100%	100%	91%	100%	57%	100%	90%	100%	100%	100%	90%	100%	100%

4. Human Capital and Institutions														
4.1 Are there governmental and/or independent bodies that carry out formulation and implementation of EE strategy, policy and regulation for each of the roles listed below	sum/7													
Setting EE strategy	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Setting EE standards	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Regulating EE activities of energy suppliers	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Regulating EE activities of energy consumers	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Certifying compliance with equipment EE standards	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Certifying compliance with building EE standards	o = 50 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Selecting and/or approving third party auditors tasked with certifying EE standards	o = 50 / x = 0	o	o		o	x	o	x	o	o	o	x	o	o
4.3 Are there professional certification/accreditation programs mandated for any of the following energy efficiency activities														
Energy auditing/energy management		x	o		o	x	o	o	o	o	o	o	o	o
Energy efficiency financing		x	o		o	x	x	x	x	x	o	x	x	x
Monitoring and verification of energy consumption/savings	o to at least 1 = 25 / x to all = 0	x	x		o	x	o	x	o	o	o	o	o	o
Building energy efficiency construction/design		o	o		o	x	o	o	o	x	o	o	x	o
other		x	x		x	x	x	x	x	x	x	x	x	x
Indicator 4. EE Incentives from Electricity Rate Structures	200	100	133	155	167	167	134	167	167	167	167	200	200	200
		50%	67%	78%	83%	83%	67%	83%	83%	83%	83%	100%	100%	100%

9. Electricity rate structure														
9.1 What types of electricity rate structure do the residential, commercial services, and industrial customers face?	if more then one option, highest score selected													
Industrial Sector														
Flat fee (per connection)	o = 33.3 / x = 0	o	o		x	o	x	x	o	x	x	x	x	x
Constant (uniform) block rates	o = 67 / x = 0	x	x		x	o	o	o	o	o	o	o	o	o
Declining block rates	o = 0 / x = 0	x	x		x	x	x	x	x	x	x	x	o	o
Increasing block rates	o = 100 / x = 0	x	x		o	o	x	x	x	x	x	o	o	o
10 Demand charges (large customers)														
10.1 Which of the following charges do electricity customers pay in the commercial services sector and industrial sector?														
Industrial Sector														
Energy (kWh)	o = 33.3 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Demand (kW)	o = 33.3 / x = 0	o	o		o	o	o	o	o	o	o	o	o	o
Reactive power (kVAr)	o = 33.3 / x = 0	x	o		x	x	x	o	o	o	o	o	o	o
Indicator 5. Incentives & Mandates: Industrial and Commercial End Users	600	0	600	512	400	200	600	500	200	200	567	533	567	600
		0%	100%	85%	67%	33%	100%	83%	33%	33%	94%	89%	94%	100%
12 Mandates for large consumers														
12.1 Are there any of the following energy-efficiency mandates for large energy users?	o to 1 or more = 66.7 / x to all = 0													

Targets (e.g. kWh savings or lower energy intensity or carbon dioxide reductions, etc.)		x	o		o	o	o	x	o	o	x	o	x	x
Mandatory audits		x	o		o	x	o	o	o	o	x	o	o	o
Progress/tracking reports		x	o		o	o	o	x	o	o	o	o	x	o
Energy-management system (computer technologies to optimize energy use)		x	o		x	c	x	x	o	x	x	x	o	o
12.2 Are there penalties in place for non-compliance with regulatory obligations for EE?	o = 66.7 / x = 0	x	o		o	o	o	x	o	o	o	x	o	o
12.3 Is there a requirement for periodic reporting of energy consumption in order to enforce and/or track progress of energy efficiency in large consumers' facilities?	o = 33.3 / x = 0	x	o		o	o	o	o	o	o	o	o	o	o
12.4 Is there a measurement and verification program in place?	o = 33.3 / x = 0	x	o		o	o	o	x	o	o	x	o	x	o
13 Incentives for large consumers														
13.1 Are energy efficiency incentives in place for large-scale users?	o = 200 / x = 0	x	o		x	x	o	o	x	x	o	o	o	o
14 Small-medium size enterprises (SMEs)														
14.1 Is there an energy efficiency mandate or incentive program for SMEs?	o = 200 / x = 0	x	o		o	x	o	o	x	x	o	o	o	o
Indicator 8. Financing Mechanisms for Energy Efficiency	50	50 100%	50 100%	36 72%	50 100%	50 100%	50 100%	50 100%	25 50%	25 50%	50 100%	50 100%	50 100%	50 100%
22. Financing mechanisms available in each sector														

22.1 Are any of the following financing mechanisms for energy efficiency activities available in the (R) residential sector, (C) commercial services sector, and (I) industrial sector?														
Industrial Sector														
Tax incentives		o	o		o	o	o	o	x	x	o	o	x	o
Discounted “green” mortgages	o to 3 or more = 50 / o to 1 or 2 = 25 / x to all = 0	x	o		x	x	x	x	x	x	x	o	x	o
On-bill financing		x	x		x	x	x	o	x	x	x	x	x	o
Credit lines and/or revolving funds with banks for energy efficiency activities		o	x		x	x	o	o	o	x	o	x	o	o
Green or energy efficiency bonds		o	o		o	x	x	o	x	x	o	x	x	x
Energy services agreements (pay-for-performance contracts)		o	o		o	o	o	x	x	x	o	o	o	o
Vendor credit and/or leasing for energy efficiency activities		x	x		x	o	x	o	o	o	o	x	o	o
Partial risk guarantees		x	o		o	x	x	x	x	x	x	o	x	o
Indicator 9. Minimum Energy Efficiency Performance Standards	600	520 87%	520 87%	494 82%	300 50%	560 93%	600 100%	520 87%	0 0%	240 40%	0 0%	280 47%	240 40%	560 93%
23. Have minimum energy performance standards been adopted for the following product categories?														
23.4 Industrial electric motors	o = 200 / x = 0	o	o		x	o	o	o	x	o	x	o	x	o
23.5 Other industrial equipment	o = 200 / x = 0	o	o		o	o	o	o	x	x	x	x	o	o
24. Verification and penalties for non-compliance														
Industrial electric motors														
24.1 Are the standards mandatory?	o = 20 / x = 0	o	o		x	o	o	o	x	o	x	o	o	o

24.2 Is there a requirement for periodic reporting to verify compliance with standards?	o = 20 / x = 0	x	x		x	o	o	o	x	x	x	o	x	o
24.3 Is the verification of standards compliance carried out by a third party?	o = 20 / x = 0	x	o		x	x	o	o	x	o	x	o	x	x
24.4 Is there a penalty for non-compliance with energy efficiency standards?	o = 20 / x = 0	o	o		x	o	o	x	x	x	x	o	x	o
24.5 Is there a periodic update of standards to reflect technological advances and changes in best practices for energy efficiency standards?	o = 20 / x = 0	o	x		x	o	o	o	x	x	x	x	x	o
Other industrial equipment														
24.1 Are the standards mandatory?	o = 20 / x = 0	o	o		o	o	o	o	x	x	x	x	o	o
24.2 Is there a requirement for periodic reporting to verify compliance with standards?	o = 20 / x = 0	x	x		o	o	o	x	x	x	x	x	x	o
24.3 Is the verification of standards compliance carried out by a third party?	o = 20 / x = 0	x	o		o	x	o	o	x	x	x	x	x	x
24.4 Is there a penalty for non-compliance with energy efficiency standards?	o = 20 / x = 0	o	o		o	o	o	x	x	x	x	x	x	o
24.5 Is there a periodic update of standards to reflect technological advances and changes in best practices for energy efficiency standards?	o = 20 / x = 0	o	x		o	o	o	x	x	x	x	x	x	o
Indicator 10. Energy Labeling Systems	400	400 100%	400 100%	164 41%	400 100%	400 100%	200 50%	0 0%	0 0%	0 0%	0 0%	200 50%	200 50%	400 100%
25. Have energy efficiency labeling schemes been adopted for?														
25.4 Industrial electric motors	o = 200 / x = 0	o	o		o	o	x	x	x	x	x	o	x	o

25.5 Other industrial equipment	o = 200 / x = 0	o	o		o	o	o	x	x	x	x	x	o	o

Source: World Bank (2018). Adapted methodology and own calculation. "o" means a "yes", "x" means a "no".

C.2.5 ACEEE Score

Table 72: ACEEE Score

Country / Indicator	Rank	Sum	Energy intensity of the industrial sector	Share of combined heat and power (CHP) in total installed capacity
max. points possible		8	6	2
Brazil	8.0	1.5	1.0	0.5
China	10.0	1.0	0.0	1.0
EU	3.0	6.0	5.0	1.0
India	8.0	1.5	1.0	0.5
Japan	2.0	6.0	6.0	0.0
Korea	4.0	4.5	4.0	0.5
Russia	6.0	2.0	0.0	2.0
Saudi Arabia	6.0	2.0	2.0	0.0
Turkey	4.0	4.5	4.0	0.5
USA	1.0	6.5	6.0	0.5

Work package 3 – Effect of allocation rules in the 3rd trading period on carbon leakage risk

6 Effect of allocation rules in the 3rd trading period on carbon leakage risk

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List of abbreviations

ARDL	Autoregressive model with distributed lags
CO_2	Carbon dioxide
COP	Conference of the Parties
DOLS	Dynamic ordinary least squares estimator
EU-ETS	EU Emissions Trading System
EU-27 + UK	European Union (27 Member States) and the United Kingdom
F-gases	Fluorinated greenhouse gases
FTIP	Federal Transport Infrastructure Plan
FMOLS	Fully modified ordinary least squares estimator
GHG	Greenhouse gas
HGV	Heavy goods vehicle
ICAO	International Civil Aviation Organization
IMO	International Maritime Organization
KSBV	UBA-study Klimaschutzbeitrag des Verkehrs bis 2050 [UBA, 2016a]
NDC	Nationally Determined Contributions (in Paris-Agreement)
NEDC	New European Driving Cycle
N_2O	Nitrous oxide (laughing gas)
PJ	Petajoule (energy measuring unit)
PtG	Power-to-Gas (any power-based gaseous fuels)
PtL	Power-to-Liquid (any power-based liquid fuels)
RDE	Real Driving Emissions
TWh	Terawatt hours (measuring units for energy)
UNFCCC	United Nations Framework Convention on Climate Change
WLTP	Worldwide Harmonized Light-Duty Vehicles Test Procedure

6.1 Introduction

6.1.1 Introduction

The fear that unequal carbon prices affect competition of EU industries has been a dominant argument since the start of the EU ETS in 2005. Adverse impacts of unequal carbon prices would translate themselves into changes in the market shares of EU industries in global markets, or on the domestic EU markets. Such change in market shares will be accompanied by a change in trade patterns where EU carbon prices would stimulate imports from and reduce exports to non-EU countries where producers are not being faced with carbon prices.

The impact of unequal carbon prices on trade patterns has been subject to theoretical and empirical research efforts (see work package 1.2, chapter 4). However, relatively few efforts have been undertaken that have empirically estimated the impact of unequal carbon prices on trade intensities. Among the very few exceptions are Reinaud (2008) and Constantini and Mazzanti (2012) that have both employed a „before and after“ analysis where the trade patterns before introduction of the EU ETS are being compared with the trade patterns after introduction of the EU ETS. The problem, however, is that it is very difficult to control for all the other influences that may have changed over time. This approach therefore rarely leads to reliable results, as has been observed already in the literature (OECD, 2015).

An alternative approach has focused primarily on prospective future impacts of higher carbon prices than today on trade. In this approach, the analysis is oriented at the impact of differences in energy prices on trade intensities., as a kind of proxy to enable a hypothetical prediction of what effect on trade could be expected from an increase in carbon prices of a similar scope. This has been done, amongst others, by Sato and Dechezleprêtre (2015) who have empirically estimated the impact of asymmetrical energy prices on net imports. Their results show a statistically significant but small effect of the difference in energy prices on trade patterns. Garsous and Kozluk (2017) have extended this approach towards foreign direct investments and do find a statistically significant but small effect of energy price differentials on foreign direct investments using micro-data.

The latter approach of analysing the trade impact of energy price differentials instead of carbon prices is also used if observed carbon prices are in plce bu are fairlylow (like in the EU ETS until 2018) so that their possible future influence on the carbon leakage risk under sunstantially higher carbon prices cannot be detected directly (see Sato and Dechezleptrêtre 2015).

The goal of Task 3 in the UBA project “Analyse der Wettbewerbssituation und des Carbon Leakage-Risikos der europäischen Industrien” was to empirically investigated the impact of unequal carbon prices on the risk of carbon leakage in the industrial sectors participating in the EU ETS and to transfer it to future rising carbon prices. This has been done by means of an econometric analysis of the trade impacts of unequal carbon prices and energy prices between the EU and important trading partners.

6.1.2 Objective and methods

The objective of this task is to investigate the relationship between unequal carbon pricing and carbon leakage in an empirical manner. The task will consider the empirical relation between trade patterns and unequal carbon prices from the perspective of the EU 27 + UK with major trading partners.

Carbon leakage can manifest itself through a change in trade patterns and a change in investment patterns. The present research will only consider changes in trade patterns as a cause of carbon leakage. Eventual changes in investment patterns will not be considered. It should be noted that in the end, changes in investment patterns due to unequal carbon prices should translate themselves to a change in trade patterns also as all sectors that are prone to carbon leakage have considerable trades with the rest of the world.

The analysis has been conducted using econometrics. Through econometrics the hypothesis is investigated that trade patterns are not influenced by unequal carbon prices. Standard test procedures from econometrics can be used to investigate to what extent this hypothesis can be rejected. If the hypothesis is rejected within pre-agreed scientific thresholds of evidence, it is said that the hypothesis of no influence is not true and one can conclude that trade patterns are influenced by unequal carbon prices.

6.1.3 Synopsys and reading guide

Within this project, we have run over 10.000 regressions and tests. In general these regressions provide some information on the hypothesis, but we observe that model quality is relatively poor for all regressions. Below we present a very rough overview of our findings and the various estimation routines we have employed. In short: neither of the estimation methods we have employed generated results that were robust and consistent with theory. So despite our efforts, we can’t report results that allow us to derive solid policy messages. However, we do make up account of our efforts, to provide other researchers with information on the avenues we have taken that turned out to be in vain.

We have employed three estimation routines that will be described in the remainder of this report. That is, we have taken the following steps:

1. **Estimate a trade model.**

We started with a model along the lines of Sato and Dechezleprêtre (2015) for a selected choice of sectors and trade partners of each of the countries in the EU 27 & UK. On the one hand, it seems that the hypothesis that unequal CO_2 prices have no impact on trade patterns can be rejected. However, a precise interpretation was hindered by the fact that the trade variables were insignificant, instable and sometimes had the wrong sign (also: see section 6.3.2) . As a solution to this, we estimated a concise trade model, where we left out the typical trade variables. This model turned out not to yield satisfactory results (see section 6.3.3), among other reasons because the long run effect that is implied by our estimated coefficients is implausibly large.

2. **Estimate an ARDL model.**

To “fix” the problems we encountered with the concise trade model, we extended it to an Autoregressive model with distributed lags (ARDL model). This model is designed to capture dynamic effects in the impact of the energy price on trade. This did not help to obtain a more plausible value of the long run effect.

3. **Estimate a cointegration model.**

The cointegration model can be seen as an extension of the ARDL-model that aims to directly estimate the long run relationship between trade and the energy price. Unfortunately, the results we obtained were implausible and unstable.

In this report, we give an account of our efforts in investigating the impact of energy price differentials on trade. In Chapter 6.2, we will provide information about the literature that has empirically estimated the impact of unilateral climate policies on carbon leakage and formulate our own estimation strategy. In Chapter 6.3, we will present the main results of our different type of analyses at the level of the EU 27 + UK. Chapter 6.4 concludes.

6.2 Methods

6.2.1 Introduction

In this chapter, we will elaborate on the methods that we have employed in this part of the study. First in paragraph 6.2.2 we will elaborate on different models that have been used in the literature. In paragraph 6.2.3 we will present the data that have been collected in order to estimate the empirical influence from unequal carbon price on trade patterns.

Although the topic of this chapter is very technical, we have tried to move the more technical explanations to the Annexes without compromising on the main arguments needed to understand the methods employed and interpreting the results in Chapter 6.3.

6.2.2 Literature

The literature overview from Task 1.2, chapter 4 indicated that various studies have tried to estimate the impact of energy or carbon prices on trade patterns by means of econometric analyses. These studies are most relevant for our present research. From an econometric point of view, the studies can be divided into two different types of research:

1. Studies that observe the situation before the introduction of the EU ETS in the EU with the situation after introduction of the ETS.
2. Studies that observe differences in trade patterns between countries with different levels of CO_2, or energy prices.

The first type of studies can be found in, amongst others, Reinaud (2008) and Constantini and Mazzanti (2012) that have both employed a „before and after“ analysis where the trade patterns before introduction of the EU ETS are being compared with the trade patterns after introduction of the EU ETS. The problem, however, is that it is very difficult to control for all the other influences that may have changed over time. This approach therefore rarely leads to reliable results, as has been observed already in the literature (Ellis *et al*., 2019).

The second type of research has been trying to analyse the impact of between-country differences in energy prices on trade patterns. We have identified three approaches to estimate this impact.

The first is placed within the framework of models that explain trade patterns by a so-called gravity model (Head and Mayer, 2013). Typically, these models expain trade between two regions by economic activity on the one hand, and barriers to trade on the other hand. Typical proxies for economic activity are the GDP of both trading partners. Proxies for barriers to trade are. e.g. different languages spoken or the distance between trading partners. Amongst others, Sato and Dechezleprêtre (2015) have done a research that falls within this framework. They have empirically estimated the impact of asymmetrical energy prices on net imports. Their results show a statistically significant but small effect of the difference in energy prices on trade patterns. Garsous and Kozluk (2017) have extended this approach towards foreign direct investments and find a statistically significant but small effect of energy price differentials on foreign direct investments using micro-data. The analysis by Garsous and Kozluk is on a higher level of aggregation (NACE 2-digit) than that of Sato and Dechezleprêtre (partly on a NACE 3-digit), presumably because investment data is typically monitored at NACE-2 level rather than NACE-3 or beyond level.

Box: project specific shortcomings in current research of the second type

Although important, the existing body of research has three shortcomings to be interpreted in the light of the overall project objective:

1. The literature is dealing with energy costs instead of carbon costs. Technologies to reduce energy often also reduce carbon. However, reducing carbon can be done by other technologies as well (e.g. fuel switches such as coal to gas) that do not reduce energy demand. Therefore, the factor elasticities of substitution are likely to be higher for carbon than for energy, implying that it may be more costly to reduce energy than to reduce carbon. This implies that the trade elasticity of energy costs can be expected to be higher than the trade elasticity of carbon costs. Analysis based on energy costs may thus overestimate the impact of unequal carbon costs – although it would be best to test this hypothesis in econometric work.

2. The literature presents average results for highly aggregated sectors that may neglect potential carbon leakage in smaller subsectors. For example, it can be that carbon leakage is not an issue for the whole group of building materials, but that carbon leakage exists in the smaller subgroup of clay bricks. The larger the group, the more likely it is that econometrics will reveal that the impact of unequal energy costs is not significantly different from zero even though impacts at the level of subsector exist. Such approaches may therefore underestimate the impact of unequal energy prices on carbon leakage in particular smaller subsectors.

3. The literature cannot distinguish the difference in auctioning and free allocation in absorbing carbon costs. Energy costs are by definition out of pocket costs, as are carbon costs when sectors need to buy the allowances through auctions. However, free allocation implies that a difference exists between marginal and average costs. In general, in economics, companies in the short-term adhere to marginal cost pricing, and as the marginal costs of freely obtained allowances still are equivalent to the opportunity costs, there may not be a difference in the short-run. This is also observed in econometric work that show that the majority of the sectors do pass through the opportunity costs of their freely obtained allowances (CE Delft and Öko Institut, 2015). However, in the long-run, average costs can be important for the cost structure of companies. Because average costs are lower under a system of free allocation, the impact of the ETS on competitive position of companies may be smaller for carbon policies than for energy policies. Therefore the work on energy prices may overestimate the "true" impact of unequal carbon prices of emission trading systems.

The second approach falls within the framework of timeseries analysis. In time series analysis, a variable is explained by its own lags and possibly (lags of) other variables. The application we use in this paper is an autoregressive model with distributed lags. In this model, we assume the effect of the energy price on trade is distributed over time (Heij et al., 2004). An example of this approach is the IMF working paper by Lossifov and Fei (2019). They analyse the effect of exchange rate changes on the trade balance using an ARDL model.

The third approach for studies that explain differences in trade patterns by differences in energy prices, is the cointegration approach. This can be seen as an extension of the second approach, in that it accounts for trends in the variables. An example of this approach is the IMF working paper by Saito (2004), that explains the effect of international differences in production costs on sales of exporting industries. Saito uses a panel data estimator that accounts for cointegration (similar trends) in both variables.

6.2.3 Focus and data

6.2.3.1 Model formulation

In our research, we have started to estimate the Sato and Dechezleprêtre model for a few selected sectors (see 6.2.3.3). The Sato and Dechezleprêtre paper is an important piece of research in this matter as they are among the first papers that are able to econometrically estimate the impact of unequal energy prices on the trade patterns.

The model in Sato and Dechezleprêtre (2015) can be given as:

$$trade_{ijst} = EXP\left(\lambda_p \sum_{p=1}^{n} trade_{ijs(t-p)} + \beta_1 epgap_{ijst-1} + \beta_2 GDPT_{ijt-1} + \beta_3 gdpsim_{ijt-1} + \beta_4 rfac_{ijt-1} + \beta_5 wagegap_{ijt-1} + \beta_6 reerratio_{ijt-1} + \beta_7 gravityvars_{ij}\right)\eta_{ijs} + v_{ijs}$$

Where:

- $trade_{ijst}$ is the value of annual trade by country *i* from country *j* for sector *s* at time *t*;[93]
- $epgap_{ijst-1}$ is the lagged difference in the log of the energy prices (or: log of the ratio of energy prices) for countries i and j in sector s at time t-1. Sato *et al.* (2015) experiment with various types of energy price index that reflects the change in energy prices.
- $GDPT_{ijt-1}$ is the log of the sum of GDP (in USD) of both trading partners i and j, at time t-1. This controls for overall bilateral economic size. The interpretation of this variable is that the larger the economic size of the two trading partners, the more trade will flow between the countries.
- $gdpsim_{ijt-1}$ is an index number reflecting the relative size of the economies of country *i* and *j* in order to test a hypothesees that the more similar are countries in economic size, the more trade between both countries will flow. The more unequal the GDP, the smaller (more negative) the value of this variable.
- $rfac_{ijt-1}$ is an indicator reflecting the relative factor endowment. Bergstrand (1999) illustrates that bilateral trade flows between high-income countries is positively related to similarity in factor endowments.
- $wagegap_{ijt-1}$ gives the relative gap in wages between countries *i* and *j*.[94]
- $reerration_{ijt-1}$ gives the relative exchange rates of the currencies of country *i* and *j* against the US$.
- $gravityvars_{ij}$ is a vector of gravity variables, notably

93 Data for this variable can be seen as observations on import, stacked on observations on exports. Both import and exports are therefore seperate observations in the regression and have positive values. In case the "trade" concerns export, the negative of the energy price is used as an explanatory variable. See e.g. S134 of Sato and Dechezlepretre (2015).

94 Notice that the model only considers the *average wage differential* between two countries.

- Distance (population weighted distance).
- Common currency (dummy).
- Contiguity (dummy)[95].
- Common official language (dummy).

► η_{ijs} control for other time invariant country-pair sector specific effects, , colonial ties or relatively stable differences in tax regimes or competitiveness. These are included as presample averages of trade for the relevant sector and countries.

► ν_{ijs} is a normally distributed error term.

Important in this respect is especially the influence of $\beta_1$explaining the influence of the energy price gap. In an earlier paper, Sato *et* al., (2015) have constructed an energy price index that covers four key types of fuel carriers (electricity,gas, coal and oil) in 12 sectors in 48 countries (see Sato et al., 2015 and Annex E.1.2 for a description). This energy price index is allocated to more sectors in Sato and Dechezleprêtre (2015) that estimates the impact of energy price differential in 62 sectors in 43 countries (see also Annex E.1.2). This energy price index database was updated in later work (Sato et al., 2019) .

6.2.3.2 Adding carbon costs

One important drawback of the Sato and Dechezleprêtre approach is that it focusses on energy costs instead of carbon costs. Therefore we have attempted to re-estimate the model including both the energy cost differential and the carbon cost differential (see paragraph 6.3.2).

The advantage of including the carbon costs is that the objective of this part of the study is to analyse the impact of carbon price differentials on trade patterns. Energy prices are in general a poor indicator for carbon prices. Within the EU ETS there has been almost no correlation between, for example, the oil price and the CO_2 price in the first few years of operation of the EU ETS (see e.g. CE Delft, 2010). Therefore, energy price differentials between countries may not be representative for eventual carbon price differentials.

However, only taking carbon costs may underestimate the true impact of unequal carbon prices. In the literature, it has been observed that carbon prices have not resulted in a significant negative impact on trade (see e.g. Ecorys/Öko-Institut, 2014). However, as ETS prices were very low for a long period of time, such results may not hold if the ETS price were to increase considerably in the future.

Therefore we aim to include our model both the carbon and energy price and test whether both can be included simultaneously, or whether, because of multicollinearity problems, one of them would better fit the variation in trade data. [96]

Including carbon prices also allows us to test the impact of freely obtained allowances on the difference in trade patterns.

[95] The dummy equals 1 if two trade partners share a common border (i.c. are neighbouring countries).

[96] We observe here also that the current Energy Price Index by Sato et al. does not include an estimation of carbon costs, so we feel safe that including them will not lead to double counting.

6.2.3.3 Choosing specific sectoral classification

Another drawback of the Sato and Dechezleprêtre (2015) paper was the sectoral classification. In our study we have attempted to arrive at a more granular sectoral classification at the NACE 4-digit level. This level is also playing a role in the EU ETS as the NACE-4 digit level also determines the harmonized allocation rules in the EU ETS with respect to risk of carbon leakage and benchmarks. .

In order to investigate in particular the impacts of carbon intensive sectors, we have selected 15 sectors in our study that are the most emission intensive sectors. These sectors have been linked to the Energy Price index from Sato *et al*. (2019, see also Annex E.1.1)., as indicated in Table 73.

Table 73: Top 15 sectors with respect to verified emissions in the EU ETS excluding airline operators, mining and electricity generators

#	NACE	Name	Verified CO_2 in 2015 in Germany (Mt)	Link with energy price from Sato *et al.* (2019)
1	24.10-24.30	Basic iron and steel and ferro-alloys	158.3	Iron and steel
2	19.20	Refined petroleum products	132.3	Chemical and Petrochemical
3	23.51	Cement	113.1	Non-metallic minerals
4	20.14	Other organic basic chemicals	54.2	Chemical and petrochemical
5	20.15	Fertilisers and nitrogen compounds	35.9	Chemical and petrochemical
6	23.52	Lime and plaster	25.8	Non-metallic minerals
7	17.12	Paper and paperboard	24.3	Paper, pulp and print
8	24.42	Aluminium	12.9	Non ferrous metals
9	20.13	Other inorganic basic chemicals	11.3	Chemical and petrochemical
10	23.13	Hollow glass	10.3	Non-metallic minerals
11	10.81	Sugar	8.2	Food and tobacco
12	20.11	Industrial gases	6.5	Chemical and petrochemical
13	19.10	Coke oven products	6.2	Iron and steel
14	23.32	Bricks, tiles and construction products, in baked clay	5.8	Non-metallic minerals
15	23.11	Flat glass	5.7	Non-metallic minerals

Source: EUTL, CE Delft calculations

We have chosen to include all EU 27 + UK countries in the analysis and link their trade data with trade of 7 major trading partners:

- Switzerland;
- China;
- India;
- South-Korea;
- Russia;
- Turkey;
- United States of America.

Some of these countries have priced CO_2 for industry, while other countries did not yet have installed a system of CO_2 prices. In Task 2 chapter 5.4 more information is given. We have collected data in principle for the period 1995-2018. The energy price index data are only available for the period 1995-2015 so the endperiod of our estimation is in principle 2015.

6.2.3.4 Data

In Annex E.1 a full description of the relevant data can be found including descriptive statistics. The data can be handed over upon request.

6.3 Results of the econometric estimations

6.3.1 Introduction

This chapter presents some more background and results for the different models we have estimated and analysed. Section 6.3.2 covers the full trade model estimated by Sato and Dechezleprêtre (2015). Section 6.3.3 describes the results of an econometric estimation of a more concise trade model. Sections 6.3.4 and 6.3.5 are devoted to econometric estimation of an ARDL-model and cointegration model respectively. In the Annexes C.1-C.8 more details of our estimation routines can be found.

6.3.2 The Sato and Dechezleprêtre (2015) trade model

We have started our work in estimating the Sato and Dechezleprêtre (2015) model (see paragraph 6.2.3.1 for model formation) using both energy and carbon prices for a selected set of sectors and trade patterns (see paragraph 6.2.3.3). Like in Sato and Dechezleprêtre (2015) all variables have been transformed into logs so that coefficients can be interpreted as elasticities.

6.3.2.1 Results

Below, we report the results of 2 models reported in Sato and Dechetzlepetre (named in their paper as models 2 and 3) next to our own replication of model (3) in Annex E.1. The two models by Sato differ in the specification of the control variables: the first (model 2) includes the wage gap, the second the exchange rate. In our replication of model (3) by Sato al. we left out common currency as our selection of trade partners (see paragraph 6.2.3.3) always have a different currency unit. We estimate the average effect of energy prices on the trade pattern, for the trade relations of the EU 27 + UK with the 7 trade partners.

Table 74: Econometric results of trade models that explain trade patterns by asymmetries in Energy prices and/or CO_2 prices

Model	**Sato et al. (2)**			**Sato et al. (3)**			**Replication of Sato et al. (3)**	
Variable	Coef	Sign		Coef	Sign		Coef	Sign
Energy price gap	0,011	**		0,021	**		0,14	*
Gravity variables								
Distance	-0,01	***		-0,02	**		-0,00	
Common currency	-0,003			-0,008			-	
Contiguity	0,007			-0,003			0,04	
Common offical language	0,004			0,009			-0,02	
Control variables								
Wage gap	0,014							
GDP total	-0,17	*		0,11			-0,16	*
GDP similarity	-0,09	*		0,05			-0,10	**
Relative fact. Endow	-0,007	**		-0,003			-0,01	
Exchange rate ratio	-			0,05	**		0,17	***
Lagged dep. Vars.								
lag 1	0,90	***		0,88	***		0,77	***
lag 2	0,05	***		0,06	***		0,05	**
lag 3	0,04	***		0,04	***		0,08	***
Fixed Effects								
Country-pair sect. FE	Presamp			Presamp			Presamp	
Sector fixed effects	Yes			Yes			Yes	
Year FE	Yes			Yes			Yes	
Imp & Exp dummies	Yes			Yes			Yes	
long run effects (calculated)								
Energy price gap	0,69			1,00			1,45	

Model	Sato et al. (2)			Sato et al. (3)			Replication of Sato et al. (3)	
ETS-price				0,35			0,34	

Notes:
Significance levels: *** < 1%; ** < 5%; * < 10%; “-“: not included in model; Presamp denotes that presample mean of the dependent variable over the years 1996-2000. These are proxies for the fixed effects; All models are estimated with PPML; Long run effects are calculated as $\beta/(1-\sum_{p=1}^{n}\lambda_p)$. Long run elasticities reflect the change of trade caused by price change after a period of 10 to 20 years.

If we look at the results of the two models by Sato and Dechezleprêtre, we see that the gravity variables are mostly insignificant, and/or have implausible signs. Further, the control variables are instable and where they are significant, they have implausible signs.

Our replication of model (3) suffers from the same problems.

6.3.2.2 Conclusions for the method

The result that the control and gravity variables are not robust or have implausible signs, may well arise from the inclusion of the country fixed effects, the country-pair sector fixed effects and the lagged dependent variables next to the control variables and gravity variables. The fixed effects would tend to pick-up the major part of the effects that the gravity variables and control variables are supposed to measure, because the control variables and gravity variables do not have much variation over time.

To solve this problem, we propose to use a more concise version of the trade model, that does not include the gravity and control variables (except for the real exchange rate which seems to work well and does have substantial variation over time).

6.3.3 Econometric results of concise trade models

Below, we present the econometric results of our main models that explain trade patterns, by asymmetry in:

- Energy price.
- Energy price and CO_2 price.
- CO_2 price.

We have estimated the model described in Annex D both in full form and in reduced form estimations. In the reduced form estimation we have left out all variables that were insignificant or led to inconsistent results. We do this for a number of reasons. First, the theoretical foundation for including them next to the country-pair sector fixed effects and the lagged dependent variable is not very convincing. The country-pair sector fixed effects are supposed to pick up any (not observed) time invariant effects of the combination of trade partners, even taking into account sector characteristic. Hence, factors that are associated with these partners or a specific sector for which they trade are already controlled for. Proxies for such factors are GDP total, GDP similarity, relative factor endowments as well as the gravity variables distance, common currency, contiguity and common official language.

Second (and as can be expected) the estimated coefficients for these variables are often insignificant, have an implausible sign or are instable.

As sensitivity analysis, we show that the effect of the asymmetry in energy price on trade is rather stable for excluding or including the control variables. However, we feel the overall model is more convincing when excluding them, for the reasons given above.

6.3.3.1 Results

Below, we present the econometric results of the main models estimated (Table 75).

We observe that the effect of asymmetry in energy prices on trade is significant, with a value of 0,14 (model 1). This implies that a growth of the energy price in the EU, with respect to the energy price of the trading partner of 1%, leads to a rise in imports (and a fall in exports) of 0,14%. This elasticity is the so-called short run elasticity. The short run elasticity is the reaction of trade to a price change within one year.

Including the CO_2 price to this model makes the Energy Price variable insignificant (Models 2 and 3). Moreover, the indicator of allocation[97] (Model 3) seems to be insignificant. Looking at the effect of the CO_2 price[98], we see that a rise in the ETS price of 1% leads to a rise in imports in EU countries of 0,011 to 0,012% (models 2 to 4).

Table 75: Econometric results of concise trade models that explain trade patterns by asymmetries in Energy prices and/or CO_2 prices

Nr.	**(1)**			**(2)**			**(3)**			**(4)**	
Model	**Energy price**			**ETS price and energy price**			**Including allocation**			**Only ETS price**	
Variable	Coef	Sign		Coef	Sign		Coef	Sign		Coef	Sign
Energy price gap	0,14	**		0,03			0,03			-	
ETS price	-			0,011	***		0,011	***		0,012	***
Allocation	-			-			0,008			-	
Control variables											
Exchange rate ratio	0,13	***		0,15	***		0,15	***		0,16	***
Lagged dep. Vars.											
lag 1	0,84	***		0,83	***		0,83	***		0,84	***
lag 2	0,06	**		0,06	**		0,06	**		0,06	**
lag 3	0,07	***		0,07	***		0,07	***		0,07	***
Fixed Effects											

[97] For a definition, see Annex A, table 7

[98] Above, we present a model with only the ETS price. We have also estimated models with a CO2 price gap, resulting in insignificant coefficients. Identification of the parameters in these models requires data on CO2 prices in non-EU countries. Non EU-countries started with trading systems that create a CO2 price at later stage than the ETS. This implies a fall in data coverage by about 50% for models with CO2 price gaps instead of ETS price, which in our view explains the insignificant coefficients.

Nr.	(1)		(2)		(3)		(4)	
Country-pair sect. FE	Presamp		Presamp		Presamp		Presamp	
Sector fixed effects	No		No		No		No	
Year FE	Yes		Yes		Yes		Yes	
Imp & Exp dummies	No		No		No		No	
long run effects (calculated)								
Energy price gap	4,45		NS		NS		NS	
ETS-price			0,35		0,34		0,35	

Notes:
Significance levels: *** < 1%; ** < 5%; * < 10%; "-": not included in model; Presamp denotes that presample mean of the dependent variable over the years 1996-2000. These are proxies for the fixed effects; All models are estimated with PPML; Long run effects are calculated as $\beta/(1-\sum_{p=1}^{n}\lambda_p)$. Long run elasticities reflect the change of trade caused by price change after a period of 10 to 20 years.

We conducted some sensitivity checks that show that our findings are rather stable for the inclusion of different control variables and dummy's (see Annex C4).

6.3.3.2 Discussion of the results and conclusions for the method

We present a small discussion on the interpretation of the findings regarding our main variables. We focus our discussion on:

1. Relative size of energy price versus CO_2 price.
2. Insignificance of energy price in model with CO_2 price.
3. Treatment and interpretation of long run effects.

Ad 1) The estimated coefficient for the energy price gap has a size of 0,14, while the estimated coefficient of the CO_2 price has a value of 0,011. The difference in the order of magnitude (a factor 10) reflects the share in the costs of energy vis a vis CO_2 in total production costs. Theoretically, one would expect a change in costs to translate into a change in product price. Then, the change in product price leads to a change in trade. So, the larger the cost share, the larger is the value of the coefficient. We find these results plausible and reassuring.

The value of 0.14 is still a factor 7 larger than the original estimation by Sato and Dechezleprêtre for energy intensive sectors. This is quite a large difference, perhaps the preselection of a number of most energy intensive sectors and trade patterns between the EU MS and specific countries has "inflated" our estimate compared to their earlier study.

Less plausible is the finding in model (2), including the CO_2 price renders the energy price insignificant. As yet, we don't have a good explanation for this finding, other than that the two variables have correlation of around 40%. This is quite large compared to the correlation of these variables with trade (around 1 to 2%).

Ad 2) The coefficient estimates present the direct short-term impact of a change in energy price (or CO_2 price) on trade. However, such changes tend to have a long-run impact because the best explanatory variable in the regression analysis are the lagged dependent variables. So a change in the present year trade patterns influences also trade in the next years. When we precisely calculate this long run elasticity of the energy price we arrive at a value of 4,5[99]. This long run elasticity concerns the change in trade caused by a change in price after a prolonged period of time, let's say 1 to 20 years. The value implies that a growth of the energy price in the EU, with respect to the energy price of the trading partner of 1%, leads to a rise in imports (and a fall in exports) of 4,5% in the long run. We find this value too high to be plausible. We roughly estimate the share of energy costs in total production costs to be around 20% for the sectors considered, so the long run elasticity would imply that 1% change in market price leads to a change in export of around 22,5%[100]. This value can be compared with estimates of Armington elasticities. For these elasticities, we typically find values in the literature of around 5 for the sectors concerned (Aspalther, 2016). Therefore, an average value of 22.5 seems to be unrealistically high.

Ad 3) Probing a bit deeper in what causes the value of the long run elasticity to be so high, we see that the accumulated value of the coefficients of the lagged depend is around 0,95 or higher. This value close to 1 implies that the short run coefficient is inflated by a factor 20 or more to obtain the long run effect. This has a number of implications:

1. The value of the long run coefficient is quite sensitive to changes in the accumulated value of the coefficients for the lagged dependent variable. For example, a value of 0.99 would further inflate the value of the long run coefficient to a factor 100; while a value of 0,90 would inflate it with "just" a factor 10. Judging from the standard error of the lagged dependent variables, this range of values is not improbable. Thus: the long run value is surrounded with a high degree of uncertainty.
2. The explanatory power of the energy price variable is quite low. Calculations by Sato et al. show that only 0,01% of the total variation in trade patterns is explained by energy prices. Moreover, we have shown that most of the control variables, such as those related to GDP and the gravity variables are not significant (meaning they explain close to zero of the variance in trade patterns). On the other hand, the lagged dependent variable seems to explain a quite large portion of the variance in trade patterns[101]. Taken together, this rises some doubt on whether the concise trade model is adequate for capturing long run effects. That is: The combination of low explanatory power of the variables in our model with intertemporal correlation in trade patterns would indeed draw the value of the lagged dependent towards 1. We suspect this value is as much a sign of temporal patterns in trade flows, as well as a sign of the lack of variables in our model that explain the fundamentals of the trade patterns adequately. Or, in other words: the lagged dependent variables are a proxy for unobserved fundamentals that explain trade patterns, rather than a reflection of "real" temporal adjustment patters in trade.

We have deployed a number of econometric strategies that, in theory, are for the implications mentioned above. We present details of these strategies below. The strategies are:

- To estimate ARDL-models that aim to model time-dynamics in effects of variables explicitly;
- To estimate cointegration models that aim to model the long-run relationship between variables.

[99] The long run elasticity is calculated as: short run elasticity / (1-sum of lagged dep). In our case this is: 0,14/(1-(0,84+0,06+0,07))=0,14/0,03=4,45.

[100] This is calculated as 1%*4,5/20%=22,5%

[101] We did not do simulations to calculate the exact share, but from the significance and the accumulated value of nearly 1 we know it is high.

Within economics, these models are common practice when analysing time series data.

6.3.4 Econometric results ARDL-models

One option to model time-dynamics more appropriate is through the use of an autoregressive distributed lags (ARDL)-model. In such a model, one includes one or more lags of the dependent variable (trade in our case) as well as lags of an independent variable (in our case: the energy gap). So we extend model (1) with lags of the energy price. The aim of including the lags is to allow for a time-lag in the way the energy price affects trade. This is justified by the fact that a rising energy price differential may not be priced in immediately and that trade only responds in a longer term to changes in energy prices. The ARDL-model can appropriately capture the effect of energy prices on trade, if that effect materialises after a period of 1 or more years[102]. Reasons for this delayed response may be that price differences materialize themselves in a long-term impact through a change in investments or that a large share of trade takes place through long-term contracts. Price differentials can therefore take a while before being translated into a change in trade patterns.

The econometric estimation of ARDL-models does not differ substantially from the estimation of the trade model we started with. Technically, the procedure is to include the lags of the energy price and estimate the model with the original estimator (PPML in our case). For a complete description of variables included in the model, see Annex E.5.

6.3.4.1 Results of the ARDL-models

The table below depicts the results of the ARDL-models. We estimated an ARDL(2) to ARDL(4) model where the number in brackets indicates the delay , as an alternative to our baseline model (1) that explains trade by the energy price.

We observe that in all ARDL-models the added lags of the energy price gap (2 to 4) are not significant. Moreover, including these lags makes the energy price gap (lag 1) turn up insignificant as well. This is most likely caused by the high correlation between lags of the energy price gap, as the intertemporal variation of this variable is limited.

Table 76: Econometric results of ARDL-models models that explain trade patterns by asymmetries in Energy prices

Nr. **Model**	**(1)** **Energy price**		**(5)** **ARDL (2)**		**(6)** **ARDL(3)**		**(7)** **ARDL(4)**	
Variable	Coef	Sign	Coef	Sign	Coef	Sign	Coef	Sign
Energy price gap (lag 1)	0,14	**	0,29		0,37		0,35	
Lagged Energy price gap								
Lag 2			-0,18		0,32		0,32	
Lag 3			-		-0,60		-0,51	
Lag 4			-		-		-0,09	

102 We have data on a yearly basis.

Nr.	(1)			(5)			(6)			(7)	
Control variables											
Exchange rate ratio	0,13	***		0,11	**		0,11	**		0,10	*
Lagged dep. Vars.											
lag 1	0,84	***		0,83	***		0,82	***		0,82	***
lag 2	0,06	**		0,12	***		0,06	**		0,07	***
lag 3	0,07	***		-	-		0,08	***		0,11	***
Lag 4				-			-			-0,04	**
Fixed Effects											
Country-pair sect. FE	Presamp			Presamp			Presamp			Presamp	
Sector fixed effects	No			No			No			No	
Year FE	Yes			Yes			Yes			Yes	
Imp & Exp dummies	No			No			No			No	
long run effects (calculated)											
Energy price gap	4,45			NS			NS			NS	

Notes:
Significance levels: *** < 1%; ** < 5%; * < 10%; "-": not included in model; Presamp denotes that presample mean of the dependent variable over the years 1996-2000. These are proxies for the fixed effects; All models are estimated with PPML; Long run effects are calculated as $\beta/(1-\sum_{p=1}^{n}\lambda_p)$. Long run elasticities reflect the change of trade caused by price change after a period of 10 to 20 years. NS = Not significant impact of energy price and therefore not able to calculate

6.3.4.2 Conclusions for the method

For the ARDL-method, we draw the following conclusions:

- Adding additional lags of the energy price gap on top of the (concise) trade model does not add significant explanatory power to the model. Hence the ARDL-model is not able to capture the time-dynamics of the effect of the energy price on trade adequately, for data with a yearly frequency;
- Including additional lags of the energy price gap makes the energy price gap (lag 1, included in the original model) loose its significance. This is most likely a result of the lack of intertemporal variation of the energy price gap, which hampers identification of the individual impact of the energy price.

6.3.5 Econometric results of cointegration models

Models that estimate a cointegration relation aim to determine if there is a long-run trend relation between two time series variables. The concept of cointegration was introduced by Engle and Granger (1987) with the aim of designing an appropriate statistical test for finding a relationship between two variables that both exhibit a trend (are non-stationary). Simple linear regression between these variables is prone to deliver a statically significant relation, but this relation may be spurious if in fact the underlying trends diverge in the long run. If the trends are cointegrated, they do not diverge in the long run.

Below, we present the results of cointegration models and a trend-test. First, we present the results of models for cointegration between (logs of) trade and the energy price gap. Then, we present the results for tests of the existence of individual trends in trade and the energy price gap separately. If the trend-test signals a trend, a cointegration model is suitable. Otherwise, other models like the trade model or ARDL are more suitable.

Given the nature of our data, we employ cointegration models and run trend-tests that are suitable for panel data.

6.3.5.1 Results of cointegration models

The table below summarizes the results of two types of panel data cointegration estimators: a group-mean fully modified ordinary least squares estimator (FMOLS) and a group-mean dynamic ordinary least squares estimator (DOLS).

We use the group-mean variant of the estimators because they offer the property of providing consistent estimators of the sample mean of cointegrating vectors, in contrast to other variants like the pooled and weighted estimators. For a description of the models estimated, see annex H.

From the table below, we observe that the estimated size of the long-run effect of the energy price gap on trade is instable. That is: the differences between the DOLS estimator and the FMOLS estimator is large. These two estimators should produce similar results (for data sets that are infinitely large). Further, applying a cointegration model does not help to get a more plausible order of magnitude.

Table 77: Results of some panel data cointegration models (long run effect of energy price gap on trade

	Method	**Method**
Control variables included	FMOLS	DOLS
Non	-4,2	47
GDP total	-5,5	NA[103]
GDP total, GDP similarity	-5,5	NA[104]

Notes:
Reported coefficients are signiifant < 1%;
Models differ in estimation method (FMOLS or DOLS) and exogenous variables included in the cointegration relation;
Detailed results are presented in the appendix.

103 Evies does not offer this option.
104 Evies does not offer this option.

6.3.5.2 Results of stationary tests

In this section, we present the results of panel data tests for stationarity of a variable.

We employ 5 tests offered by Eviews:

- Levin, Lin and Chu (2002);
- Breitung (2000);
- Im, Pesaran and Shin (2003);
- Maddala and Wu (1999);
- Choi (2001), and Hadri (2000).

We use these tests both on logs of the variables (as in the trade model) as well as on the non-transformed value of the variables. For the results, see below.

We have also performed the test for import and export separately.

The tables below present the results. We see that the evidence for a trend in the variables is weak. Rather: the evidence points to the variables being stationary.

Table 78: Number of panel data tests that identify a trend in the variable (log).

Variable	Trend specification	Trend specification
	Intercept	Intercept, Linear trend
Log trade	0/4	2/5
Log import	0/4	1/5
Log export	0/4	1/5
Log energy price gap	2/4	2/5
Log energy price gap if trade is import	1/4	2/5
Log energy price gap if trade is export	2/4	4/5

Note: the number before the / denotes the number of tests that point towards a trend; the number after the / denotes the number of tests deployed.

Table 79: Number of panel data tests that identify a trend in the variable (non-transformed value).

Variable	Trend specification	Trend specification
	Intercept	Intercept, Linear trend
Trade	0/4	1/5
Import	0/4	1/5
Export	0/4	1/5
Energy price gap	2/4	2/5

Variable	Trend specification	Trend specification
Energy price gap if trade is import	2/4	3/5
Energy price gap if trade is export	2/4	3/5

Note: the number before the / denotes the number of tests that point towards a trend; the number after the / denotes the number of tests deployed.

If we test for a unit root in trade in individual sectors, for 25% of the sectors, the NULL of a unit root is rejected. This is remarkable, because each sector contains 15 or less observations, which favours the NULL substantially. See Annex J for detailed results.

6.3.5.3 Conclusions for the method

From the above, we draw the following conclusions:

- The panel data cointegration estimators we employed deliver results that are not stable. The size of the cointegration relationships estimated by FMOLS differs substantially from that estimated by DOLS. This is a sign of model misspecification.
- We could set-up a model that satisfies the condition that errors are not correlated over the panels. Models that included additional control variables like time trends resulted in a near-singularity problem.
- Tests for trends in the individual variables point to the direction that the variables, when expressed in years, are stationary, which makes the cointegration model inappropriate.

Therefore we do not think that for these data the cointegration framework delivers reliable results.

6.4 Conclusions

The fear that unequal carbon prices have an adverse impact on the competiveness of EU industries has been a dominant concern since the start of the EU ETS in 2005. The present academic literature has largely addressed this through simplistic econometric approaches (before and after) or investigated the impact of energy price differentials in generalized trade models. Within this research we have attempted to investigate the influence of carbon prices directly by focussing on a few selected energy intensive industries and a limited number of trade relations.

We have investigated the trade patterns between the EU 27 + UK and a group of 7 countries (Switzerland; China; India; South-Korea; Russia; Turkey; United States of America) for the 15 most energy intensive sectors in the EU ETS (defined as NACE4 digit level as Basic iron and steel and ferro-alloys; Refined petroleum products; Cement; Other organic basic chemicals; Fertilisers and nitrogen compounds; Lime and plaster; Paper and paperboard; Aluminium; Other inorganic basic chemicals; Hollow glass; Sugar; Industrial gases; Coke oven products; Bricks, tiles and construction products, in baked clay; Flat glass) using annual data for the period 2000-2016. For these 28*7 trade partners * 7 sectors, we have empirically estimated the average effect of an increase in the energy price difference on the volume of trade.

Compared to other approaches in the literature our study aimed to combine the best of two methods:

(i) the full richness of gravity trade models that have been used to investigate the impacts of cost differentials on trade, such as in the influential paper by Sato and Dechezleprêtre (2015) that have estimated impacts of energy prices on trade at the NACE 2-digit level;

(ii) The much more granular statistical basis of ex-post analysis such as Ecorys/Öko-Institut (2014) that used ETS data to determine eventual impacts of ETS costs on trade patterns.

However, the results of this effort have been disappointing. We noticed that the Sato and Dechezleprêtre model did not properly describe our situation: most of the gravity variables were insignificant casting doubts about the appropriateness of these models. A concise trade model resulted in large impacts of unequal carbon or energy prices on trade, especially in the long-run. The impact would imply an Armington elasticity (price elasticity of export) that is a factor 4 higher than commonly found in literature and macro-economic models. Combined with the low explanatory power of the models, we have doubts about the appropriateness of these results. Further methodological refinements have been sought in the area of alternative model specifications. However, these alternative model specifications did not provide a better explanation of the impacts of unequal carbon prices on trade.

All in all we draw the following conclusions from our work:

- All of our modelling efforts used annual data as this was the basis of our data collection using the annual index of energy prices from the Sato *et al*. (2019) paper. However, our regressions show that that annual data are probably too coarse to provide a realistic picture of the impact of carbon pricing on trade. Time lag models provided no realistic results indicating that a time lag of a year is too long for the processes underlying the (potential) impact of carbon prices on trade.
- Our results provide some evidence that by focussing only on the most energy intensive sectors, impacts of unequal carbon prices on trade may be much larger than initially indicated. However, given the relatively poor quality of our models in terms of explanatory power, stability of the estimators and plausibility of the long-term results we cannot state this with any degree of certainty.

We also have two recommendations for future work in this area which we would like to share with the research community.

- A first recommendation would be to consider using physical indicators of trade in future work. The present work has used monetary indicators of trade (values of imports and exports). However, the direct impact of a price increase in carbon on monetary indicators is ambigious as the price increase on the one hand increases the value of trade as the carbon price is forwarded in the costs but on the other hand diminishes the volume of trade through the Armington elasticities. As these two impacts counteract each other, the net impact may be small – too small to discern in our trade models.
- A second recommendation would be to consider using monthly data in future work. Our efforts show that annual data are probably not fit for purpose when estimating the impacts of unequal carbon prices on trade as the changes in trade may be more immediate than on an annual level.

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D Annex

D.1 Data description

We collected data on trade flows of European countries with Switzerland, China, India, South Korea, Russia, Turkey and the United States. For our analysis, we only focus on the most emission intensive sectors and sectors that are strongly dependent on emission intensive sectors.

Furthermore, we collected data on energy prices and if applicable CO_2 prices, as well as the country's GDP (per capita), real exchange rate, and dummy variables to indicate whether the origin and destination country share a language and/or a currency. In the table below we present the data sources for our variables.

Table 80: Data sources

Variable	Source
$trade_{ijs}$	Eurostat Comext (2019)
$CO2pgap_{ij}$	EUTL (2019), Tanjiaoyi (2019)
$Allocation_i$	EUTL (EEA, 2019)
$epgap_{ij}$	Sato, et al. (2019)
$GDPT_{ij}$	CEPII's Gravity Dataset (2019)
$gdpsim_{ij}$	CEPII's Gravity Dataset (2019)
$rfac_{ij}$	CEPII's Gravity Dataset (2019)
$reerratio_{ij}$	Zsolt (2019)
$Distance_{ij}$	CEPII's Gravity Dataset (2019)
$Common\ currency_{ij}$	CEPII's Gravity Dataset (2019)
$Contiguityo_{ij}$	CEPII's Gravity Dataset (2019)
$Common\ official\ language_{ij}$	CEPII's Gravity Dataset (2019)

In Table 81 we present the descriptive statistics. We have 81,425 observations regarding trade between European countries and Switzerland, China, India, South Korea, Russia, Turkey and the United States for the specific sectors, of which 42,634 observations regarding imports to European countries and 38,791 observations regarding exports from European countries. Moreover, only the EU 27 + UK, China, South Korea, Switzerland and the USA have a CO_2 price.

Table 81: Descriptive statistics

Variable	N	Mean	Standard deviation	Min	Max
$trade_{ijs}$	81,425	34,207,219	191,669,835	1	7,494,082,046
$VEPL\ epgap_{ij}$	59,976	0	0.632	-2.095	2.095
$FEPI\ epgap_{ij}$	73,680	0	0.134	-0.428	0.428
$CO2pgap_{ij}$	20,160	0	3.072	-6.336	6.336
$Allocation_i$	49,896	0	0.546	-6.182	6.182
$reerratio_{ij}$	129,360	0	0.202	-0.906	0.906
$GDPT_{ij}$	124,740	27.978	1.157	25.609	30.623
$gdpsim_{ij}$	124,740	-0.693	1.395	-7.213	-0.693
$rfac_{ij}$	124,740	1.497	1.106	0.0004	4.932
CO_2 prices:					
EU ETS	14	10.983	6.695	0.660	22.515
China	6	0.344	0.083	0.239	0.467
South Korea	4	14.780	3.478	9.820	17.580
Switzerland	5	14.613	12.430	7.594	36.590
USA	9	0.492	0.448	0.023	0.990

In Table 82 we present our key variables and the necessary data mutations to calculate the variables.

Table 82: Explanatory variables

Name	Definition	Explanation
$epgap_{ij}$	$\ln(energy\ price_i) - \ln(energy\ price_j)$	Difference in the log of the energy prices for country i and j. Variable can consist of a fixed set of fuels (FEPI) or a variable set of fuels (VEPL)
$CO2pgap_{ij}$	$\ln(CO2price_i) - \ln(CO2price_j)$	Difference in the log of the CO_2 prices for country i and j
$Allocation_i$	$\ln\left(\frac{Allocated\ emissions}{Verified\ and\ waste\ gasses\ in\ excess\ of\ natural\ gas}\right)$	Ratio of the allocated emissions in the sector relative to the verified and waste gasses in excess of natural gas.
$GDPT_{ij}$	$\ln(GDP_i + GDP_j)$	Log of the sum of GDP of both trading partners i and j
$gdpsim_{ij}$	$\ln\left(1 - \left[\frac{GDP_i}{GDP_i + GDP_j}\right]^2 - \left[\frac{GDP_j}{GDP_i + GDP_j}\right]^2\right)$	This controls for similarity in GDP. If two counties have an identical GDP, then the variables equals zero. However, should

Name	Definition	Explanation
		two countries have a very dissimilar GDP, then the variable is larger.
$rfac_{ij}$	$\ln(GDP\ per\ capita_i) - \ln(GDP\ per\ capita_j)$	This controls for the similarity in the factor capital/labour ratio
$reerratio_{ij}$	$\ln(reer_i) - \ln(reer_j)$	Difference in the log of the country's real exchange rate relative to the dollar.

D.1.1 Capita Selecta

This Annex provides detailed information on a few selected issues.

D.1.2 Sector and country classifications

In Sato and Dechezleprêtre (2015)

Table 83: List of sectors in Sato and Dechezleprêtre (2015)

Sectors	Sectors
Animal feed	Metal ores and scrap
Animal oils	Metalworking machinery
Apparel products	Non-ferrous metals
Beverages	Non-metallic minerals
Chemical products	Non-primary plastics
Coal and coke	Office machinery
Coffee and tea	Oil seeds
Cork and wood	Organic chemicals
Cork and wood manufacturers	Other foods
Cereals	Other manufacturing
Crude animal and vegetable materials	Other transport equipment
Crude fertilisers	Paper and paperboard
Crude rubber	Petroleum products
Dairy products	Pharmaceuticals
Dyeing materials	Photographic and optical goods

Sectors	Sectors
Electrical machinery	Power generation equipment
Essential oils and perfume	Prefabricated buildings
Fertilisers	Primary plastics
Fish	Processed animal and veg oils
Footwear	Pulp and waste paper
Furniture	Road vehicles
General industrial machinery	Rubber manufactures
Gold	Scientific instruments
Hides and skin	Sugars
Industrial machinery	Telecom machinery
Inorganic Chemicals	Textile fibres
Iron and steel	Textile yarn and fabric
Leather manufactures	Tobacco
Live animals	Travel goods
Meat	Vegetable fats
Metal manufacturing	Vegetables and fruit

Table 84: List of countries in Sato and Dechezleprêtre (2015)

Country	Country
Australia	Japan
Austria	Kazakhstan
Belgium	South Korea
Brazil	Lithuania
Bulgaria	Mexico
Canada	Netherlands
Chile	New Zealand
China	Norway
Croatia	Poland
Cyprus	Portugal

Country	Country
Czech Republic	Romania
Denmark	Russian Foundation
Finland	Slovak Republic
France	Slovenia
Germany	South Africa
Greece	Spain
Hungary	Sweden
India	Switzerland
Indonesia	Thailand
Ireland	Turkey
Italy	The United Kingdom
	The United States

In Sato *et al*. (2019) for the energy price index

An energy price index is calculated for 12 sectors in 48 countries.

The 12 sectors are:

1. Chemical and petrochemical.
2. Construction.
3. Food and tobacco.
4. Iron and steel.
5. Machinery.
6. Mining and quarrying.
7. Non-ferrous metals.
8. Non-metallic minerals.
9. Paper, pulp and print.
10. Textile and leather.
11. Transport equipment.
12. Wood an wood products.

The 47 countries are:

1. Austria.
2. Belgium.
3. Brazil.
4. Bulgaria.
5. Canada.
6. Chile.
7. China.
8. Croatia.
9. Cyprus.
10. Czech Republic.

11. Denmark.
12. Estonia.
13. Finland.
14. France.
15. Germany.
16. Greece.
17. Hungary.
18. India.
19. Indonesia.
20. Ireland.
21. Italy.
22. Japan.
23. Kazakhstan.
24. Korea, Republic of.
25. Latvia.
26. Lithuania.
27. Luxembourg.
28. Mexico.
29. Netherlands.
30. New Zealand.
31. Norway.
32. Poland.
33. Portugal.
34. Romania.
35. Russian Federation.
36. Slovakia.
37. Slovenia.
38. South Africa.
39. Spain.
40. Sweden.
41. Switzerland.
42. Taiwan, Republic of China.
43. Thailand.
44. Turkey.
45. United Kingdom.
46. United States of America.
47. Venezuela (Bolivarian Republic of).

D.2 Estimated model of the trade model

For the trade model, the proposed model to estimate is:

$$trade_{ijst} = EXP\left(\lambda_p \sum_{p=1}^{n} trade_{ijs(t-p)} + \beta_{01}CO2pgap_{ijst-1} + \beta_{02}Allocation_{ist-1} + \beta_1 epgap_{ijst-1} + \beta_2 GDPT_{ijt-1} + \beta_3 gdpsim_{ijt-1} + \beta_4 rfac_{ijt-1} + \beta_5 reerratio_{ijt-1} + \beta_6 gravityvars_{ij}\right)\eta_{ijs} + \nu_{ijs}¶$$

With:

$trade_{ijst}$ is the value of annual trade[105] (in USD by country i (in our case: this would be EU27+UK) from country j (one of the major trading partners) for sector s at time t, and ν_{ijs} is the error term.

$CO2pgap_{ijt-1}$ is the lagged difference in the log of the CO_2 price (in USD/ton) (or: log of the ratio of CO_2 prices), for countries *i* and *j* in sector *s* at time t-1[106].

The interpretation of β_{01} is that a 1% rise in the ratio of CO_2 prices of Germany and its trading partner, lead to a β_{01}% rise in imports.

$Allocation_{ijst-1}$ is an indicator for the share of freely allocated emissions with respect to verified emissions, measured in the lagged difference in the log, for country *i* (e.g. EU 27 + UK) in sector s at time t-1.

The interpretation of β_{02} is that a 1% rise in the ratio of allocated to verified emissions, leads to a β_{02}% fall in imports.

$\sum_{p=1}^{n} trade_{ijs(t-p)}$ (expressed in USD) is the n-years lagged dependent variable. Sato et al. experimented with different values of n and use n=3 in their baseline specification for the reason that the coefficient on the lagged dependent variables becomes statistically insignificant from n = 4 onwards. We will test the significance of the lags as well as the sensitivity of our results with respect to the choice of the amount of years of the lagged dependent variable.

$epgap_{ijst-1}$ is the lagged difference in the log of the energy prices (or: log of the ratio of energy prices), for countries i and j in sector s at time t-1. This variable will be based on the energy price index by Sato et al.

The interpretation of β_1 is that a 1% rise in the ratio of energy prices of EU27+UK and its trading partner, leads to a β_1% rise in imports.

$GDPT_{ijt-1}$ is the log of the sum of GDP (in USD) of both trading partners i and j, at time t-1. This controls for overall bilateral economic size[107].

$gdpsim_{ijt-1}$ is calculated as:

[105] The variable trade is column of data on imports staked on top of data on exports (both non-negative values). In case the trade concerns exports, the CO2 price gap and Energy price gap are given negative signs.

[106] CO2 price gap does not differ per sector, but only per country/year. This is because the respective ETS's span multiple sectors with one market price for CO2 Emission allowances.

[107] The interpretation of this variable is that the larger the economic size of the two trading partners, the more trade will flow between the countries.

$$gdpsim_{ijt} = \ln\left[1 - \left(\frac{GDP_{it}}{GDP_{it} + GDP_{jt}}\right)^2 - \left(\frac{GDP_{jt}}{GDP_{it} + GDP_{jt}}\right)^2\right]¶$$

And controls for similarity in GDP[108].

Note that together, $GDPT_{ijt-1}$ and $gdpsim_{ijt-1}$, are a proxy for bilateral economic size[109].

And measures the similarity in factor capital/labour ratio's (express in USD capital endowments/hours worked[110]).

A value of 0 represents equal relative factor endowment, a positive value unequal endowment. Bergstrand (1999) illustrates that bilateral trade flows between high income countries is positively related to similarity in factor endowments. Hence we expect a negative coefficient.

$$reerratio_{ijt} = \ln(reer_{it}) - \ln\,(reer_{jt})$$

The real exchange rate is expressed against the US dollar; we expect the value of a high exchange rate on imports to be positive.

- $gravityvars_{ij}$ is a vector of gravity variables, notably
  - Distance (population weighted distance).
  - Contiguity (dummy)[111].
  - Common official language (dummy).
- η_{ijs} control for other time invariant country-pair sector specific effects, , colonial ties or relatively stable differences in tax regimes or competitiveness. These are included as presample averages of trade for the relevant sector and countries.
- v_{ijs} is a normally distributed error term.

Notice that this model is relatively similar to Sato and Dechezleprêtre (2015) but excludes common currency and the wage ratio and includes CO_2 price and allocation variables. We excluded common currnency because non of our trade partners have this. We have not been able to obtain wages at the NACE-4 level.[112]

[108] The interpretation of this variable is that it enables to test the hypothesis that the more similar countries are in their economic size, the more trade will flow between the countries. This variable takes its maximum value (ln 0.5) if both trading partners have equal GDP. The more unequal the GDP, the smaller (more negative) the value of this variable.

[109] Note that (Wang, 2002) states: $lnGDP_iGDP_j = -ln2 + 2lnGDPT_{ij} + lnSIMGDP_{ij}$

[110] Ideally for labour we take hours worked. This depends on data availability. It may be that we have to resort to number of employees.

[111] The dummy equals 1 if two trade partners share a common border (i.c. are neighbouring countries).

[112] Higher level wage data were available but these tend to correlate highly with GDP in our model. We excluded therefore the wage differential variable from the model and expect that general wage differentials are captured by the GDP variable.

D.3 Estimated model of the concise trade model

For the concise trade model, the proposed model to estimate is:

$$trade_{ijst} = EXP\left(\lambda_p \sum_{p=1}^{n} trade_{ijs(t-p)} + \beta_{01} CO2pgap_{ijst-1} + \beta_{02} Allocation_{ist-1} + \beta_1 epgap_{ijst-1} + \beta_2 reerratio_{ijt-1} + t_d\right)\eta_{ijs} + v_{ijs}¶$$

With:

$trade_{ijst}$ is the value of annual trade[113] (in USD by country i (in our case: this would be EU 27 + UK) from country j (one of the major trading partners) for sector s at time t, and v_{ijs} is the error term.

$CO2pgap_{ijt-1}$ is the lagged difference in the log of the CO_2 price (in USD/ton) (or: log of the ratio of CO_2 prices), for countries *i* and *j* in sector *s* at time t-1[114].

The interpretation of β_{01} is that a 1% rise in the ratio of CO_2 prices of EU27 + UK and its trading partner, lead to a β_{01}% rise in imports.

$Allocation_{ijst-1}$ is an indicator for the share of freely allocated emissions with respect to verified emissions, measured in the lagged difference in the log, for country *i* (e.g. EU 27 + UK) in sector s at time t-1.

The interpretation of β_{02} is that a 1% rise in the ratio of allocated to verified emissions, leads to a β_{02}% fall in imports.

$\sum_{p=1}^{n} trade_{ijs(t-p)}$ (expressed in USD) is the n-years lagged dependent variable. Sato et al. experimented with different values of n and use n=3 in their baseline specification for the reason that the coefficient on the lagged dependent variables becomes statistically insignificant from n = 4 onwards. We will test the significance of the lags as well as the sensitivity of our results with respect to the choice of the amount of years of the lagged dependent variable.

$epgap_{ijst-1}$ is the lagged difference in the log of the energy prices (or: log of the ratio of energy prices), for countries i and j in sector s at time t-1. This variable will be based on the energy price index by Sato et al.

The interpretation of β_1 is that a 1% rise in the ratio of energy prices of EU 27 + UK and its trading partner, leads to a β_1% rise in imports.

$$reerratio_{ijt} = \ln(reer_{it}) - \ln(reer_{jt})$$

The real exchange rate is expressed against the US dollar; we expect the value of a high exchange rate on imports to be positive.

113 The variable trade is column of data on imports staked on top of data on exports (both non-negative values). In case the trade concerns exports, the CO2 price gap and Energy price gap are given negative signs.

114 CO2 price gap does not differ per sector, but only per country/year. This is because the respective ETS's span multiple sectors with one market price for CO2 Emission allowances.

t_d are yearly fixed effects.

η_{ijs} control for time invariant country specific effects, such as distance, common language, common borders, common currency, colonial ties or relatively stable differences in tax regimes or competitiveness.

Notice that this model is relatively similar to Sato and Dechezleprêtre (2015) but excludes the typical trade variables (like GDP similarity, total GDP of trading partners and distance). We drop these variables for the reasons explained in section 6.3.3.

We include the CO_2 price and allocation variables.

D.4 Sensitivity analysis of concise models

In this annex, we present a number of sensitivity tests. These tests allow us to check whether our main results are sensitive to the inclusion of a number of additional control variables. We have performed this tests for model (1) only; depending on the next steps in this project, we can perform them for models (2) till (4) as well.

We present results for the following tests:

- Models with different number of lagged dependent.
- Model without country pair sector fixed effects.
- Model without country pair sector fixed effects and gravity variables.
- Models with different specifications of the dummies/fixed effects.

Table 85: Sensitivity of effect of energy price on trade with respect to specification of lagged dependent

Nr.	(1)		(2)		(3)		(4)		(5)	
Lags included	0		1		2		4		5	
Variable	Coef	Sign	Coef	Sign	Coef	Sign	Coef	Sign	Coef	Sign
Energy price gap	0,37	**	0,11	*	0,12	**	0,13	**	0,13	**
Exchange rate ratio	0,71	***	0,11	**	0,12	***	0,12	**	0,12	***
Lagged dep. vars.										
lag 1	-	-	0,95	***	0,84	***	0,83	***	0,83	***
lag 2	-	-	-		0,11	***	0,07	***	0,08	***
lag 3	-	-	-		-		0,10	***	0,09	***
lag 4	-		-		-		-0,04	**	-0,04	**

Nr.	**(1)**			**(2)**			**(3)**			**(4)**			**(5)**	
lag 5	-			-			-			-			0,01	NS

Notes:
Significance levels: *** < 1%; ** < 5%; * < 10%; “-“: not included in model; Presamp denotes that presample mean of the dependent variable over the years 1996-2000. These are proxies for the fixed effects; All models are estimated with PPML; All models include year dummies and country pair sector fixed effects.

Table 86: Sensitivity of effect of energy price on trade with respect to different control variables

Nr.	**(1)**			**(2)**			**(3)**			**(4)**	
Model	**With gravity variables**			**No country-pair sect FE**			**No country pair sect fixed effects, with gravity variables and control variables.**			**Different dummies**	
Variable	Coef	Sign		Coef	Sign		Coef	Sign		Coef	Sign
Energy price gap	0,14	*		0,14	**		0,11	*		0,12	**
Control variables											
GDP total	-0,16	*		-			0,00			-	
GDP similarity	-0,10	**		-			-0,00			-	
Relative fact. Endow	-0,01			-			0,03	***		-	
Exchange rate ratio	0,17	***		0,13	***		0,15	***		0,13	***
Gravity variables											
Distance	-0,00						0,03	**			
Contiguity	0,04			-			0,03			-	
Common offical language	-0,02			-			0,01			-	
Lagged dep. Vars.											
lag 1	0,77	***		0,83	***		0,79	***		0,82	***
lag 2	0,05	**		0,06	***		0,06	**		0,06	***
lag 3	0,08	***		0,07	***		0,09	***		0,08	***

Nr.	(1)			(2)			(3)			(4)	
Fixed Effects											
Country-pair sect. FE	Presamp			No			No			No	
Sector fixed effects	Yes			No			Yes			No	
Year FE	Yes			Yes			Yes			No	
Imp & Exp dummies	Yes			No			No			No	
Sensitivity checks											
IMP_EXP_Yr dummies	No			No			No			Yes	

Notes:
Significance levels: *** < 1%; ** < 5%; * < 10%; “-“: not included in model; Presamp denotes that presample mean of the dependent variable over the years 1996-2000. These are proxies for the fixed effects; All models are estimated with PPML.

We observe that the effect of the energy price gap on trade is rather stable, with a value of around 0,11-0,14.

D.5 Estimated ARDL-model

For the ARDL- model, the proposed model to estimate is:

$$trade_{ijst} = EXP\left(\lambda_p \sum_{p=1}^{n} trade_{ijs(t-p)} + \sum_{p=1}^{n} \beta_{1,p}\, epgap_{ijst-p} + \beta_2 reerratio_{ijt-1} + t_d\right)\eta_{ijs} + v_{ijs}$$

With:

$trade_{ijst}$ is the value of annual trade[115] (in USD by country i (in our case: this would be EU27 + UK) from country j (one of the major trading partners) for sector s at time t, and v_{ijs} is the error term.

$CO2pgap_{ijt-1}$ is the lagged difference in the log of the CO_2 price (in USD/ton) (or: log of the ratio of CO_2 prices), for countries *i* and *j* in sector *s* at time t-1[116].

The interpretation of β_{01} is that a 1% rise in the ratio of CO_2 prices of EU27 + UK and its trading partner, lead to a β_{01}% rise in imports.

[115] The variable trade is column of data on imports staked on top of data on exports (both non-negative values). In case the trade concerns exports, the CO2 price gap and Energy price gap are given negative signs.

[116] CO2 price gap does not differ per sector, but only per country/year. This is because the respective ETS’s span multiple sectors with one market price for CO2 Emission allowances.

$Allocation_{ijst-1}$ is an indicator for the share of freely allocated emissions with respect to verified emissions, measured in the lagged difference in the log, for country i (e.g. EU27 + UK) in sector s at time t-1.

The interpretation of β_{02} is that a 1% rise in the ratio of allocated to verified emissions, leads to a β_{02}% fall in imports.

$\sum_{p=1}^{n} trade_{ijs(t-p)}$ (expressed in USD) is the n-years lagged dependent variable. We will test the significance of the lags as well as the sensitivity of our results with respect to the choice of the amount of years of the lagged dependent variable.

$epgap_{ijst-\mathrm{p}}$ is the n-years lagged difference in the log of the energy prices (or: log of the ratio of energy prices), for countries i and j in sector s at time t-1. This variable is based on the energy price index by Sato et al.

The interpretation of β_1 is that a 1% rise in the ratio of energy prices of EU27 + UK and its trading partner, leads to a β_1% rise in imports.

$$reerratio_{ijt} = \ln(reer_{it}) - \ln\,(reer_{jt})$$

The real exchange rate is expressed against the US dollar; we expect the value of a high exchange rate on imports to be positive.

t_d are yearly fixed effects.

η_{ijs} control for time invariant country specific effects, such as distance, common language, common borders, common currency, colonial ties or relatively stable differences in tax regimes or competitiveness.

Notice that this model is relatively similar the concise trade model, but that we add lags of the energy price gap. The number of lags matches the lags of trade.

D.6 Estimated cointegration model

For the cointegration-model, the proposed model to estimate cointains a cointegration relation between the log of trade and the log of the energy price gap.

The model for the cointegration relation is:

$$logtrade_{ijst} = \beta_1 + \beta_2 \log\ epgap_{ijst-1} + \beta_3 Controls$$

With:

$\log trade_{ijst}$ is the log of the value of annual trade[117] (in USD by country i (in our case: this would be EU 27 + UK) from country j (one of the major trading partners) for sector s at time t, and v_{ijs} is the error term.

[117] The variable trade is column of data on imports staked on top of data on exports (both non-negative values). In case the trade concerns exports, the CO2 price gap and Energy price gap are given negative signs.

$logepgap_{ijst-1}$ is the 1-year lagged difference in the log of the energy prices (or: log of the ratio of energy prices), for countries i and j in sector s at time t-1. This variable is based on the energy price index by Sato et al.

For the $Controls$, we ran three different models:

- No controls
- $GDPT_{ijt-1}$
- $GDPT_{ijt-1}+\beta_3 gdpsim_{ijt-1}$

D.7 FMOLS no additional deterministic regressors

Dependent Variable: TRADE_LOG

Method: Panel Fully Modified Least Squares (FMOLS)

Date: 08/12/20 Time: 11:22

Sample (adjusted): 2002-2016

Periods included: 15

Cross-sections included: 3276

Total panel (unbalanced) observations: 33635

Panel method: Grouped estimation

Cointegrating equation deterministics: C

Long-run covariance estimates (Bartlett kernel, Newey-West fixed bandwidth)

Warning: one more more cross-sections have been dropped due to estimation errors

Independent Variable:

EPGAP_LOG_1

Coefficient: -4,22416

Std. Error: 1,95079

t-Statistic: -2,16536

Prob: 0,0304

R-squared: -7,84722

Adjusted R-Squared: -8,85878

S.E of regression: 11,19946

Long-run variance: 1,483759

Mean dependent var: 13,57983

S.D dependent var: 3,566857

Sum squared resid: 3785791

D.7.1 FMOLS with GDP total as additional deterministic regressor

Dependent Variable: TRADE_LOG

Method: Panel Fully Modified Least Squares (FMOLS)

Date: 08/12/20 Time: 11:19

Sample (adjusted): 2002-2016

Periods included: 15

Cross-sections included: 3130

Total panel (unbalanced) observations: 32215

Panel method: Grouped estimation

Cointegrating equation deterministics: C

Additional regressor deterministics: GDPT_1

Long-run covariance estimates (Bartlett kernel, Newey-West fixed bandwidth)

Warning: one more more cross-sections have been dropped due to estimation errors

Independent Variable:

EPGAP_LOG_1

Coefficient: -5,47839

Std. Error: 1,778856

t-Statistic: -3,07973

Prob: 0,0021

R-squared: -8,93474

Adjusted R-Squared: -10,0671

S.E of regression: 11,82223

Long-run variance: 1,409257

Mean dependent var: 13,61118

S.D dependent var: 3,55372

Sum squared resid: 4041731

D.7.2 FMOLS with GDP total and GDP similarlity as additional deterministic regressors

Dependent Variable: TRADE_LOG

Method: Panel Fully Modified Least Squares (FMOLS)

Date: 08/12/20 Time: 11:22

Sample (adjusted): 2002-2016

Periods included: 15

Cross-sections included: 3130

Total panel (unbalanced) observations: 32215

Panel method: Grouped estimation

Cointegrating equation deterministics: C

Additional regressor deterministics: GDPT_1 GDPSIM_1

Long-run covariance estimates (Bartlett kernel, Newey-West fixed bandwidth)

Warning: one more more cross-sections have been dropped due to estimation errors

Independent Variable:

EPGAP_LOG_1

Coefficient: -5,54463

Std. Error: 1,665763

t-Statistic: -3,32858

Prob: 0,0009

R-squared: -6,87337

Adjusted R-Squared: -7,77075

S.E of regression: 10,5245

Long-run variance: 1,519294

Mean dependent var: 13,61118

S.D dependent var: 3,55372

Sum squared resid: 3203107

D.7.3 DOLS with no additional deterministic regressors

Dependent Variable: TRADE_LOG

Method: Panel Dynamic Least Squares (DOLS)

Date: 08/12/20 Time: 11:22

Sample (adjusted): 2002-2016

Periods included: 15

Cross-sections included: 3123

Total panel (unbalanced) observations: 32237

Panel method: Grouped estimation

Cointegrating equation deterministics: C

Long-run covariance estimates (Bartlett kernel, Newey-West fixed bandwidth) used for individual coefficient covariances

Warning: one more more cross-sections have been dropped due to estimation errors

Independent Variable:

EPGAP_LOG_1

Coefficient: 46,93013

Std. Error: 0,854833

t-Statistic: -54,89978

Prob: 0

R-squared: -835,346

Adjusted R-Squared: -1079,8

S.E of regression: 116,5238

Long-run variance: 1,470371

Mean dependent var: 13,60262

S.D dependent var: 3,544401

Sum squared resid: 3,39E+08

Work package 4 – Implications of an adjusted indicator for trade intensity

7 Implications of an adjusted indicator for trade intensity

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7.1 Introduction

The European Commission announced the European Green Deal in December 2019, which proposes to raise the ambition level of the EU's GHG reduction target for 2030 to at least 55 % below 1990 levels (European Commission 2020). This represents a substantial increase compared to the existing target of at least 40 % and this has far-reaching implications for industrial sectors in Europe that will now be required to decarbonise and reach carbon neutrality by 2050. Given that the EU Emissions Trading System (ETS) is the key instrument for reducing GHG emissions from power and industrial sectors, there is a concern from industry that this enhanced level of ambition will lead to an increase in direct and indirect CO_2 costs that may undermine their international competitiveness and result in carbon leakage.[118] To limit the risk of carbon leakage, it was agreed within the revision to Phase IV of the EU ETS to continue to provide free allowances to industry with those sectors deemed at risk of carbon leakage receiving 100 % of their allocation up to the relevant benchmark for free.

Recital 24 of the EU ETS Directive defines carbon leakage as 'an increase in greenhouse gas emissions in third countries where industry would not be subject to comparable carbon constraints' (European Union 2009). In order to prevent carbon leakage, free allocation will be prolonged in Phase IV of the EU ETS up until 2030 with the list of sectors and sub-sectors eligible for support (i.e. receive 100 % of their benchmark allocation for free[119]) revised to target only those at the highest risk of relocating their production outside of the EU. Indeed, the number of sectors and sub-sectors eligible for the carbon leakage list has declined in Phase IV of the EU ETS compared to previous phases of the EU ETS.

In total, 44 sectors and sub-sectors at the NACE 4-digit level have been included in the carbon leakage list for 2021-2030 based upon only the first level assessment (i.e. sectors and sub-sectors with a carbon leakage indicator exceeding a threshold of 0.2) (European Commission 2018). The carbon leakage indicator is now the product of both the trade intensity indicator and the emission intensity indicator whereas in previous years sectors and sub-sectors could qualify for support based upon only one of these indicators.

The European Commission did not consider the policies of non-EU ETS countries to be comparable to those currently implemented by the EU and therefore the first level assessment of the carbon leakage list for 2021-2030 did not adjust the carbon leakage indicator values accordingly to account for any comparable policies implemented by non-EU ETS countries. Despite the difficulty in defining the comparability of effort to address climate change amongst different countries, this decision by the European Commission not to account for the improved efforts of non-EU ETS countries is open to criticism.

The aim of this study is to show the potential impact of adjusting the trade intensity indicator on the number of sectors and sub-sectors that would be eligible for the carbon leakage list for 2021-2030. The following two scenarios were considered in this study:

- **Deduction (comparability) scenario:** The selected non-EU ETS countries do not all embody a comparable level of climate policy ambition to the EU. The share of EU ETS imports from, and EU ETS exports to, each non-EU ETS country that was deducted from the trade intensity calculation was therefore derived based upon the outcome of the comparability scores from Work Package 2 (refer to Section 2.2).

[118] Refers to the situation that may occur if, for reasons of costs related to climate policies, domestic products were replaced by more carbon-intensive imports. This could lead to an increase in global GHG emissions.

[119] Although no cross sectoral correction factor (CSCF) is expected, nevertheless the specific emissions are above the benchmark so that emission allowances still have to be acquired.

- **Deduction (maximum) scenario:** The selected non-EU ETS countries were simply assumed to have climate policies that are equivalent to the ambition of the EU and therefore 100 % of the EU ETS imports from, and the EU ETS exports to, each non-EU ETS country were deducted from the trade intensity calculation.

The methodology applied, including the development of a data tool specifically for this study, will be documented in Section 7.2. The results of the different scenarios for varying the calculation of the trade intensity indicator will then be outlined and discussed in Section 7.3 followed by concluding remarks in Section 7.4.

7.2 Methodology

The development of a data tool for adjusting the trade intensity indicator in this project builds upon previous work undertaken for DG CLIMA to support with the preparation of the carbon leakage list for 2021-2030. In this section, the calculation of the carbon leakage indicator will firstly be outlined, and this will then be followed by a more detailed discussion of the methodology and the publicly available data sources required for calculating the trade intensity indicator. Thirdly, the adaptation of the trade intensity calculation to incorporate the comparable efforts of non-EU ETS countries in a new data tool for this project will then be further outlined.

7.2.1 Overview of carbon leakage indicator

In a previous project undertaken for DG CLIMA, the quantitative assessment of the risk of carbon leakage was carried out for all industrial sectors including mining/quarrying and manufacturing industries. The carbon leakage indicator combines both a trade intensity indicator and an emissions intensity indicator that results in a value to determine the carbon leakage risk status of a sector. The following thresholds were applied in the recent carbon leakage list exercise for 2021-2030:

- Sectors with carbon leakage indicator above 0.2 (Art. 10b para 1);
- Sectors with carbon leakage indicator above 0.15 (Art. 10b para 2);
- Sectors with carbon leakage indicator below 0.2 but above 1.5 for emission intensity (Art. 10b para 2a); and,
- Sectors that are currently included on the list for 2015-2019 (extended to cover also 2020) at the sub-sector level (Prodcom 6 or 8) but would no longer be included (potential MS route). This route is limited to a maximum of 22 sub-sectors.

The assessment covered all countries that participated in Phase III of the EU ETS: the EU-28 and the EEA countries Norway, Iceland and Liechtenstein. The assessment was based on data from the three most recent years available at the time, which were 2013, 2014 and 2015.

7.2.2 Trade intensity

7.2.2.1 Methodology

The trade intensity calculation is defined as the ratio of imports and exports in relation to the domestic market (domestic turnover + imports) in the European Economic Area:

$$TradeIntensity = \frac{Imports + Exports}{Turnover + Imports}$$

The EEA countries were included based on the “bubble approach” which in a nutshell means treating them as any other EU Member State: turnover of EEA countries is added to the EU turnover and trade to/from those countries to the EU is considered internal trade for the purpose of the assessment.[120]

7.2.2.2 Data sources

7.2.2.2.1 Turnover data

Turnover data for the trade intensity calculation can be obtained for the majority of NACE codes from two main sources in Eurostat (Comext[121] / PRODCOM annual sold[122] and Structural Business Statistics (SBS)[123] databases)

- **PRODCOM:** Production data, which is assumed to be equivalent to turnover data by the European Commission, is reported for EU-28, Norway and Iceland at the Comext website based on a list of products called PRODCOM list (about 4500 headings at 8-digit level relating to industrial products). The first 4-digits of the PRODCOM list refer to the equivalent NACE class and the next two digits referring to sub-categories within the Statistical classification of products by activity (CPA). The corresponding classifications are CPA 2008 and CN 2008. The National Statistics Institutes in each reporting country conducts an in-country survey of industrial production and provides the results to Eurostat, who subsequently calculate EU totals and publish the national and EU data together along with related trade data. Production value data is published on the ‘PRODCOM ANNUAL SOLD’ dataset (EUROSTAT 2019c).
- **Structural Business Statistics (SBS):** The SBS provides an alternative source for turnover data, which can be accessed via EUROSTAT (2019a). The SBS covers industry, construction, trade and services and presents data on the structure, conduct and performance of businesses in accordance with the NACE activity classification for the EU-28 and Norway. Iceland is included in the SBS from 2015 onwards. The data within the SBS can be disaggregated to a detailed sectoral level (NACE classification at 4-digit level) and is generally collected by National Statistical Institutes among enterprises through statistical surveys, the business register or administrative sources. Although PRODCOM data can be directly compared with SBS data on turnover, it is important to acknowledge that differences will occur between the datasets as PRODCOM data covers products while SBS data covers companies as a whole. For example, the sum of the value of production goods produced by enterprises classified to a NACE class is not necessarily equal to the turnover reported for that NACE class. Additional (service) activities such as repair, installation and maintenance may also contribute to the turnover of an enterprise.

In light of these difficulties, SBS data was used in this analysis only to fill gaps where no PRODCOM data was available.

[120] Bolscher, H. et al. (2014): Carbon Leakage and Competitiveness Assessment. Final Report to the European Commission, DG Climate Action; Rotterdam.

[121] http://epp.eurostat.ec.europa.eu/newxtweb/

[122] https://ec.europa.eu/eurostat/web/prodcom

[123] https://ec.europa.eu/eurostat/web/structural-business-statistics

7.2.2.2.2 Trade data

Trade data for the trade intensity calculation can be obtained for the majority of NACE codes assessed from the Comext database which is briefly described in the following along with an overview of the coverage of the data source.

- COMEXT: Data on imports and exports, in terms of trade volumes or value, to non-EU ETS countries are published by Eurostat in the Comext database. Trade data is collected for products (rather than industrial sectors) and needs aggregation to be comparable to sectors in the NACE classification. In the Comext database, trade data is provided in different classifications (CN, HS, SITC and BEC). The Combined Nomenclature (CN) classification is the most detailed one; it includes ca. 10,000 eight-digit codes and can therefore be converted to many other classifications. The Comext database also provides trade data per partner country. The trade intensity was calculated based upon the bubble approach, which required the following trade data flows:
  - EU-28 trade with Extra EU-28, Norway and Iceland;
  - Norwegian trade with Extra EU-28 and Iceland;
  - Icelandic trade with Extra EU-28 and Norway.
- There are three data sources within the Comext database which can provide the required information; one per reporting entity:
  - EU Trade since 1988 by CPA_2008 (DS-057009; Comext database): The trade of EU-28 countries with individual partner countries and the overall aggregate (Extra EU-28) is reported in 'EU Trade since 1988 by CPA_2008'. The classification (CPA 2008) can easily be aggregated to NACE rev.2 values as the first four digits are identical in both classifications.
  - EFTA Trade Since 2003 By HS2,4,6 (NO - DS-044225; Comext Database) Norwegian trade (in Euro) is reported in the Comext database, EFTA Trade since 2003 by National Products – NO. The national products classification is based on HS 6-digit which can be attributed to CPA at 4-digit level and thus to NACE at 4-digit level. HS classification is product based and thus service related sectors are not reported.
  - EFTA Trade Since 2003 By HS2,4,6 (IS - DS-044225; Comext Database): Icelandic trade (in Euro) is reported in the Comext database, EFTA Trade since 2003 by National Products – IS. As in the Norwegian dataset the national products classification is based on HS 6-digit which can be attributed to CPA at 4-digit level and thus to NACE at 4-digit level. HS classification is product based and thus service related sectors are not reported.

For the vast majority of NACE codes can be attributed to PRODCOM classification codes in the Comext datasets. However, for several NACE codes further gap filling was required to reflect the availability of data for the EU-28, Norway and Iceland.

7.2.2.3 Data tool

A data tool based upon publicly available data was developed in order to provide alternative values for the trade intensity indicator.

Recital 7 of the revised EU ETS Directive states that the assessment of leakage risk should only consider those trading partners who do not take comparable climate protection measures (European Union (EU) 2018). In the carbon leakage list, EU ETS related imports from and exports to Norway, Iceland and Liechtenstein are therefore excluded from the trade intensity calculation because these countries also participate in the EU ETS. As more countries have committed to take efforts under the Paris Agreement, or are in the process of doing so, this should be taken into account in the assessment of the carbon leakage risk.

In order to better reflect international efforts to reduce GHG emissions, the trade intensity values for each sector and sub-sector were re-calculated in the data tool by deducting the EU ETS related trade of selected non-EU ETS countries whose climate change efforts were deemed comparable to the EU (based upon the outcome of the previous work package). If it could not be established that the climate policies in the EU and the non-EU ETS country embody a comparable level of ambition, different scenarios were worked out and evaluated. The data tool allows for the mapping of partial comparisons, i.e. if a climate policy is significantly less ambitious; a corresponding discount factor is added to take account of trade flows. The following two scenarios were evaluated in this study:

- Deduction (comparability) scenario: The selected non-EU ETS countries do not all embody a comparable level of climate policy ambition to the EU. The share of EU ETS imports from and EU ETS exports to each non-EU ETS country that was deducted from the trade intensity calculation was therefore derived based upon the outcome of the comparability scores from the previous work package (refer to Table 87).
- Deduction (maximum) scenario: The selected non-EU ETS countries have climate policies that are equivalent to the ambition of the EU and therefore 100 % of the EU ETS imports from and the EU ETS exports to each non-EU ETS country were deducted from the trade intensity calculation (refer to Table 88).

The data tool shows how an adjusted trade intensity value could have changed the carbon leakage risk status of a sector or sub-sector compared to the reference case (i.e. the carbon leakage list for 2021-2030)[124] assuming that the emission intensity value remains the same for all sectors and sub-sectors as in the reference case. The results of the data tool are aggregated in order to show the number of sectors and sub-sectors that are excluded from the carbon leakage list if the new average trade intensity values for 2013-2015 under the deduction approach are applied to the carbon leakage calculation. For certain sectors and sub-sectors where annual data is either not available or where the carbon leakage indicator calculated differs from the publication of the carbon leakage list, these sectors and sub-sectors are fixed as in the reference case. The results of the data tool also show the decline in the share of direct emissions that are covered by the carbon leakage list when the new trade intensity values from the deduction approach are applied to the carbon leakage indicator calculation.

7.3 Results

7.3.1 Deduction (comparability) scenario

The following set of criteria was applied in the previous work package to analyse the ambition level of climate policies for industry in the EU and its most relevant industrial trading partners.

- Effective carbon prices;
- Energy efficiency standards;

[124] All carbon leakage indicator values within the data tool have been cross-checked with those published by the Commission.

- Air quality standards and other measures.

An overall weighted score was then calculated for the EU and its most relevant industrial trading partners. For the deduction approach these overall scores were converted into a percentage value relative to the overall score for the EU that then determined the share of EU ETS related trade to deduct for a selected non-EU ETS country. For example, Table 87 shows that the ambition level of climate policies for industry in the USA was assessed to be lower than the EU and therefore it was given a lower overall score relative to the EU. The overall score of the USA was 24 % less than the overall score for the EU, so it was assumed that only 76 % of the EU ETS related trade of the USA was comparable and this was then deducted from the trade intensity calculation. If a country achieved a higher overall score than the EU then 100 % of its EU ETS related trade was deducted. The selected non-EU ETS countries were ranked in order of their impact on the sum of all of the trade intensity values for the 245 sectors assessed when a share of their EU ETS related trade was deducted from the trade intensity calculation relative to the reference case.

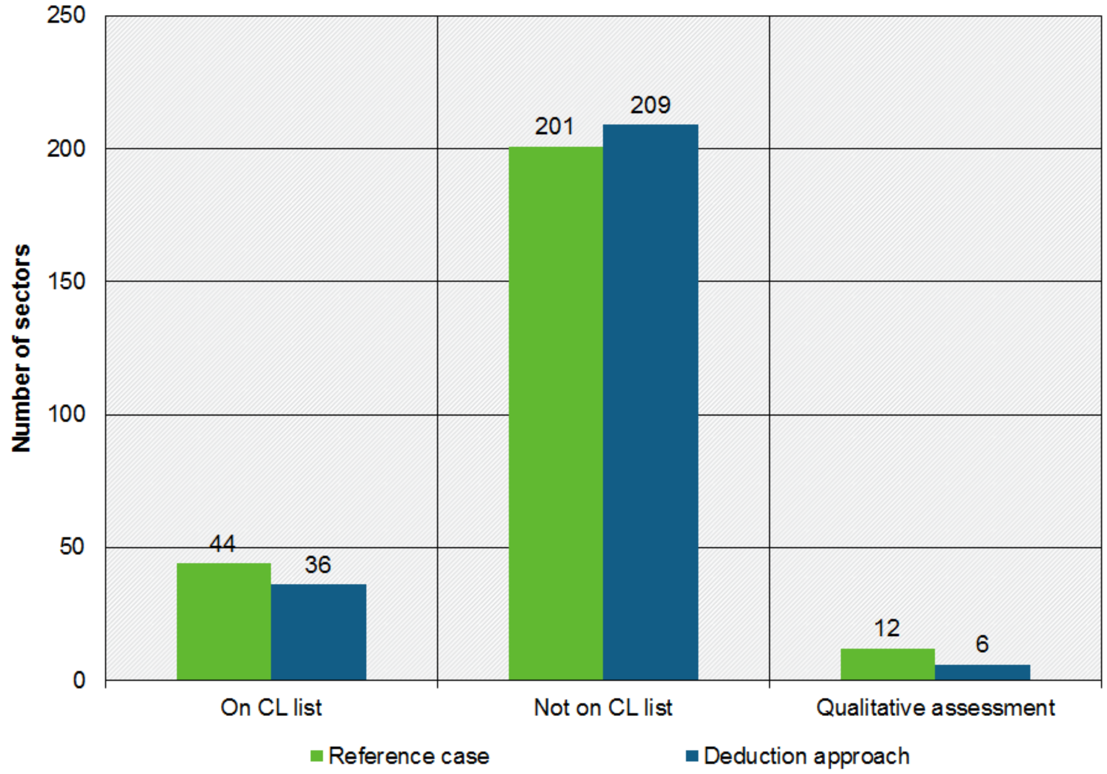
Table 87 Impact of the deduction (comparability) scenario on the trade intensity calculation

Country	Comparability score (share of EU ETS trade to deduct)	Change in aggregate trade intensity value
USA	76 %	-8.2 %
China	53 %	-4.7 %
Switzerland	100 %	-4.5 %
Japan	97 %	-2.2 %
South Korea	100 %	-1.6 %
Russia	31 %	-1.3 %
Turkey	39 %	-1.2 %
India	57 %	-1.1 %
Brazil	33 %	-0.5 %
Singapore	43 %	-0.4 %
Saudi Arabia	31 %	-0.4 %

Source: Own author

Figure 16 illustrates the impact of adjusting the trade intensity indicator value downwards for each of the selected non-EU ETS countries based upon their comparability scores in the previous work package. The number of NACE 4-digit sectors that are eligible for inclusion on the carbon leakage list between 2021 and 2030 (according to Article 10b (1) of the EU ETS Directive) declines from 44 under the reference case to 36 under the deduction (comparability) scenario. This corresponds to a 1.4 % reduction in direct emissions covered by the carbon leakage list between 2021 and 2030. However, three of the eight sectors that would no longer be eligible for the carbon leakage list in accordance with Article 10b (1) under the deduction (comparability) scenario could still remain on the list via a qualitative assessment (refer to Table 89 in the Annex).

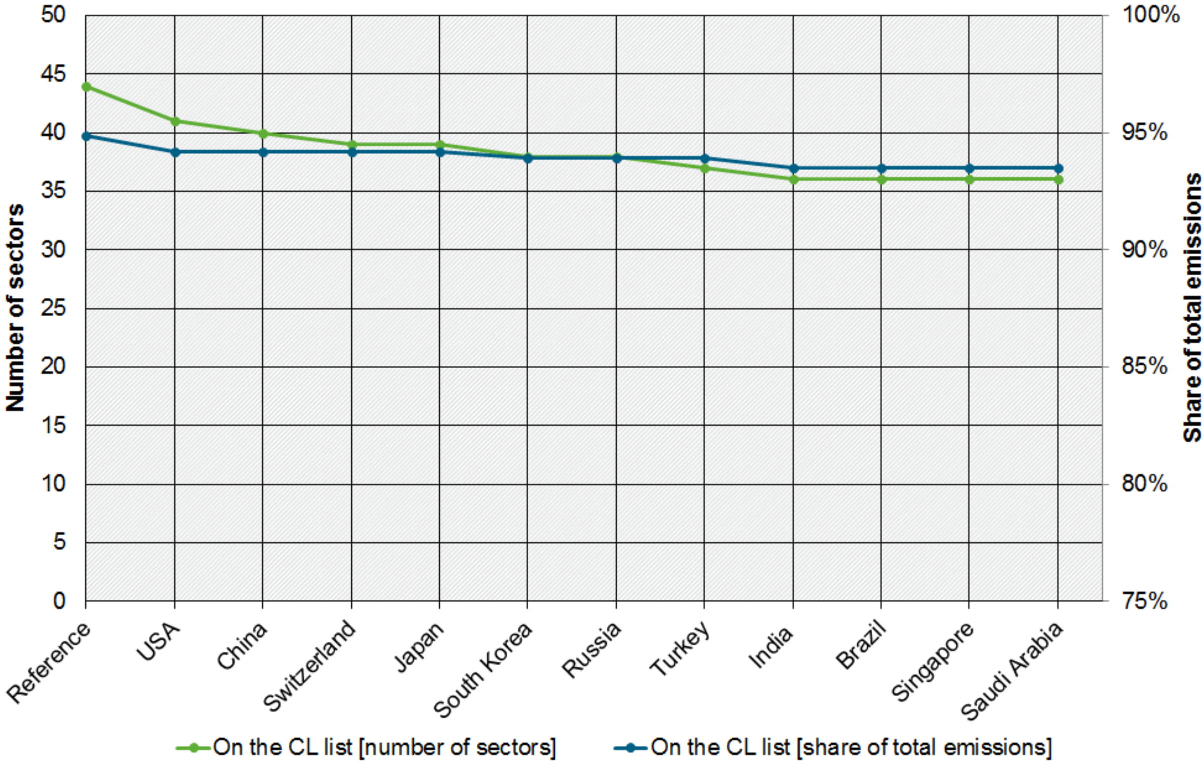
Figure 16 NACE 4-digit sectors on the carbon leakage list under the reference case compared to the deduction (comparability) scenario



Source: Own calculations by the authors (Öko-Institut) based on Eurostat data (COMEXT / SBS)

The number of sectors and direct emissions covered by the carbon leakage list (according to Article 10b (1) of the EU ETS Directive) under the deduction (comparability) scenario are shown in Figure 17, whereby the non-EU ETS selected countries are added cumulatively one by one in order of their impact on the aggregate trade intensity value (refer to Table 87). Figure 17 shows that if 76 % of the EU ETS related trade of the USA would be deducted from the trade intensity calculation, the number of NACE 4 digit sectors that are currently on the carbon leakage list for 2021-2030 (according to Article 10b (1) of the EU ETS Directive) would reduce from 44 under the reference case to 41. The corresponding reduction in the direct emissions covered declines from 94.9 % under the reference case to 94.2 %. The cumulative impact of trading partners such as China and Russia are less influential due to their lower levels of comparability with the EU.

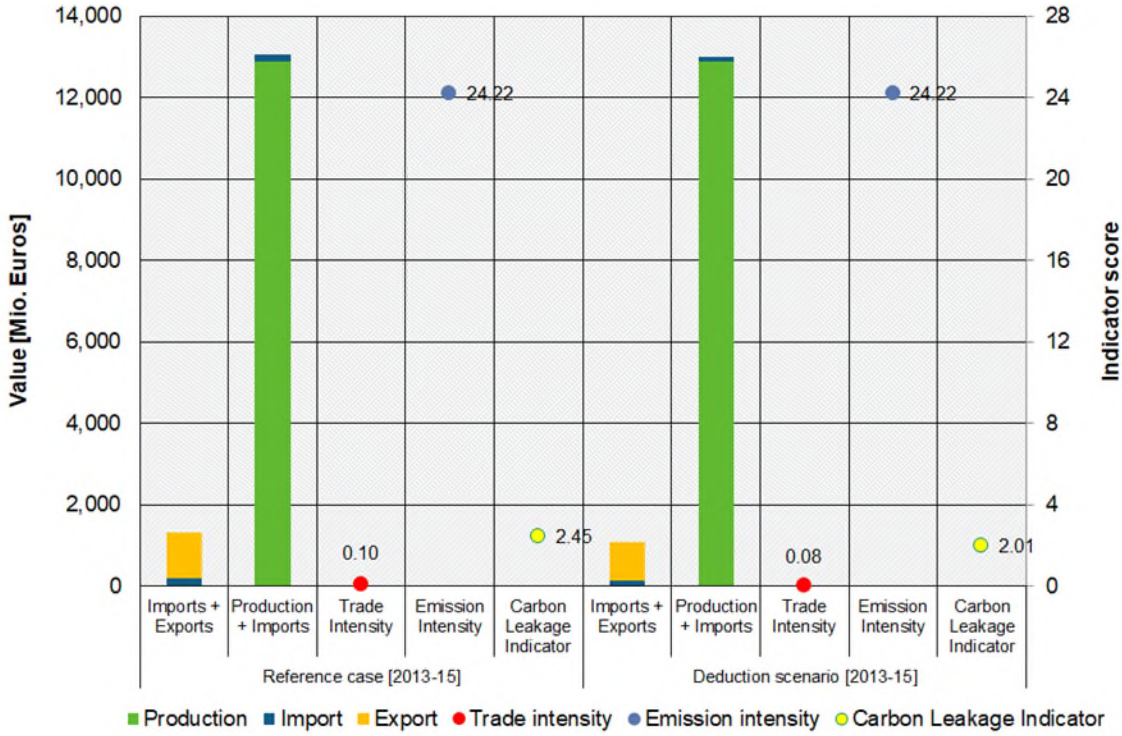
Figure 17 Cumulative impact of the deduction (comparability) scenario on the number of sectors and direct emissions covered by the carbon leakage list



Source: Own calculations by the authors (Öko-Institut) based on Eurostat data (COMEXT / SBS)

The relatively low impact of deducting trade from comparable countries when re-calculating the carbon leakage indicator value underlines the importance of the emission intensity of a sector. Given that the emission intensity remains the same when calculating the carbon leakage indicator in this analysis, only sectors with low emission intensities are at risk of declining below the 0.2 threshold value. For example, Figure 18 shows that for a sector such as cement, which is characterized by a low trade intensity and high levels of domestic production, the impact of deducting trade from comparable countries is low, Indeed, the average 2013-15 trade intensity value for the cement sector would need to reduce from 8 % under the deduction (comparability) scenario to only 0.8 % for it to fall below the 0.2 threshold. This reflects the fact that the relatively high emission intensity of the cement sector is further away from the 0.2 threshold value than for sectors with considerably lower emission intensities.

Figure 18 **Change in the carbon leakage indicator for the manufacture of cement between the reference case and the deduction (comparability) scenario**



Source: Own calculations by the authors (Öko-Institut) based on Eurostat data (COMEXT / SBS)

7.3.2 Deduction (maximum) scenario

Given the uncertainty in assessing the comparability of climate policies in non-EU ETS countries with the ambition of the EU, a sensitivity scenario has been added in this study to determine the maximum potential impact of the deduction approach. This sensitivity scenario assumed that the non-EU ETS countries selected in Table 88 have comparable policies to the EU and therefore 100 % of their EU ETS related trade was deducted from the trade intensity calculation. The non-EU ETS countries have been ranked according to their individual impact on the trade intensity calculation if 100 % of their EU ETS related trade was deducted (i.e. the USA has the largest individual impact on the trade intensity calculation reducing the aggregate trade intensity value by 10.8 %).[125] However, the impact of deducting 100 % of the trade of the countries selected in Table 88 will vary considerably by sector.

Table 88 **Impact of the deduction (maximum) scenario on the trade intensity calculation**

Country	Share of EU ETS trade to deduct	Change in aggregate trade intensity value
USA	100 %	-10.8 %
China	100 %	-9.4 %
Switzerland	100 %	-4.5 %
Russia	100 %	-4.3 %

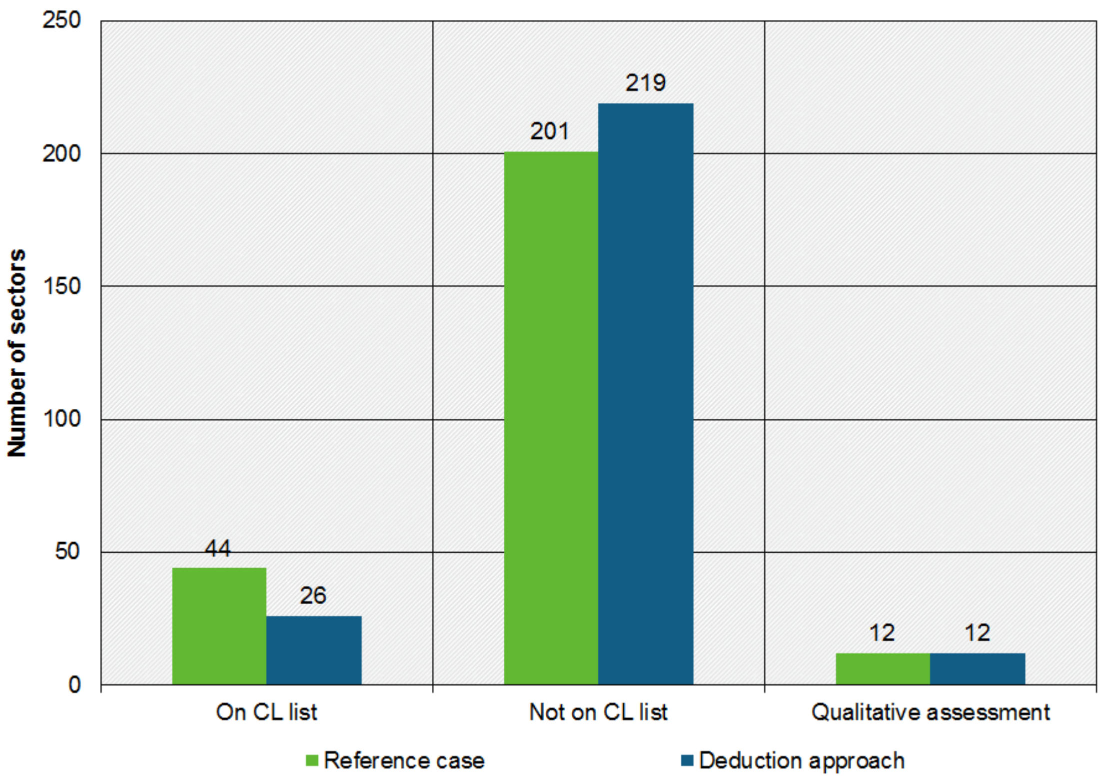
[125] The change in the aggregate trade intensity value refers to the deviation in the sum of the trade intensity values for all of the 245 sectors on the carbon leakage list from the reference case if 100 % of the trade of a selected non-EU ETS country is deducted from the trade intensity calculation.

Country	Share of EU ETS trade to deduct	Change in aggregate trade intensity value
Turkey	100 %	-3.1 %
Japan	100 %	-2.3 %
India	100 %	-1.9 %
Brazil	100 %	-1.6 %
South Korea	100 %	-1.6 %
Saudi Arabia	100 %	-1.3 %
Singapore	100 %	-0.9 %

Source: Own calculations by the authors (Öko-Institut) based on Eurostat data (COMEXT / SBS)

Figure 19 illustrates the impact of deducting 100 % of the EU ETS related trade of selected non-EU ETS countries from the trade intensity calculation. The number of NACE 4-digit sectors that are eligible for inclusion on the carbon leakage list between 2021 and 2030 according to Article 10b (1) of the EU ETS Directive (i.e. with a carbon leakage indicator value above 0.2) declines from 44 under the reference case to 26 under the deduction approach (maximum) scenario. This results in the coverage of direct emissions on the carbon leakage list between 2021 and 2030 declining from 94.9 % under the reference case to 88.4 % under the deduction (maximum) scenario. However, nine of the eighteen sectors that would no longer be eligible for the carbon leakage list in accordance with Article 10b (1) under the deduction (maximum) scenario could still remain on the list via a qualitative assessment (refer to Table 89 in the Annex).

Figure 19 NACE 4-digit sectors on the carbon leakage list under the reference case compared to the deduction (maximum) scenario



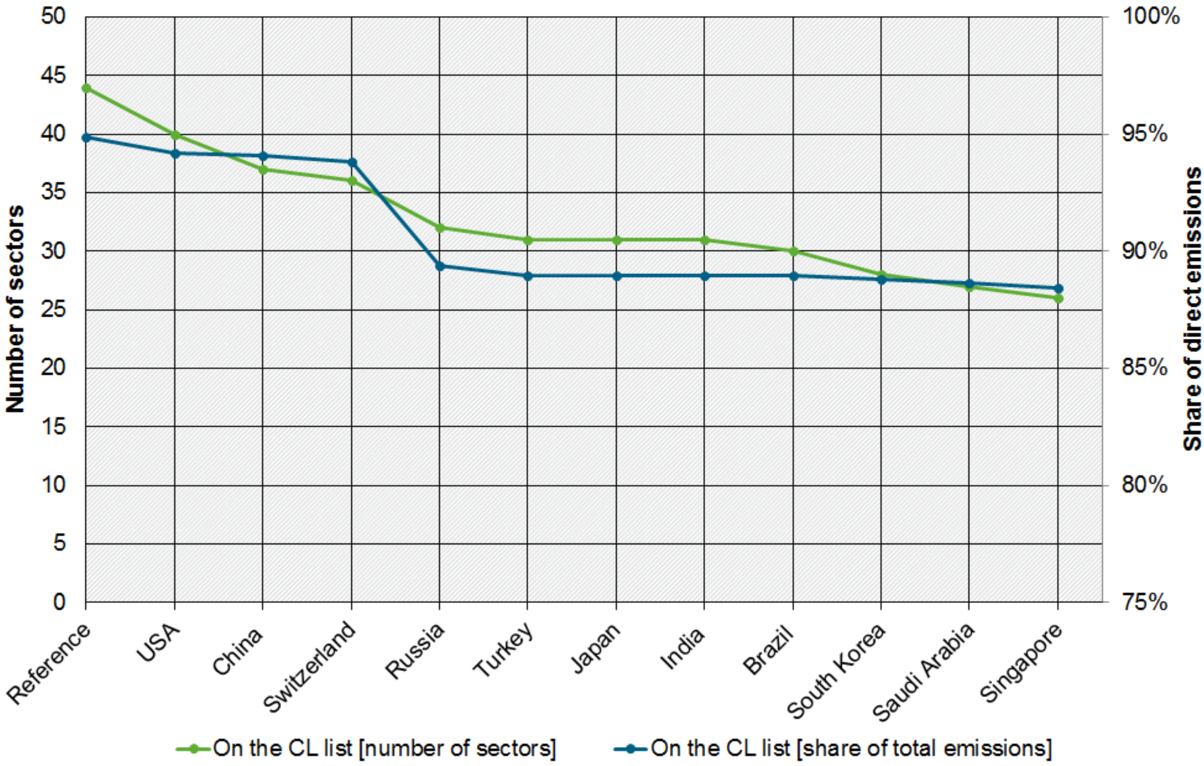
Source: Own calculations by the authors (Öko-Institut) based on Eurostat data (COMEXT / SBS)

The number of sectors and direct emissions covered by the carbon leakage list (according to Article 10b (1) of the EU ETS Directive) under the deduction (maximum) scenario are shown in Figure 20, whereby the non-EU ETS countries selected are added cumulatively one by one in order of their impact on the aggregate trade intensity value (refer to Table 88). Figure 20 shows that if 100 % of the EU ETS related trade of the USA, China, Switzerland and Russia would be deducted from the trade intensity calculation, the number of NACE 4 digit sectors that are currently on the carbon leakage list for 2021-2030 (according to Article 10b (1) of the EU ETS Directive) would reduce from 44 under the reference case to 32. The corresponding reduction in the direct emissions covered declines from 94.9 % under the reference case to 89.4 %.

Interestingly, the deduction of 100 % of the EU ETS related trade of Russia (after already deducting 100 % of the EU ETS related trade of the USA, China and Switzerland) leads to a significant decline (i.e. by a further 4.4 %) in the direct emission coverage of the carbon leakage list for 2021-2030. Given that the extraction of crude petroleum (06.10) accounts for 67 % of the 2013-2015 direct emissions of the eighteen sectors that are no longer eligible for the carbon leakage list (according to Article 10b (1) of the EU ETS Directive) under the deduction (maximum) scenario and that 35 % of the EU ETS average 2013-2015 import value for the sector originates from Russia; this explains why the deduction of the EU ETS related trade of Russia has a relatively high impact on the direct emission coverage.

The cumulative impact of deducting 100 % of the EU ETS related trade of the remaining non-EU ETS countries is less significant in terms of direct emissions, but this still results in six more sectors having a carbon leakage indicator below the 0.2 threshold.

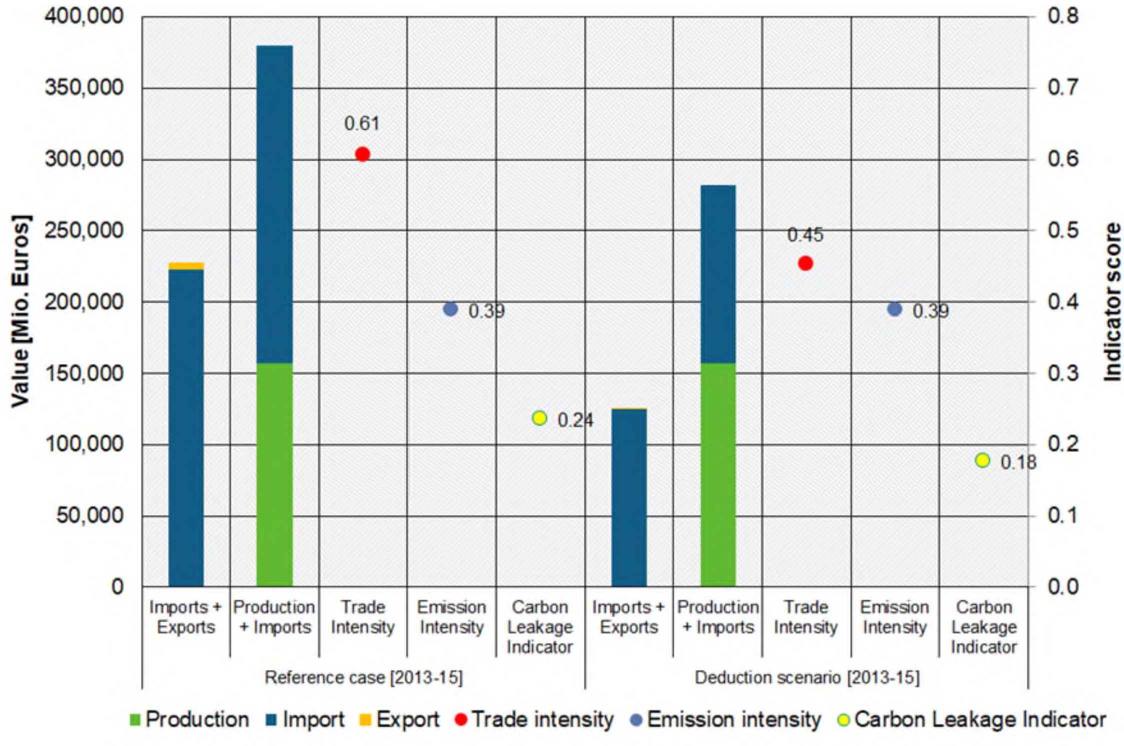
Figure 20 Cumulative impact of the deduction (maximum) scenario on the number of sectors and direct emissions covered by the carbon leakage list



Source: Own calculations by the authors (Öko-Institut) based on Eurostat data (COMEXT / SBS)

Given that the emission intensity remains the same when calculating the carbon leakage indicator in this analysis, only sectors with low emission intensities are at risk of declining below the 0.2 threshold value. However, the deduction (maximum) scenario shows that if trade is deducted from certain countries that currently do not have comparable policies, this may have a significant impact for sub-sectors with high trade intensities. For example, Figure 21 shows that for a sub-sector such as the extraction of crude petroleum, which is characterized by a high trade intensity, the impact of deducting 100 % of trade from the countries in Table 88 regardless of their comparability, results in a change to its carbon leakage status. Indeed, the average 2013-15 carbon leakage indicator value for the extraction of crude petroleum reduces below the 0.2 threshold under the deduction (maximum) scenario.

Figure 21 Change in the carbon leakage indicator for the extraction of crude petroleum between the reference case and the deduction (maximum) scenario



Source: Own calculations by the authors (Öko-Institut) based on Eurostat data (COMEXT / SBS)

7.4 Conclusion

The current carbon leakage assessment assumes that no countries has climate policies comparable to the EU in place. The aim of this study has therefore been to show the potential impact of adjusting the trade intensity calculation (in order to better reflect international efforts to reduce GHG emissions) on the number of sectors and sub-sectors that would, in these circumstances, remain on the carbon leakage list for 2021-2030.

Under the deduction (maximum) scenario it was assumed that the selected non-EU ETS countries (USA, China, Switzerland, Russia, Turkey, Japan, India, Brazil, South Korea, Saudi Arabia and Singapore) all had 100 % comparable climate policies to the EU. The impact of deducting the EU ETS related trade of these selected non-EU ETS countries on the trade intensity calculation resulted in a reduction from the original number of NACE 4-digit sectors and sub-sectors on the carbon leakage list (44) in accordance with Article 10b (1) of the EU ETS Directive to 26. Given that this sensitivity scenario over-estimates the comparability of non-EU ETS country efforts to reduce GHG emissions; in the deduction (comparability) scenario only a proportion of each non-EU ETS country's EU ETS related trade was deducted based upon the outcome of Work Package (refer to Section 2.2). This resulted in 36 NACE 4-digit sectors and sub-sectors still remaining eligible for carbon leakage support (in accordance with Article 10b (1) of the EU ETS Directive).

The study shows that even with a very optimistic assumption under the deduction (maximum) scenario, many sectors and sub-sectors (accounting for a large share of EU ETS emissions) would still remain eligible for carbon leakage support. The high emission intensity indicator values for many sectors and sub-sectors ensure that the overall carbon leakage indicator remains above the 0.2 threshold. Given that the emission intensity indicator is based on average historical values for 2013-15 and may not be updated during the 2021-30 period, this raises the question as to whether the emission intensity indicator provides a true reflection of a sector or sub-sector's risk of carbon leakage as it fails to take into account efforts to decarbonise over the coming decade. Therefore, an adjustment to the carbon leakage calculation, i.e. such as an increase in the carbon leakage indicator threshold value for determining carbon leakage risk, could be an option to further consider in order to respond to the increased climate policy ambition of non-EU ETS countries.

The carbon leakage provisions for 2021-2030 may still be subject to further reform depending upon the outcome of the Global Stocktake under the Paris Agreement, which is scheduled to take place in 2023 and the enhanced level of ambition resulting from the reform to the EU ETS for Phase IV in response to the recent announcement of the European Green Deal. Indeed Article 24 of the revised ETS Directive states that 'measures to support certain energy intensive industries that could be subject to carbon leakage […] should also be kept under review in the light of climate policy measures in other major economies' (European Union 2018). Under consideration would also be whether it is appropriate to 'replace, adapt or complement any existing measures to prevent carbon leakage with carbon border adjustments or alternative measures' (European Union 2018).

7.5 Publication bibliography

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E Annex

Table 89 and Table 90 provide an overview of the NACE 4-digit sectors that would no longer be eligible for the carbon leakage list in 2021-2030 based upon the quantitative assessment under both deduction scenarios.

Table 89 Sectors and sub-sectors that would no longer be eligible for the carbon leakage list under the deduction (comparability) scenario

NACE code	Description	Trade intensity	Emission intensity	Carbon leakage indicator	Direct emissions 2013-15
20.16	Manufacture of plastics in primary forms	0.214	0.867	0.185	2,888,591
23.99	Manufacture of other non-metallic mineral products n.e.c.	0.099	1.136	0.112	2,674,632
16.21	Manufacture of veneer sheets and wood-based panels	0.161	1.093	0.176	1,932,004
24.20	Manufacture of tubes, pipes, hollow profiles and related fittings, of steel	0.301	0.473	0.142	1,384,101
23.19	Manufacture and processing of other glass, including technical glassware	0.278	0.471	0.131	651,583
13.95	Manufacture of non-wovens and articles made from non-wovens, except apparel	0.227	0.614	0.139	96,029
24.31	Cold drawing of bars	0.199	0.707	0.141	24,983
13.10	Preparation and spinning of textile fibres	0.345	0.538	0.185	22,221

Table 90 Sectors and sub-sectors that would no longer be eligible for the carbon leakage list under the deduction (maximum) scenario

NACE code	Description	Trade intensity	Emission intensity	Carbon leakage indicator	Direct emissions 2013-15
06.10	Extraction of crude petroleum	0.562	0.388	0.176	30,155,337
20.16	Manufacture of plastics in primary forms	0.111	0.867	0.097	2,888,591
23.99	Manufacture of other non-metallic mineral products n.e.c.	0.052	1.136	0.059	2,674,632
16.21	Manufacture of veneer sheets and wood-based panels	0.103	1.093	0.113	1,932,004
20.12	Manufacture of dyes and pigments	0.183	1.070	0.196	1,453,240
24.20	Manufacture of tubes, pipes, hollow profiles and related fittings, of steel	0.192	0.473	0.091	1,384,101
23.20	Manufacture of refractory products	0.203	0.929	0.188	1,212,800
23.14	Manufacture of glass fibres	0.088	1.467	0.129	1,164,124
23.19	Manufacture and processing of other glass, including technical glassware	0.151	0.471	0.071	651,583
20.60	Manufacture of man-made fibres	0.168	0.933	0.157	554,046
24.46	Processing of nuclear fuel	0.318	0.592	0.188	516,554
20.17	Manufacture of synthetic rubber in primary forms	0.156	1.096	0.171	366,192
13.95	Manufacture of non-wovens and articles made from non-wovens, except apparel	0.126	0.614	0.077	96,029
24.45	Other non-ferrous metal production	0.473	0.335	0.158	74,466
08.91	Mining of chemical and fertiliser minerals	0.466	0.424	0.198	72,362
05.10	Mining of hard coal	0.437	0.402	0.176	50,319
24.31	Cold drawing of bars	0.095	0.707	0.067	24,983
13.10	Preparation and spinning of textile fibres	0.216	0.538	0.116	22,221