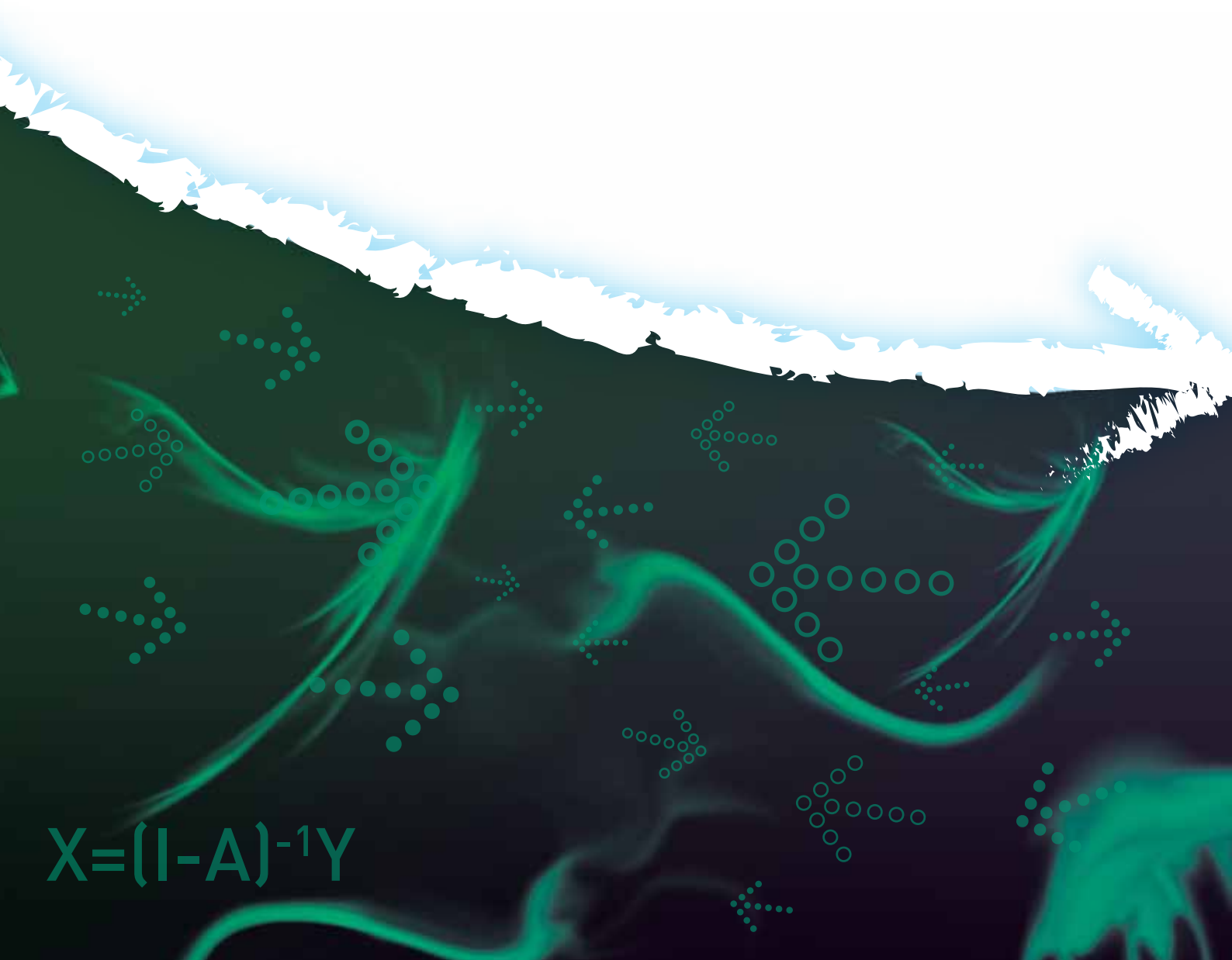
Centre for
Low Carbon Futures
2050

GHG emissions embodied in trade

Is Border Adjustment an appropriate and effective response?



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ABSTRACT

Between 1990 and 2010, developed countries have generally stabilised or reduced their GHG emissions. However, emissions embodied in trade to developed countries have grown rapidly over this time period more than neglecting the reductions achieved.

With no globally comprehensive agreement until 2020, there is a serious concern that the environmental effectiveness of climate policy in developed countries will be compromised. This report explores how to extend the responsibility of developed countries to minimise the effects of emission leakage in the absence of a global agreement between 2012 and 2020, focusing on the application of Border Carbon Adjustments (BCA) within a system of consumption-based GHG accounting.

The report explores the various options available to capture the emissions embodied in trade based on the current political discussions around the issue. In conclusion, it is extremely difficult to devise a system that truly captures a large proportion of emissions embodied in trade due to the complexity of global supply chains. Approximately 95% of the emissions would not be captured if the supply chain emissions embodied in finished products were not included in such a scheme.

A simplified approach is required that could be implemented quickly to ensure the effectiveness of climate policy in developed countries. With limitations in carbon accounting, even the most highly sophisticated BCA could fail to achieve the goal of capturing emissions embodied in trade. The system must consider how to extend responsibility of developed countries to include embodied emissions without having a full product level knowledge of supply chains.

PREFACE

Consumption based emissions are reportedly growing faster than national emissions, partly related to an increasing reliance on imported finished goods. This questions whether a consumption, rather than a production based approach would be more effective in reducing our overall emissions. We need to develop some new thinking on how to account for the GHG emissions embodied in trade to help protect the environmental effectiveness of climate policy.

With this in mind, I approached John Barrett at the University of Leeds to gain a new and hopefully refreshing perspective on possible policy options. Some of John's earlier work has provided fascinating insights on quantifying the levels of carbon in key trade flows. John's good at cutting through the confusion and providing clarity, witnessed by the fact at time of writing, he has just been voted by students at his University as the most Inspirational Teacher for 2011/12. As you read the report I hope you find that it provides that refreshing view, not least because we have also been privileged to receive inputs and advice from some of the most published authors on related issues to ensure we build on existing thinking and research.

There are two specific areas that I hope we have made progress on: firstly, to draw out further evidence and objectively consider the emerging view that "a consumption rather than a production based approach may be as equally relevant in reducing overall emissions". Our insights reveal for the UK a 1% growth in consumption emissions against a decline in territorial emissions for the past 20 years, and in this way the report is able to further the debate on the adequacy of current emissions pricing systems.

Secondly, to provide some new thinking on alternatives to border adjustments. This is clearly needed given many years of unsuccessful attempts to bring the USA into the world of emissions trading and pricing carbon. China depends on both EU and US consumption for their current level of GDP growth, and talk of border adjustments fuel the competiveness debate, causes concern to business and creates tension in international negotiations.

Evolving over the past five years, the 'traditional approach' to managing these issues is the well published analyses of competitiveness and carbon leakage, mitigating impacts through border adjustments, be that taxation or leveling up and down at the border. Of course which national border, and upon which common accounting method remains ambiguous at best, fuelling further tensions. Is there another way? This report aims to develop new thinking on alternative approaches.

This marks our tenth in a series of reports focused on the big issues facing both governments and industry. The Centre for Low Carbon Futures aims to produce useful insights, drawing on evidence based research, led by academics and disseminated at international fora. We complement our University member's aims to deliver impact and increase international recognition.

Jon Price

Director, Centre for Low Carbon Futures

FOREWORD

The international climate negotiations are unlikely to result in global emission targets for this decade, but are more likely to provide frameworks to support national and regional climate policy and mechanisms for their international support. It raises two questions and this report sets out options on how to tackle them:

First, how to formulate national decarbonisation objectives in light of the global carbon footprint of internationally traded goods? Should countries with an increasing carbon footprint of their imports, typically OECD countries, compensate the emission increase with more stringent mitigation action in other sectors? Or should such countries encourage consumers to substitute carbon intensive products, both domestically produced and internationally imported, with lower-carbon alternatives?

Secondly, how to implement national policies to reduce carbon intensity of products that can be globally traded. The focus is typically on the carbon price, as it creates market opportunities and incentives for lower carbon alternatives along the often complex production chain. However, a clear and strong carbon price for the production of internationally traded products is often seen to create risks for re-location of production and investment. The question is how to avoid that these concerns result in low carbon prices and in tax exemptions or free allocation of allowances?

These two questions are often discussed separately. What is unique about this new report is that it provides a timely contribution by evaluating policy options from the perspective of both sets of questions.

Addressing questions on embedded carbon is linked to issues of international trade and can thus easily result in heated discussions on the appropriate economic paradigm or concerns that national specificities and experiences are not respected. The report makes three contributions towards a constructive discussion. First, it summarises and clearly structures the variety of arguments in the discussion. Second, it provides numbers to illustrate the relevance of the effects. Third, it integrates perspectives from different countries, including a study commissioned in India.

The focus of the report – which seems very appropriate for the Centre for Low Carbon Futures – is on policy options that can support the low carbon transformation of industry. The policies will be all the more credible for investors and thus effective in accelerating the low-carbon transformation, where they can be designed so that nations that implement more stringent policies are not discouraged by negative trade effects. However, it will be essential to retain this positive approach, and to avoid temptations to use trade related measures as a tool to pressure countries into pursuing more stringent climate policies.

The report provides some guidance on how to succeed in this process – through close cooperation among policy analysts and experts across countries and with their respective policy makers, to develop a shared perspective on the different options based on evidence, numbers and understanding of national specificities. The urgency for such an effort is confirmed by press statements of the newly appointed French industry minister calling for a carbon tariff. To avoid that such an initiative triggers fierce responses, it needs to be embedded in an international dialogue that ensures that any measure jointly addresses climate, economic and development objectives. A concrete discussion based on the example of simple products like clinker and cement might provide both a platform to build such understanding and trust, and could be the starting point for gradual progress.

Karsten Neuhoff

Head of Department for Climate Policy, German Institute for Economic Research (DIW Berlin)

KEY POLICY INSIGHTS

Numerous publications highlight the need for global emissions to peak by 2020 to have any chance of achieving a two degree emissions target. The contribution to cumulative emissions now and in the future demonstrates the leadership role required of developed countries.

While emissions in many developed countries have either reduced or stabilised since 1990, consumption-based accounting has demonstrated that the increases in consumption is a key driver of emissions in rapidly developing and least developing countries. The concept of "common but differentiated responsibility" has been interpreted as established targets for developed countries and no targets for others. However, under the Kyoto Protocol this resulted in territorial emission reduction being lost as emissions from imports were greater than the reduction achieved. Added to this, numerous studies demonstrate that current territorial commitments will simply not be sufficient.

There is clearly a need for the concept of "common but differentiated responsibility" to be interpreted as more than having or not having a target. One approach is to extend the responsibility of emissions of developed countries to include their consumption-based emissions as well as the emissions that occur within the territory of the country.

This report explores one approach, border GHG emissions adjustments, to assess whether it has application in extending the responsibility of developed countries to take account of the emissions associated with consumption. It explores the importance of specific design elements of a BCA in an effort to ensure that such a scheme would capture the emissions of imports already priced domestically. The key insights for policy makers are:

1. CONSUMPTION BASED EMISSIONS GROWING FASTER THAN NATIONAL EMISSIONS

By 2020, for the majority of developed countries, emissions embodied in imports to satisfy consumption will be higher than that emitted within the country. For example, the UK's territorial emissions are declining by approximately 1% a year, while from a consumption-based emissions perspective they are increasing by 1% a year. At present climate policy in developed countries is almost entirely dominated by changes in domestic technology and emissions embodied in imports undermines the environmental effectiveness of climate policy.

Currently only 11% of global emissions are priced. If the imports were captured related to priced commodities to countries with trading schemes, this would double to 22%, demonstrating the huge greenhouse gas mitigation potential by extending responsibility to a consumption-based approach.

There is little doubt that there needs to be a scheme to address the issue of emissions embodied in trade. Without such a scheme, emission reduction targets by developed countries between 2012 and 2020 could be completely undermined by imports.

RECOMMENDATION: USING BORDER GHG EMISSIONS ADJUSTMENTS TO EXPAND THE RESPONSIBILITY OF DEVELOPED COUNTRIES FROM EMISSIONS TO SATISFY CONSUMPTION IS ONE WAY TO CAPTURE THE EMISSIONS EMBODIED IN IMPORTS, HOWEVER THERE ARE A NUMBER OF ISSUES TO OVERCOME AND SIMPLIFIED SYSTEMS THAT ARE FOCUSED ON CLIMATE MITIGATION AND SPEED OF IMPLEMENTATION ARE THE BEST WAY FORWARD.

2. GHG EMISSIONS IN FINISHED PRODUCTS MUST BE ACCOUNTED FOR

INSIGHT: Without truly accounting for embodied emissions in the finished product, as opposed to capturing the emissions related to the raw materials currently priced, our analysis shows that 95% of the emissions would be lost. By way of example, European countries don't import electricity from China, but the emissions from Chinese electricity are embodied in many of the products consumed. These would only be captured through understanding the complete supply chain emissions of finished products.

No GHG emissions accounting can accurately and robustly measure the emissions associated with individual products taking into account global supply chains and individual country efficiencies at a low cost. While many of the methodological challenges to achieve such a system are known, the data is not available now and most likely not in the future.

RECOMMENDATION: A SIMPLIFIED SCHEME THAT OVERCAME THE COMPLEXITIES OF ESTABLISHING THE EMBODIED EMISSIONS IN FINISHED PRODUCTS IS REQUIRED. CONSIDERABLE TIME AND EFFORT COULD BE WASTED IN DERIVING SUCH A SYSTEM THAT WOULD NOT TRULY CAPTURE THE EMBODIED EMISSIONS IN TRADE.

3. LEAST DEVELOPED COUNTRIES CAN BE EXEMPT FROM BORDER ADJUSTMENTS

INSIGHT: Excluding LDCs would make no difference to the effectiveness of border GHG emissions adjustment. The results suggest that the impact of excluding LDCs would be small as imports from LDC's only represent 1% of emissions embedded in imports. Excluding traded flows considered not to be material has more of an impact, but still 73% of the relevant export emissions would be captured.

RECOMMENDATION: BY EXCLUDING LDCS WOULD ALLOW ROOM FOR THEIR DEVELOPMENT WHILE NOT UNDERMINING THE ENVIRONMENTAL EFFECTIVENESS OF DEVELOPED COUNTRY CLIMATE POLICY. HOWEVER, EXCLUDING LDCS RISKS DISTORTING INVESTMENT AND TRADE FLOWS AND EXCLUDING NON-MATERIAL FLOWS WOULD LEAVE THE SYSTEM MORE OPEN TO LEGAL CHALLENGE WITHIN THE WTO.

4. A COMPLEX MATRIX OF BORDER GHG EMISSIONS ADJUSTMENTS COULD BE COUNTERACTIVE AND FAIL TO CAPTURE ALL THE EMISSIONS EMBODIED IN TRADE.

INSIGHT: Time is of essence. A simplified approach is required that could be implemented quickly to ensure the effectiveness of climate policy in developed countries. With limitations in GHG emissions accounting, even the most highly sophisticated BCA could fail to achieve the goal of capturing emissions embodied in trade. While issues of investment leakage are important, it is an imperative not to lose sight of global mitigation goals.

The design of a mechanism has to take on some extremely important elements. Primarily, the key message is **simplicity**. The system must consider how to extend responsibility of developed countries to include embodied emissions without having a full product level knowledge of supply chains.

RECOMMENDATION: SUCH A SYSTEM COULD EITHER MAKE A DOMESTIC ADJUSTMENT TO AN EXISTING SCHEME. FOR EXAMPLE, THE EU ETS COULD TAKE A CONSUMPTION-BASED APPROACH AND ADD THE IMPORTED EMISSIONS INTO THE SCHEME WITHOUT ADJUSTING THE CAP. THIS WOULD HAVE THE ADDED BENEFIT OF DRIVING INNOVATION IN LOW GHG EMISSIONS TECHNOLOGIES AND PROVIDING A CLEAR SIGNAL TO THE CONSUMER THROUGH A CHANGE IN PRICE. THE ADDITIONAL REVENUE COULD BE USED TO FUND INTERNATIONAL CLIMATE MITIGATION SCHEMES THAT WOULD RESULT IN A REDUCTION IN EMISSIONS OF IMPORTS.

1. EXECUTIVE SUMMARY

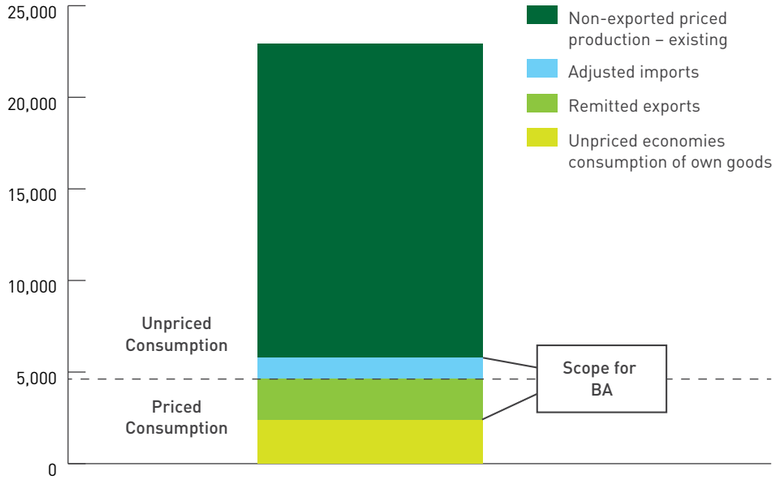
Numerous publications highlight the need for global emissions to peak by 2020 to have any chance of achieving a two degree emissions target. The contribution to cumulative emissions, now and in the future, demonstrates the leadership role required of developed countries to acheive this goal.

This report explores how to extend the responsibility of developed countries to minimise the effects of emission leakage in the absence of a global agreement between 2012 and 2020, focusing on the application of Border Adjustments within a system of consumption-based GHG accounting.

The GHGs embodied in the trade of goods and services has been increasing at a rate of around 6% per year for the past 20 years. Not only is global trade growing at a faster rate than global GDP, but also the countries which often have the most GHG intensive production are expanding quickly, while manufacturing in countries with a limit (or 'cap') on their GHG emissions have typically remained stable. These issues together undermine the present territorial system of accounting for GHGs as policy efforts by some countries to reduce global emissions are being undermined by consumers in these countries importing good from outside these systems of control (i.e. system leakage). System leakage takes two forms. Strong system leakage occurs as a result of the climate change policy; whereas weak system leakage represents the flow of embodied GHGs into the system with climate policy.

Peters et al. (2011) demonstrated that the volume of emission reductions made by countries with a legally binding agreement during the period of the Kyoto Protocol were lost through system leakage. Although there is insufficient evidence for this to represent strong system leakage, such pressures act to limit the scope that governments who have committed to reduce their GHG emissions have to control all of the GHGs emissions associated with their citizens. The outcome from the Conference of the Parties (COP) in Durban means that this situation is set to perpetuate for a further eight years.

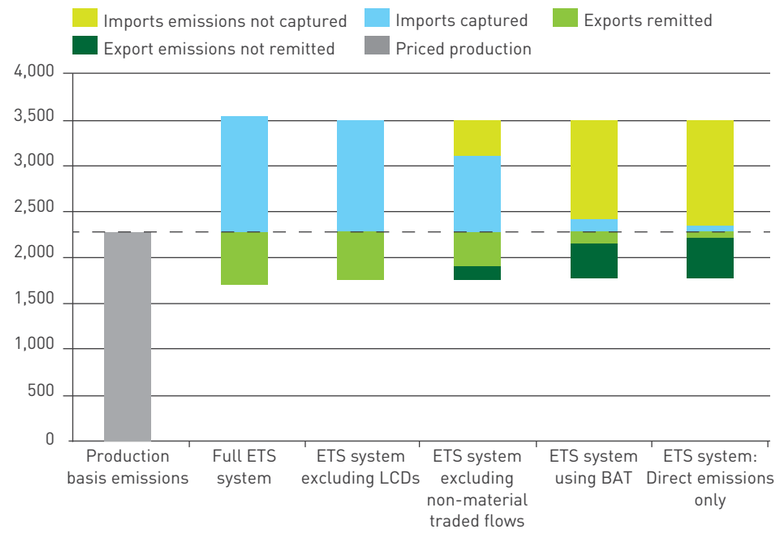
Figure 1: The present scope for Border Adjustment - $MtCO_2$



Based on 2004 data.

The results are for all existing GHG pricing assuming a EU ETS design. The results are presented as a series of sensitivities based on 2004 data.

Figure 2: The volume of emissions captured due to Border Adjustment design element: Extending existing trading schemes – $MtCO_2e$



The hypothetical volume of GHG emissions which could be involved in a Border Adjustment scheme within the Kyoto system, is considerable at 9,383 MtCO2e or 29% of global industrial emissions including emissions from goods exported from Annex I countries that could potentially have remittance payments under certain system designs. However, only 11%[1] of global industrial emissions are being emitted within a pricing mechanism. A further 11% of emissions are embodied in imports to a country with a trading scheme related to the priced commodities (such as electivity, cement, steel, aluminium etc (see figure 1).

The project team modelled the impact of introducing a number of the key design elements related to Border Carbon Adjustments. The results are presented in Figure 2 in the form of a series of variation in the design of a Border Adjustment system implemented for the existing GHG emissions trading systems.

The results suggest that the impact of excluding Least Developed Countries (LDCs) would be small as imports from LDCs only represent 1% emissions embedded in imports. Therefore, from an emissions perspective, it would be appropriate to exclude LDCs from a scheme, giving additional room for development. Excluding traded flows considered not to be material[2] has more of an impact, but still 73% of the relevant export emissions would still be captured.

The most important design element that would affect the level of emissions captured relates to direct and indirect emissions. Direct emissions refer to emissions associated with the import of raw materials, such as steel or aluminium, without including any emissions that occur through the supply chain in their production. The reality being that European countries don't import electricity from China but finished products that have emissions from electricity in their production. If the full supply emissions are not included, 95% of emissions are lost, rendering the system ineffective.

In conclusion, countries attempting to use pricing mechanisms, such as a trading scheme, only capture 50% of the emissions associated with the consumption of the priced commodities. They account for 11% of global emissions; a further 11% is imported that is not captured. It is essential that mechanisms to mitigate these emissions are considered. The responsibility sits firmly with the developed countries from the perspective of cumulative emissions, per capita emissions and the ability to act to achieve emission reductions.

However, by not capturing the embodied emissions through the supply chain associated with finished products, 95% of the emissions embodied in imports would not be included in the scheme. Currently, while there are a number of models that can, with some precision, understand the emissions embodied in the imports of large product groups, there is no system that can accurately and robustly measure the emissions associated with individual products taking into account global supply chains and individual country efficiencies at a low cost.

Therefore, the design of a complex scheme of Border Adjustments of GHG emissions could be counteractive as it would, most likely, not capture the carbon embodied in imports. The design of a mechanism has to take on some extremely important elements. Primarily, the key message is simplicity. The system must consider how to extend responsibility of developed countries to include embodied emissions without having a full product level knowledge of supply chains.

Such a system could either make a domestic adjustment to an existing scheme. For example, the EU ETS could take a consumption-based approach and add the imported emissions into the scheme without adjusting the cap. This would have the added benefit of driving innovation in low carbon technologies and providing a clear signal to the consumer through a change in price. The additional revenue could be used to fund international climate mitigation schemes that would result in a reduction in emissions of imports.

[1] Calculated based on total 2004 global emissions of GHGs being 32,301 MTCO2e

[2] In the failed Waxman-Markey bill had a range of materiality clauses but the main one assumes materiality to represent more than 0.5% of total global GHG emissions and less than 5% of United States imports of covered goods with respect to the eligible industrial sector.

2. INTRODUCTION

2.1 THE ISSUE

The Kyoto Protocol was adopted in 1997 as a key policy response by the international community to tackle the issue of climate change. It included targets for some countries but not all, under the notion 'of common but differentiated responsibilities'. However, this agreement has not eliminated the growth in global emissions. Between 1990 and 2010, global emissions grew by 40% and the growth rate in the later years was faster than the previous 10 year (Peters et al, 2010). In this sense, while the Kyoto Protocol has been in place, global emissions have gone up and are growing at a faster rate. In fact, the highest annual growth rate in emissions occurred between 2009 and 2010, amounting to nearly 6% (Peters et al, 2010).

Additionally, global trade is growing faster than global GDP. Between 1990 and 2008, world trade has almost tripled, growing by 6% a year on average. The growth of world gross domestic product (GDP) was significantly slower, with 3.1% per year on average. The ratio of world exports of goods and commercial services to GDP in real terms has increased steadily since 1985, and increased by nearly one-third between 2000 and 2008. However, it decreased in 2009 as world trade fell as a result of the Global Financial Crisis (WTO, 2010).

A tonne of GHG emission has the same radiative force irrespective of where it is emitted. Therefore, the fact that no global agreement has been in place has led to a situation where climate change mitigation policies in some countries has potentially been undermined by the growth in emissions in others. The GHGs embedded in traded goods has been increasing. In 1990, the global carbon dioxide emissions associated with exported products was 4.3 Gt CO_2 (Peters et al, 2011). In 2008, this figure was 7.8 Gt CO_2, an increase of 62% between 1990 and 2008 and an average annual increase of 4.3% (Peters et al, 2011).

There is the added concern that the countries with the most GHG emission intensive production are expanding quickly, while manufacturing in countries with a GHG cap as introduced under the Kyoto Protocol have tended to remain stable. One of the consequences of international trade has been an increase in production in emerging economies such as China, Russia and India. In these countries, the GHG emission intensity of goods (measured as CO_2/$) tends to be higher than many of the countries that ultimately consume the goods and services (Davis and Caldeira, 2010). Whilst much of this expansion has been driven by lower labour rates in these emerging economies, this still represents a leakage from the present regime of accounting for GHG emissions. In this sense, Peters (2010b) distinguishes two categories of system leakage; weak and strong leakage:

- Weak system leakage relates to the flow of embedded GHG emissions into a system irrespective of a specific government policy.
- Strong system leakage refers to an increase in global emissions due specifically to climate policy.

There is clear evidence for the occurrence of weak system leakage but less evidence for the existence of strong system leakage at today's GHG emissions prices. However, both forms of leakage limit the political opportunity of Annex B governments to take the kind of far reaching future actions on climate change that are thought necessary.

Added to this, there is considerable evidence to suggest that time is running out to ensure that cumulative emissions do not exceed a level that would result in a two degree temperature rise.

2.2 WHAT ARE THE PROSPECTS FOR THE NEAR FUTURE?

The conclusions of the Conference of the Parties (COP) in Durban means that there will be no comprehensive global agreement in place until 2020, and even then it is not assured that this would lead to an agreed reduction in global emissions. Therefore, there is a period between 2012 and 2020 where there are no measures in place to mitigate emission leakage; thereby potentially undermining climate policy in Annex B countries. Peters et al (2011) demonstrated that the reductions made during the period of the Kyoto Protocol by countries with legally bindings agreements were lost through system leakage. We now face another eight years where this situation will continue and potentially hamper efforts to limit global temperature to two degrees.

2.3 AIM OF THIS STUDY

This study explores how to extend the responsibility of developed countries by minimising the effects of system leakage of GHG emissions in the absence of a global agreement between 2012 and 2020. It focuses on the application of Border Adjustments within a system of consumption-based accounting for GHG emissions and aims to:

Quantify the reduced level of GHG emissions captured when different design elements are introduced to constrain the system of border adjustments.

As background to this, the project explores the following question:

"Can current GHG emissions trading schemes in Annex B countries be extended to include the GHG emissions embedded in imports in an effort to minimise the negative consequences of system leakage[4]?"

In doing so, it explores the legal justification for the various motives for introducing Border Adjustment, but does not set out to provide a definitive legal opinion.

[3] Note, not all Border Adjustment schemes would include export adjustment.

[4] Note this this includes all forms of leakage and not just investment leakage.

2.4 STRUCTURE OF THE REPORT

The remainder of this report is structured as follows:

- **Section 3: 'Ways of accounting for GHG emissions'** introduces ways of accounting for GHG emissions and how the different accounting approaches can lead to very different conclusions about a country's emissions.
- **Section 4: 'Responses to carbon leakage'** identifies how Annex B countries have responded to the Kyoto Protocol and explores Border Adjustments of GHG emissions responds to this situation.
- **Section 5: 'Methodology and Analysis'** presents the various methods used to undertake the analysis, which focuses on extending the current trading schemes to account for more consumer emissions.
- **Section 6: 'Results of the analysis'** presents the outcome of the examination focusing on sensitivities for the volume of GHG emissions that might be captured when certain elements constrain the design of the Border Adjustment regime.
- **Section 7: 'Recommendations and Further Research'** concludes from the analysis and proposes some recommendations and a number of areas of future research.
- **Section 8: 'Annexes'** contain detailed descriptions of the MRIO model, tables of numbers used to generate the graphics and further results.

3. WAYS OF ACCOUNTING FOR GHG EMISSIONS

There are three main ways in which GHG emissions can be allocated to countries:

1. **Territorial-based** emission inventories are the basis of the UNFCCC regime. The UNFCCC methodology accounts for all emissions emitted from a country's territory, but do not consider those emissions related to international aviation and shipping.
2. **Production-based** emission inventories report GHG emissions based on the system of economic activities in line with Gross Domestic Product (GDP). Under this system, international aviation and shipping are typically allocated to countries based on the operator of the vessel.

- **Consumption-based** emission inventories allocate emissions to the consumers in each country. There is no standard and internationally agreed methodology to estimate these. They are usually based on final consumption, which means that exports are subtracted from domestic emissions and imports are added (Peters, 2008). Consumption-based emissions are currently not reported officially by any country, but they are increasingly estimated by researchers (see reviews by Wiedmann et al., 2007 and Wiedmann, 2009b).

3.1 ILLUSTRATION FROM A UK PERSPECTIVE

From a climate change mitigation perspective, how emissions are accounted for is important, as different allocations may give preference to different mitigation strategies. This issue is illustrated by using these three systems to account for UK recent emissions. The case of the UK has been used to illustrate this as it represents an economy with particularly high levels of system leakage. Wiedmann and Barrett (2011) undertook such an analysis looking back to 1990. The results are shown in Figure 3.

Figure 3 illustrates the potential scale of variation that can emerge between territorial and consumption-based emissions. In this case, the UK's economic structure has focused on lowering its emitting activities, but its citizen's consumption has pushed emissions up. Figure 3 shows that:

- From a territorial perspective, the UK GHG emissions reported to the UNFCCC have shown a 19% reduction between 1990 and 2008, representing an annual decline of around 1% a year. On this basis, the UK Government has achieved its target established under the Kyoto Protocol.
- From a production perspective, there has been a 14% reduction (blue line in Figure 3). Explaining the difference with the UNFCCC territorial estimates is those production GHG emissions that were not accounted for under the Kyoto Protocol have doubled between 1990 and 2008.
- From a consumption perspective, there has been an increase in GHG emissions in the UK. In 2008, consumer GHG emissions were 20% higher than 1990. The UK's GHG emissions from a consumption perspective are rising at a rate of over 1% a year.

This has created a consumption-based 'GHG emission trade deficit'. The GHG emissions embodied in imports in order to satisfy UK consumption were greater than emissions due to domestic production (Barrett and Minx, 2011). Looking forward, this deficit is set to increase in the UK at least, where by 2050 domestic emissions could represent fewer than 20% of the UK's consumption-based emissions (see Barrett el al 2011d).

Not all countries have experienced this situation to this degree, and of course there are corresponding 'GHG emission trade surpluses' in many countries. Recent work (Peters et al, 2010) has identified that 22% of carbon emissions in developing countries were created during the production of goods that were consumed by citizens in developed countries (shown in Figure 4).

3.2 THE IMPACT OF ACCOUNTING APPROACH ON KEY EMITTERS

Peters et al (2010) explored the growth difference between consumption-based and territorial-based CO_2 emissions since 1990 for the top ten emitters. This difference was found to be the largest for the UK, with a 23% growth difference in 2008 from 1990, compared to 8% for the US and 7% for Canada. There were of course countries where territorial-based CO_2 emissions where greater than consumption-based emissions, most notably China where the difference was found to be nearly -47%.

Figure 3: Comparison of UK consumption-based GHG emissions with territorial GHG emissions from 1990 to 2008

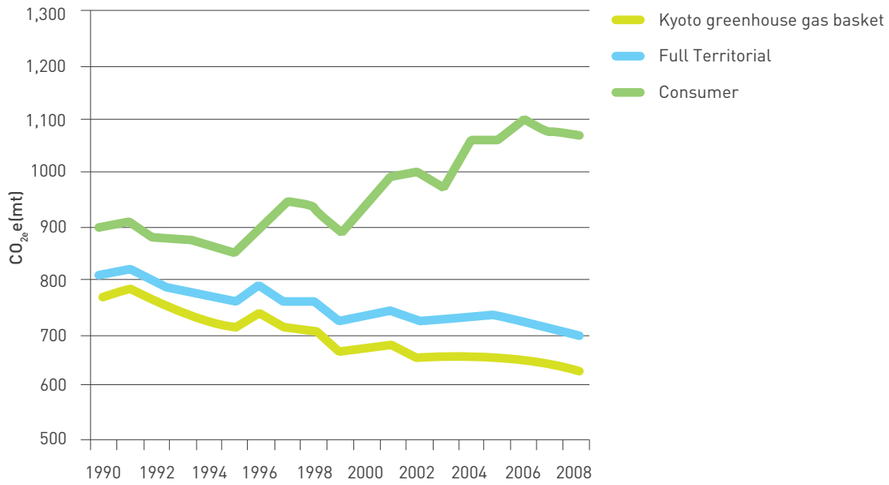
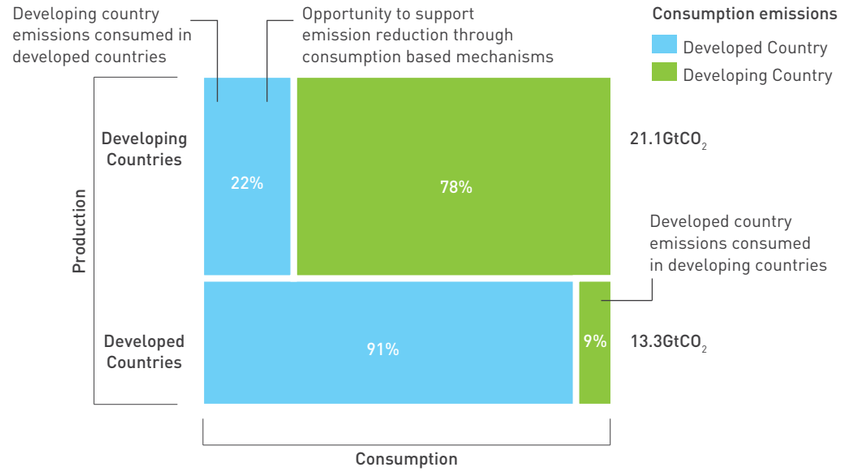


Figure 4: Carbon trade balance between the developed and developing countries



Note: Excludes household emissions (which occur in country of production, irrespective of production or consumption perspective)

Source: Carbon Trust Analysis; CICERO/SEI/CMU GTAP7 MRIO/EEBT Model (2004)

4. RESPONSES TO SYSTEM LEAKAGE OF GHG EMISSIONS

4.1 EXISTING RESPONSES TO THE KYOTO PROTOCOL AND SYSTEM LEAKAGE OF GHG EMISSIONS

Under the UNFCCC system of territorial accounting, some Annex B countries and regions have introduced policies that effectively place a cost on industrial sectors emissions of GHGs, either via taxes on GHG emissions or trading schemes. Within a closed system, these should provide an incentive to producers to reduce their emissions and consumers to reduce their consumption due to the increased prices of GHG emission intensive products. However, we live in an ever-increased globalised world where trade introduces the prospect of leakage from such systems, potentially leading to the undermining of GHG emission policy in regions that have introduced GHG emission mitigation measures. The following events illustrate those occurring in this context:

1. The USA has cited this issue in their reluctance to introduce costs for emitting GHGs: Competition and leakage concerns formed an important part of the considerations for such policies. The proposed Waxman-Markey and Kerry-Lieberman bills failed to pass, but both had measures intended to mitigate concerns about competition from imports.
2. The EU has allocated some free allowances: EU policy makers have not felt able to impose the full costs on those sectors that produce the most energy intensive and freely traded commodities, as it is believed that the resulting competition pressures would lead to greater system leakage from the policy. Within the EU's Emission Trading Scheme (EU ETS), the response has been to award free allowances to companies within these sectors as a way of mitigating these concerns5. It should be noted that free allowances will not always protect against all kinds of leakage in all cases. Companies issued with free allowances remain free to use them as they wish, including selling them on to other companies in other sectors. Companies in sectors who receive free allowances therefore do have the incentive to reduce the emissions that are emitted within the EU, but this might be achieved by reducing output within the EU leading to leakage from the EU ETS. What free allowances therefore effectively do is provide compensation in line the marginal additional cost of emitting a tonne of CO_2, and in doing so improve the financial robustness of the companies faced with competition pressures.

These contextual events mean that the UNFCCC system is diminished in its effectiveness, and developed countries have failed to take full responsibility. Furthermore, as free allowances act to compensate producers rather than necessarily increase prices (see Stephenson & Upton 2009), they do not guarantee that the price of these basic energy intensive commodities will increase to reflect the need to reduce emissions.

A leading policy response has been to the use of Border Adjustment policies aimed at levelling the GHG emission costs imposed on imported goods in line with domestically produced goods. Proposals to introduce a Border Adjustment scheme have raised notable concern at an international level, and therefore the prospect that a trading partner might take trade disputes to the WTO against a discriminatory adjustment regime has become an issue.

4.2 FUTURE RESPONSES TO SYSTEM LEAKAGE OF GHG EMISSIONS

One obvious response to system leakage of GHG emissions is to introduce levelling taxes on traded goods at the border. Adjusting for taxes on products at the border is neither new nor necessarily controversial. Examples include purchase taxes, which are levied on products within the supply chain. These are essentially consumption taxes and it has therefore been appropriate to ensure that imports are also captured by the tax, and that exporters are either reimbursed or exempted on products to be sold outside the tax regime. A development on this is to use such a conceptual approach to protect environmental policies, such as emissions trading schemes, by taxing imports and reimbursing exports in relation to the costs of the GHG emission imposed by the policy.

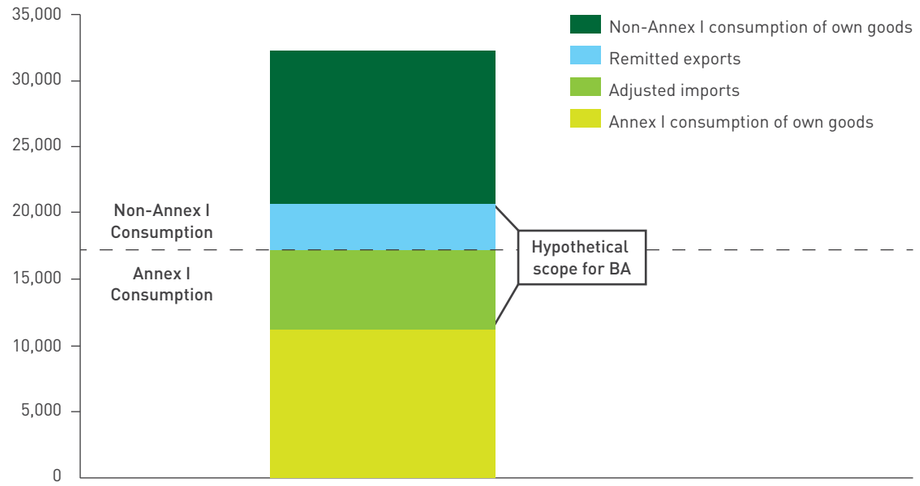
A similar example is the US Superfund case which imposed levies on imports of petroleum, seeking equivalence with that imposed on domestic producers.

4.2.1 THE SCOPE FOR BORDER ADJUSTMENT OF GHG EMISSION COSTS

The upper scope for Border Adjustment of GHG emission costs is limited by the scope of the climate policy which it sets out to protect —in the case of this study, the caps introduced within the Kyoto Protocol— and the level of trade between economies which price GHG emissions and those that do not.

[5] Under Directive 2003/87/EC

Figure 5: The limits to Border Adjustment of GHG emission costs – $MtCO_2e$



Note: The limits of the scope for border levelling hypothetically assumes that all Annex I countries implement GHG pricing mechanisms on all of their industrial emissions, along with corresponding border adjustment arrangements at the border using 'real' or actual emission factors.

FIGURE 5 REVEALS HOW MUCH INDUSTRIAL GHG EMISSIONS ARE EMBEDDED IN TRADE FLOWS BETWEEN ANNEX B AND NON-ANNEX B COUNTRIES. THIS WOULD HAVE INVOLVED 5,882 $MTCO_2E$ (OR 18% OF GLOBAL INDUSTRIAL EMISSIONS) BEING TAXED AS IMPORTS INTO A PRICED ANNEX B ECONOMY IN 2004. IT MAY HAVE ALSO IMPLIED 3,501 $MTCO_2E$ (OR 11%) BEING REMITTED UNDER CERTAIN ADJUSTMENT REGIMES. THIS MEANS THAT WITHIN ANNEX B COUNTRIES, 9,383 $MTCO_2E$ OR 29% OF GLOBAL INDUSTRIAL EMISSIONS COULD HYPOTHETICALLY BE CAPTURED WITHIN A BORDER ADJUSTMENT REGIME.

4.3 ISSUES RAISED BY BORDER ADJUSTMENT OF GHG EMISSION COSTS

Border Adjustment of GHG emission costs raises a number of issues and questions, which have been responded to in summary below and are explored in greater depth elsewhere in the report.

4.3.1 WHAT IS THE DIFFERENCE BETWEEN LEAKAGE AND COMPETITION PRESSURES?

These two terms are very closely related. Indeed, the impact of competition pressures introduced by climate change policies leads directly to the largest and best known source of system leakage — investment leakage – where investment is diverted due to the impact of a policy. The easiest way to distinguish the two terms is that competition acts on companies, whilst system leakage refers to the impact on a policy. This distinction is important when considering the legal basis for any proposed Border Adjustment in terms of motive.

4.3.2 HOW WOULD A BORDER ADJUSTMENT REGIME DEAL WITH EXPORTS FROM COUNTRIES WHICH ALREADY IMPOSE GHG COSTS?

Previous environmentally-motivated trade measures have often only targeted those imports that have not faced equivalent environmental controls. If this approach was used, a future Border Adjustment regime would adjust down for other country's GHG emission pricing policies. However, if pricing of GHG emissions is considered to be an indirect tax on the product (i.e. a tax on the product and not part of general taxation of industry), the Border Adjustment could potentially impose import taxes irrespective of the GHG emission cost imposed within the exporting country and leave the exporting country to rebate GHG emission costs at their border where they exist. This is better described as a Border Tax Adjustment (BTA) regime —as opposed to a Border Emission Levy (BEL) regime.

4.3.3 TO WHOM WOULD THE REVENUES BELONG?

There is a considerable uncertainty associated with this but of most relevance is the basis which the Border Adjustment intends to rely upon under WTO rules. If a BEL approach is taken with reference to Art. XX(i.e. exempts the adjustments where others have equivalent measures in place), a country which exports into the country introducing a Border Adjustment would be at liberty to respond with an export tax equivalent to the import levy; thus eliminating the case for the import levy for that country's exports. Under this scenario, the exporting country would have effectively captured the revenues, which it would use as it wished as with any other tax. This may well not be the case under a BTA regime based on and Art. III defence as where the importing countries have arguably introduced a consumption tax. Under this scenario, it can be anticipated that the exporting countries would remit any GHG emission taxes that they have imposed at their border to ensure their exporters compete on an equal basis. There would be nothing preventing the initiating country within either approach discussed here passing the funds back to the exporting country in the form of a clean technology investment fund; thereby increasing the case for the regime being environmentally motivated rather than protectionist.

4.3.4 WHAT ABOUT COUNTRIES WHO COMPLY WITH THEIR REDUCTION TARGETS BY OTHER MEANS?

The imposition of GHG emission costs — whether through taxes or trading — is just one possible policy approach to complying with the country's international climate change obligations. Another approach includes the regulation of certain industries to use a particular lower emitting technology. A proposed BEL system might be required to value the equivalent cost of this approach and to ensure that such industries are not faced with import costs already implicitly borne within their domestic regulatory system. Under BTA regimes, however, exporting countries that have followed a regulatory approach may not be able to rebate their producers, as regulatory costs represents a direct tax on the producer under WTO rather than an indirect tax on products (interpreted from Ismer & Neuhoff 2007).

4.4 BARRIERS TO IMPLEMENTING BORDER ADJUSTMENTS

4.4.1 LEGAL CONSIDERATIONS

The key international legal regimes relevant to Border Adjustments are the World Trade Organisation's (WTO) on General Agreement on Tariffs and Trade (GATT) and the United Nations Framework Convention on Climate Change (UNFCCC), as operationalized by the Kyoto Protocol. The GATT, which was signed in 1947, is a multilateral agreement regulating trade among 153 countries in 2012. The WTO was created by agreement in 1995 and implements the GATT, provides a forum for negotiating additional reductions of trade barriers and for settling policy disputes, and enforces trade rules. The GATT seeks to facilitate free trade without barriers or tariffs with a number of exceptions.

4.4.1.1 BORDER ADJUSTMENT AND THE WTO LEGAL FRAMEWORK

The WTO introduces a number of rules and principles to regulate trade. From this, there have been a number of trade dispute cases taken up with at the WTO where environmental protection was at issue. The following issues are relevant to the environmental motivated trade measures:

- **Most-favoured-nation (MFN):** GATT Art. I requires that such trade measures be implemented fairly for all members of the WTO. Some of the proposals for Border Adjustment of GHG emission costs would see Least Developed Countries (LDCs) exempt, in line with the UNFCCC's principle of common but differentiated responsibilities. The WTO does permit some exceptions for developing countries and LDCs in particular (the so called 'special and differential treatment provisions'). Excluding LDCs introduces the potential for a new source of system leakage with the diversion of investment patterns. Ultimately, however, for any Border Adjustment to be deemed illegal requires another WTO member to take the case to the WTO.
- **Process and Production Methods (PPMs):** Central to a number of WTO rulings on environmental protection, issues have come up against the GATT's general principle that 'like' products should not be discriminated against. This is important as many trade measures intended to protect the environment have needed to discriminate physically like products based on the environmental impacts associated with the process and production methods used. However, the Appellate Body in the Shrimp-Turtle case appeared to permit a trade measure based on PPMs, and the European Union Bananas case widened out the assessment of likeness to take into account consumer's tastes and habits.
- **Technical Barriers to Trade (TBTs):** The Agreement on Technical Barriers to Trade tries to ensure that regulations, standards, testing and certification procedures do not create unnecessary obstacles, while also providing members with the right to implement measures to achieve legitimate policy objectives, such as the protection of human health and safety, or the environment. A Border Adjustment regime would need to ensure that any administrative and technical barriers were necessary and proportionate, and not used as a disguised protectionist measure.

The following issues are relevant to the introduction of Border Adjustment in particular:

- The WTO rules for providing rebates or remittances for exports are different than that for taxing exports. The WTO rules relating to exports (GATT Art. XVI) are targeted at preventing unfair subsidies supporting a country's exports. The rules on restrictions and tariffs applied to imports aim to prevent unfair discrimination.
- Only certain costs justify remittance on exports. The assessment needs to ensure that the adjustments represent a genuine rebate on taxes and duties. Ismer and Neuhoff (2007) find that this can include inputs not physically incorporated, such as fuels. Ismer and Neuhoff (2007) did consider that tax remissions or remissions on exported products would be admissible under WTO rules, and went on to find that this would also likely be the case for emissions allowances. It therefore seems likely that tax exemptions and remissions for energy and fuels would be permissible under a future system of Border Adjustment.
- A BTA regime would need to demonstrate that the Border Adjustment relates to domestic taxes on products. It is not permitted to adjust for so called direct taxes, such as taxes on profits or charges where a particular service is provided. Ismer and Neuhoff (2007) report that scholars are divided on the question of how emissions allowances should be considered. Defence of a BTA regime under Art. III arguably depends on the precise specification of the scheme.

4.4.1.2 LEGAL COMPATIBILITY OF THE MOTIVES FOR INTRODUCING BORDER ADJUSTMENT OF GHG EMISSION COSTS

Whether Border Adjustment of GHG emission costs is compatible with WTO rules is a complex matter, and the subject of some debate. The WTO case law has often sought to judge the underlying motive of the policy in question to ensure that the measure is not being used as a disguised barrier on imports. The crucial factors in this regard are therefore the regime's design and motivations. Stephenson & Upton (2009) report that, whilst both the WTO and UNFCCC appear to hold out the prospect for protecting the integrity of a developed country's environmental policies, any future WTO ruling would be unlikely to support measures which were perceived to be motivated solely by the protection of domestic industries against competition. It is therefore worth exploring the range of motives for introducing Border Adjustments of GHG emission.

There is a range of motives for introducing a system of Border Adjustments. Reporting on the outcome of conference attended by a number of experts in the field, Dröge et al. (2008) attempted to capture these motives into a list of five:

1. **Tackle investment leakage:** Avoid relocation of production of GHG emission intensive commodities to areas not covered by the domestic emissions trading.
2. **Ensure consumer incentive:** Facilitate a move from free allowances to auctioning of allowances to ensure full GHG emission price signal also for all production including those with leakage concerns.
3. **Facilitate greater domestic targets:** Provide assurance to voters that measures are pursued to address competitiveness concerns during the implementation of GHG emission pricing.
4. **Exporter incentive:** Provide incentives for producers in countries not covered by GHG emission pricing to improve the efficiency of their production.
5. **Global climate policy:** Provide incentives for other countries to pursue more ambitious climate policy or even join an international agreement on climate policy.

These motives vary in their legal legitimacy. It is, however, clear that the last of these motivations, the 'global policy' motive would unlikely be received as a valid objective by many developing counties, and would be very unlikely to represent an effective defence within a future WTO case.

4.4.2 POLICY CONSIDERATIONS

4.4.2.1 TWO POSSIBLE BORDER LEVELLING REGIMES

As previously introduced, a Border Adjustment might make reference to two GATT articles in their defence if a case was ever to be taken to the WTO.

1. GATT Art. III allows for the equal imposition of taxes on imported products as domestically produced products.
2. GATT Art XX is intended to permit the protection from imports which have been produced under unfair or unacceptable practices, including using prison labour or production methods which harm the environment.

These are quite different regimes in terms of their legal and political basis so there are some important differences in how the Border Adjustment is to be developed. Art III has often been used without contention to adjust for taxes imposed on products, such as purchase taxes. Such schemes only take into account the tax rates imposed by the initiating country to ensure a fair treatment within that market (i.e. ensuring that purchase taxes are not added to exports but are added to imports). Such measures therefore assume that trading partners will implement equivalent measures. The implication of this is that a tax based Border Adjustment scheme implemented under Art. III would most likely impose adjustment taxes on all imports, including those from countries with climate change policies in place which impose requirements on their producers (Ismer & Neuhoff 2007).

This would not necessarily be the case for a BEL regime which relies upon Art. XX. This article permits measures which are implemented unilaterally in order to protect the environment, or at least the policy which is intended to protect the environment. In this case, Art. XX would provide for the protection of certain environmentally motivated national policies from being undermined by imports not subject to equivalent controls. There is some debate whether GHG emission taxes / trading schemes represent an indirect form of taxation on products. Most commentators do agree that it does (Stephenson & Upton 2009), but if this was not upheld by the Appellate Body, Art. III could not be relied upon.

Also, as BTA would represent a trade rather than an environmental scheme, the basis of the emissions factor used to calculate the charge would need to be non-discriminatory with reference to the tax regime within the importing country. It therefore needs to ensure that this is set at no higher level than the costs imposed on producers in the importing country. This has led Ismer and Neuhoff (2007) to suggest conservatively that only charges in relation to the importer's BAT would be permissible for all imports, perhaps with the possibility for more realistic factors to be imposed and imports to have the opportunity to refute the level with reference to actual data. As real plant data can be used in this latter system, it would have the drawback of relying on the accuracy of the importers data, as well as being susceptible to selective allocation of low emitting plants. A case might also be made that this represents a Technical Barriers to Trade. In most cases, BAT is notably lower than average or actual emissions. However, assuming that all new plants are built to BAT standards, charges based on BAT should arguable mitigate for much of the most concerning form of leakage — investment leakage.

A BEL regime may have a little more scope in this regard as its intention is to protect the environment, where the case law in this area has made reference to environmental technology being used within the exporting country. Setting the adjustments based on actual exporter's emissions would touch upon one of the developing countries concerns over the so called 'reverse leakage', where developed countries have a technological comparative advantage. Furthermore, as this is an environmental protection regime, the case for export remissions being provided to domestic producers for their exports is weaker under Art. XX. The differences in these two forms of Border Adjustment systems are summarised in Figure 6.

THE ISSUES SUMMARISED IN FIGURE 6 HIGHLIGHT THE CASE FOR INTERNATIONAL CONSULTATION AND COOPERATION IN THIS AREA IN ADVANCE OF ANY SYSTEM BEING IMPLEMENTED TO ENSURE THAT TWO DIFFERENT REGIMES ARE NOT IMPLEMENTED BY DIFFERENT COUNTRIES.

Figure 6: Summary of differences between BTA and BEL regimes

DESIGN ELEMENT		TAX ADJUSTMENT (BTA)	ENVIRONMENTAL GROUNDS (BCL)
		ART.III	ART.XX
AIM		TAX ADJUSTMENT	ENVIRONMENTAL PROTECTION
Emissions Intensity	BAT	Yes	Yes
	Exporter's emission factor	Less likely	Possibly
	Importer refutable average		
	International refutable average		
Rebate/remit domestic producers exports?		Possibly	Doubtful
Needs to have an environmental basis?		No	Yes
Needs to relate to an indirect tax		Yes	No
Who captures revenues?		Importing country	Importing and/or exporting country*

Source: Analysis from a range of literature sources with Ismer & Neuhoff (2007) being the primary source.
* This would require the exporting country to implement a responsive export levy to counteract the trade measure.

4.4.2.2 A DEVELOPING COUNTRY PERSPECTIVE

Developing nations are generally very wary of proposals for Border Adjustment, often stating that developed countries should take the lead in combating climate change under the UNFCCC's principle of 'common yet differentiated responsibilities' (Art 3.1), and so it would be inappropriate to implement such measures on developing countries. This has been interpreted by some within developing countries in the sense that 'it is the responsibility of the developed nations to incur climate mitigation costs' (TERI 2011), and that therefore 'developed country parties shall not resort to any form of unilateral measures including countervailing border measures, against goods and services imported from developing countries on grounds of protection and stabilization of climate' (part of China's and India's proposed text for the Copenhagen conference).

A group of developing countries sought that the UNFCCC take this position on the issue and, as a result, the following text was included in the Cancun Agreement. The UNFCCC:

'reaffirms that... measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade' (Cancun Agreement, Para 90).

However, this statement is based on WTO rules and therefore does not appear to provide developing countries with any additional protection from the introduction of Border Adjustments .

Underlying these positions is a number of more specific contexts and concerns which have driven these positions. The project team attempted to capture these, based on the collaboration with the Indian based research institute TERI, who were commissioned to write a paper on border levelling from a developing country perspective. These concerns include:

1. Producers in developing countries would pay. Underlying many of the concerns is the one that, not only would Border Adjustments reduce demand, but also would be the producers in the developing countries who would end up paying the tax as market conditions would not permit them to pass the costs onto consumers. The assumption behind this is that products which developing countries trade are generally highly elastic in nature.
2. Fair 'carbon space' and burden shift. Some commentators in developing countries feel that developed countries are attempting to transfer the burden of their own responsibilities onto them. Developing countries are entitled to emit these emissions based on population sizes and historical responsibility for emissions.
3. Protectionism. Some commentators in developing countries feel that, rather than the protection of their climate polices, border levelling would be motivated by the protection of developed countries' domestic industries. Historically, many of the trade measures introduced by developed countries did have the effect of protecting domestic producers from cheaper imports from developing countries. Border Adjustment is being received by some in this context.
4. Poverty eradication should be the first and overriding priority of developing countries. Indeed, the UNFCCC accepts that the extent to which developing country parties will effectively implement their commitments under the Convention will depend on the financial resources and transfer of technology.
5. Reverse leakage. There is a concern that border levelling measures would induce 'reverse leakage', wherein once a Border Adjustment is introduced, GHG emission intensive production would be diverted to those countries already using GHG emission efficient production methods. Rationally, there are two main routes that this could be introduced:
    a. The introduction of a Border Adjustment would exacerbate any technological knowledge based comparative advantage that developed countries have in energy efficiency, and therefore future investment.
    b. Even where there is equal access to technology, if Border Adjustment measures are imposed retrospective to the initiating country's climate policy, the domestic producers have an investment head start, and will therefore have a price advantage over their developing competitors. Although this should not divert future investment, it would put developing country producers at a disadvantage if global demand were to fall.

There are also potential opportunities and benefits for developing countries with the introduction of a Border Adjustment.

1. Lower cost imports. Within the present system, developing country consumers are paying GHG emission costs on some of their imports at the same level that EU consumers are. Some Border Adjustment systems would rebate these costs, which could potentially be passed on to consumers.
2. Potential export revenues. Developing countries would be at liberty to counteract BEL systems introduced under Art. XX with equivalent export taxes, without putting themselves at a disadvantage in relation to other countries. Where the revenues are captured within the initiating developed countries, there is the possibility to pass these funds back to the developing country producers via mitigation funds.
3. Ending of free allowances. Under a WTO compliant Border Adjustment system, the allocating of free allowances would need to end, to the degree that the Border Adjustment reflected the full permit price. Therefore developing country producers would no longer be competing against developed country producers who have been (in effect) allocated free assets.
4. Climate change mitigation. The risk of climate change would be reduced to the extent that concerns over system leakage end. This is actually one factor that is presently obstructing developed nations in a political sense to achieve their emissions targets. Furthermore, the adoption of a Border Adjustment system would weaken attempts by developed countries within future UNFCCC negotiations for developing countries (and LDCs in particular) to take on emissions caps.

4.4.2.3 EVIDENCE OF SYSTEM LEAKAGE

One of the most powerful justifications for Border Adjustments (both legally and politically) will be the degree that a GHG emission pricing policy may impact on the location where things are produced (or at least will be produced), due to investment decisions. Location decisions for companies are based on a myriad of different factors, climate policy being one of them. It is extremely challenging, if not impossible, to determine if a particular industry re-located specifically due to climate policy and not for any other reason. In addition, it is extremely difficult, if not impossible, to separate a company's actual decision making process from its lobbying activities for more lenient policy. An industry survey undertaken by the International Institute for Sustainable Development (IISD) demonstrated that there are far more significant issues than existing climate policy that could cause a company to relocate. These include labour costs, proximity to suppliers and consumers and infrastructure facilities, just to name a few (Wooders et al, 2009).

This finding does appear at first sight to undermine the case for Border Adjustment. However, investment leakage cannot be dismissed as a future issue. The IISD finding was based on existing levels of GHG emission pricing, and logically strong system leakage would become an issue if the price of emitting GHGs was to increase further. The IISD analysis suggests that evidence for investment leakage will unlikely be conclusively available at present permit trading prices as the influence of permit prices is masked by other factors.

5. METHODOLOGIES AND ANALYSES

5.1 BORDER ADJUSTMENT DESIGN ELEMENTS

The barriers to a Border Adjustment system will likely limit the design of a future regime and the degree that emissions can be fully captured. A number of design elements are explored here, which form sensitivities within the results section. There are a number of issues or design challenges to respond to when developing a Border Adjustment regime. These include:

1. The scope of the emissions to be adjusted for. This might be limited to a very narrow scope, and only those direct emissions emitted directly on site could be included. Alternatively, a wider scope might be used to include some of the indirect emissions, such as those associated with electricity imported into the system and those emissions embedded into other materials that are inputs in the processes.
2. The emission intensity or technology to be assumed within the Border Adjustment. Whether this be the lowest intensity and therefore the Best Available technology (BAT), the exporter's actual intensity, the importer's intensity or some kind of average intensity. Any across the board intensity that is applied raises the issue of whether the measure unfairly discriminates against individual importers over domestic producers. WTO rules would therefore tend toward the use of intensity levels based on the lowest intensity of domestic producers within the GHG emission pricing economy, which in the case of the EU ETS will very often represent BAT. Other intensities can be implemented with a refutable mechanism, whereby the exporter can make the case that their emissions are lower than this.
3. The sectorial scope of the proposed regime. This might take the form of voluntary sectorial agreements negotiated and tailored to a few key sectors at risk of emissions leakage; a mandatory Border Adjustment regime imposed on a handful of sectors at most[6] risk from emissions leakage; or a mandatory Border Adjustment regime imposed on all sectors covered by the climate policy.
4. Whether to include LDCs. Many legal frameworks including the WTO permit exceptions for LDCs, but the extent of exception might be limited by the risk of introducing new system leakage.
5. Materiality and the degree to which all trade flows are material and need to be included. Practicality would point more towards a system limited by materiality, but WTO rules would unlikely support such a system introduced without agreement.

An assessment of these different design elements has been made in Table 1 to explore whether the policy and environmental motives for implementing a Border Adjustment regime are met, as well as the main limitations and barriers to their use.

TABLE 1 SUGGESTS THE BORDER ADJUSTMENT REGIME THAT BEST RESPONDS TO THE MOTIVES FOR BORDER ADJUSTMENT WOULD TEND TO CAPTURE THE GREATEST VOLUME OF EMBEDDED EMISSIONS. THIS WOULD CAPTURE ALL EMBEDDED EMISSIONS FOR ALL IMPORTS; BE BASED ON EITHER THE EXPORTER'S ACTUAL LEVEL OF EMISSIONS INTENSITY —OR AT LEAST PROVIDE THE EXPORTER THE OPPORTUNITY TO REFUTE THE INTENSITY WHERE THEY CAN SHOW THAT THEIR EMISSIONS ARE LOWER THAN THE IMPORTERS OR AVERAGE EMISSIONS; AND CAPTURE ALL SECTORS. HOWEVER, IT IS FAR FROM CLEAR THAT SUCH A FAR REACHING BORDER ADJUSTMENT REGIME WOULD BE LEGALLY COMPLAINT OR POLITICALLY ACCEPTABLE. THE SPECIFIC ISSUES ARE EXPLORED BELOW, ALONG WITH THE ASSUMPTIONS USED TO INCORPORATE THEM INTO THE MODELLING.

[6] Whilst the EU considered that all sectors covered by the EU ETS are at risk of emissions leakage, the literature typically identifies the following sectors as at MOST risk: lime and cement; basic iron and steel; refined petroleum; aluminium; inorganic basic chemicals; pulp and paper (Stephenson & Upton 2009, p.8).

Table 1: Compliance of Border Adjustment design elements with motives for Border Adjustment

		POLICY MOTIVES		ENVIRONMENTAL MOTIVES			
DESIGN ISSUE	**DESIGN ELEMENT**	**TACKLE INVESTMENT LEAKAGE**	**ALLOW > DOMESTIC TARGETS**	**PRODUCER INCENTIVE**	**CONSUMER INCENTIVE**	**MAIN LIMITATION**	**MAIN BARRIER (MITIGATION)**
EMISSION SCOPE	**DIRECT**	Probably		In part		Lower incentive	Uncertain legality (WTO)
	DIRECT AND INDIRECT	Yes	Very likely	Largely		Greater complexity	
	EMBEDDED	Yes		Yes		Complexity	
EMISSION INTENSITY	**BAT (IMPORTER)**	Probably		In part		Lower incentive	–
	IMPORTER INTENSITY	Yes		If reputable	Yes	Limited producer incentive	Legality Refutability
	AVERAGE INTENSITY	Very probably					
	EXPORTER ACTUAL			Yes		–	Practical/ Political
SECTORIAL SCOPE	**SECTORIAL AGREEMENTS**	Very probably		Largely		Limited Scope	–
	SECTORS AT MOST RISK						–
	ALL EU ETS SECTORS	Yes				–	Political
	ALL IMPORTS			Yes			Legal (WTO)

[1] Whilst the EU considered that all sectors covered by the EU ETS are at risk of emissions leakage, the literature typically identifies the following sectors as at MOST risk: lime and cement; basic iron and steel; refined petroleum; aluminium; inorganic basic chemicals; pulp and paper (Stephenson & Upton 2009, p.8).

5.1.1 THE SCOPE OF EMISSIONS INCLUDED

The scope of the emissions to be adjusted at the border also needs to be no greater than that faced by domestic producers. There are four scopes of emission which might be included:

1. **Direct:** The direct (i.e. on site) emissions associated with the production of products from the relevant sectors.
2. **Direct + electricity:** The direct (i.e. on site) emissions and the emissions associated with the generation of electricity on and off site. This would include only the electricity emissions purchased or produced by the manufacturing outlet.
3. **Direct + power sector:** The direct (i.e. on site) emissions and the emissions associated with electricity used within all sectors that input into the production process. All electricity through the whole supply chain would be captured.
4. **Embedded (by sectors):** The emissions embedded by all the relevant sectors inputting into the production of the product.

There is therefore a cumulative process whereby the emissions from the various sectors and trading partners are added to scope of the Border Adjustment system. The ultimate design results in the Border Adjustment having an equivalent scope to the emissions trading scheme (i.e. embedded by sector) as illustrated in Figure 10 shown in the Section 8.3.2 of the Annexes.

5.1.2 ANALYSIS OF EMISSION INTENSITY DESIGN ELEMENTS

5.1.2.1 BEST AVAILABLE TECHNOLOGY (BAT)

If a narrow and physical interpretation of likeness is taken, it would unlikely be possible to impose charges greater than that applied to domestic producers. This is because such trade measures cannot discriminate unfairly against any one importer over domestic producers. Therefore, the Border Adjustment may need to be based on the lowest factor (i.e. as generated by the BAT) in the importing country.

Estimating BAT emission intensities represented a challenge to the modelling. The EU does provide 'benchmarking' figures as BAT for the relevant sectors using metric 'tonnes of CO_2 per tonne of output'[7]. However, the MRIO modelling system uses 'tonnes of CO_2 per million USD' as a metric. Furthermore, the sectoral breakdowns are very different. The study provided two estimates of BAT, one derived from the trade model used in this project and the other from EU estimates. They generated significantly different results demonstrating two key points. Firstly, there is considerable uncertainty in estimations of models and interpretation of policy documents.

Secondly, the variation demonstrates the importance of the level BAT at which is set. If the BAT is set at a level that excludes a significant proportion of emissions then this could entirely undermine the establishment of the Border Adjustment.

The ferrous metals sector is used to illustrate this as an example. A BAT for EU ferrous metals would represent the 'best available' standard of ferrous metal production within the EU. The country with the lowest emissions intensity is Malta. Closer inspection of the ferrous metals industry in Malta reveals this sector to be very small, contributing just 0.01% of the total output (in USD) of ferrous metals in the EU27 and therefore very possibly an artefact of the modelling process and not truly representative of the cleanest steel factories in Europe. The modelling therefore took BAT to be the average emissions intensity that excluded 10% of emissions.

5.1.2.2 AVERAGE EMISSIONS INTENSITIES AND THE IMPORTER'S RIGHT TO REFUTE

WTO rules do not necessarily rule out the use of higher and more realistic emission intensities being applied, either the average emission intensity of the importing country, or possibly the true emissions intensity of the country or plant where the goods were produced. If an across the board average emission factor was to be levied, it would very likely be necessary to provide importers with a possibility to refute this and provide an actual factor. This would consequently rely on the level of accuracy of the data from exporters not regulated under the system that they are importing into, as well as being susceptible to the most efficient plants being allocated for exports.

Such a measure would not be directly discriminatory as the data required would be no greater than that required of domestic producers within the scheme. However, requiring foreign producers to measure these GHG emissions as if they were in the scheme might be considered as an unreasonable technical barrier to trade. It seems likely that this will more likely be the case if a BTA rather than BEL regime was introduced, as the latter can rely more on what is necessary to achieve the environmental objectives.

5.1.3 LEAST DEVELOPED COUNTRIES

A further important issue is who is to be included. WTO rules heavily presume that all trading partners will be treated equally when such trade measures are being applied. However, it is an established convention, both within the WTO and UNFCCC, to consider the particular developmental needs of LDCs and consider treating them with more leniency than other counties when introducing such policies. To some, this issue might differ depending on whether a BEL or BTA is being envisaged as the latter of these forms part of the regulation of free trade within a move towards consumer tax policy rather than environmental protection.

It would be less likely that LDCs would be treated differently when introducing consumption or sales taxes, but more plausible that special arrangements made for LDC in the event of an environmental measure being introduced. In this latter case, there would likely be concerns raised about the risk that any special arrangement would introduce distortion and leakage into the system. This might include polluting production being diverted into LDCs or the artificial distortion of trade flows and the corresponding environmental impacts from increased transport.

A strong political justification of excluding LDCs is the outcome of the Durban process, which has established that some non-LDC developing countries will need to be part of a future GHG emission reduction process. This establishes a clear distinction between LDCs and some other developing countries within future UNFCCC negotiations.

5.1.4 MATERIALITY

Some proposed Border Adjustment schemes would introduce thresholds and thereby attempt to exclude certain 'non-material' flows. This would act to simplify the Border Adjustment system, and in some cases, reduce the impact on LDCs. From a legal perspective, this both introduces the possibility of challenge based on unfair treatment (i.e. most favoured trading partner), but also might reduce the level of complexity and costs in the system, and therefore reducing the risk of challenge based on a technical barrier to trade. The most well-known example of a material element within a proposed Border Adjustment comes from the US as introduced in two bills. Both the Waxman-Markey bill, passed by the House in 2009, and the Kerry-Lieberman bill failed to pass in the Senate in 2010. However, they set out criteria for determining which sectors would be subjected to Border Adjustment and which countries could be exempt from being subject to Border Adjustment, namely product criteria and country criteria.

The criteria are broadly similar in both bills. The conditions in Waxman-Markey bill are as follows:

- Product Criteria: An industrial sector is eligible for Border Adjustment if they are (excluding refining) are at least 5% energy (or CO_2) intensive and 15% trade intensive, or 20% energy intensive. An Interagency Report (2009) used these criteria to define 46 sectors likely to be deemed as eligible industrial sectors based on these criteria.
- Country Criteria: The Waxman-Markey bill[8] also proposed to exempt countries which either:
  - is an LDC; or
  - has a nationally enforceable GHG emissions reduction commitment at least as stringent as that of the United States'; or
  - is a party to a multilateral or bilateral emission reduction agreement for that sector to which the United Stated is a party; or
  - has an annual energy or GHG intensity for the sector that is equal to or less than the energy or greenhouse gas intensity for the industrial sector in the United States; or
  - is responsible for less than 0.5% of total global GHG emissions and less than 5% of United States imports of covered goods with respect to the eligible industrial sector.[9]

Such detailed materiality clauses are highly complex to model. We have attempted to represent the kind of impact that such clauses introduce by applying the 0.5% criteria.

[7] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011D0278:EN:NOT

[8] Section 768, HR 2454 "American Clean Energy and Security Act of 2009", p1123.

[9] In the later Kerry-Lieberman bill, it changes to 'less than 5% of global production in the eligible industrial sector'

5.2 THE MRIO MODELLING METHODOLOGY

MRIO models link environmental pressures, such as GHG emissions, with final consumption through the global supply chains. In short, the model links production to consumption by a detailed understanding of the integration between both sectors and countries. MRIO models are now recognised as one of the leading, if not only, approach to undertake such a task (Peter, 2010, Wiedmann, 2009, Minx et al, 2009). MRIO models are extremely data intensive, thus limiting the number of data sources used to construct such models. One of the key data requirements are national input-output (IO) tables. While many countries produce such tables there are gaps, and the classifications and years are inconsistent.

Therefore, for MRIO models to reflect a global picture, a consistent database provided by Purdue University is often employed, called 'Global Trade Analysis Project' (GTAP). GTAP involves a network of researchers who conduct global economic analyses by using computable general equilibrium models. Alternatively, data provided by the OECD is applied. However, the global coverage of this data is limited. A more detailed description of the history of MRIO modelling can be found in Wiedmann (2009).

An Environmentally Extended Multi-Regional Input-Output (EE-MRIO) model requires substantially more data. In addition to domestic IO tables for each region and bilateral trade data, environmental impact variables are also required. Fortunately, the Global Trade Analysis Project (GTAP) has made all this data available.

The EE-MRIO model used in this report features data for the year 2004 extracted from the GTAP version 7 dataset. The methodology adopted has been taken from Peters et al (2011b).

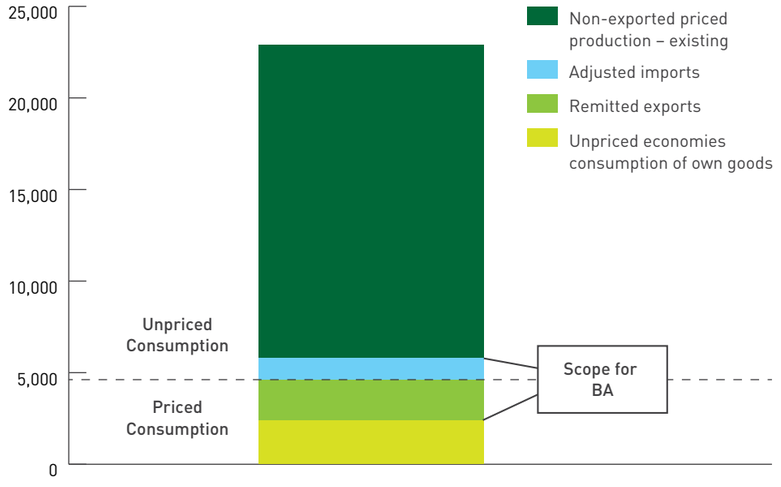
5.3 THE BENCHMARK FOR THE ANALYSIS

The full hypothetical scope for Border Adjustment, as introduced in Figure 5, is far from being available as a legal option to Annex B countries. For example, many Annex B nations have not implemented any pricing schemes. Furthermore, of those who have, not all sectors and emissions are included so, for example, the EU ETS only covers CO_2 emissions, and for only certain sectors. The impacts of these limitations have been shown in Figure 7 considering priced and unpriced economies.

FIGURE 7 REVEALS THE DEGREE TO WHICH THE MAJORITY OF GLOBAL EMISSIONS ARE NOT BEING PRICED WITHIN EXISTING POLICIES. ONLY 11% OF GLOBAL INDUSTRIAL EMISSIONS ARE BEING EMITTED WITHIN A PRICING MECHANISM. FIGURE 7 ALSO HIGHLIGHTS THAT OF THE 14% OF GLOBAL INDUSTRIAL EMISSIONS RESULTING FROM CONSUMPTION WITHIN A PRICED ECONOMY ROUGHLY HALF ARE DUE TO UNPRICED IMPORTS INTO THE SYSTEM (I.E. WEAK LEAKAGE). IT ALSO REVEALS THAT 4% OF GLOBAL INDUSTRIAL EMISSIONS ARE BEING PRICED AT THE POINT OF PRODUCTION AND EXPORTED INTO UNPRICED ECONOMIES (THESE MIGHT BE REMITTED UNDER CERTAIN BORDER ADJUSTMENT REGIMES). THIS MEANS THAT WITHIN THE EXISTING POLICY SYSTEM, THE SCOPE OF BORDER ADJUSTMENT IS LIMITED TO 11% OF GLOBAL INDUSTRIAL EMISSIONS. AS PREVIOUSLY INTRODUCED, THERE ARE A NUMBER OF LEGAL, POLITICAL AND TECHNICAL BARRIERS WHICH NEED TO BE OVERCOME BEFORE A BORDER ADJUSTMENT CAN BE IMPLEMENTED TO EXTEND SUCH SCHEMES. THESE WOULD TEND TO WEAKEN THE IMPACT OF THE BORDER ADJUSTMENT REGIME FURTHER.

THE RESULTS SECTION USES THIS FORESEEABLE SCOPE AS A BENCHMARK TO EXPLORE THE IMPACT OF INTRODUCING THE VARIOUS DESIGN ELEMENTS INTO A FUTURE BORDER ADJUSTMENT REGIME.

Figure 7: The Foreseeable (Benchmark) scope for Border Adjustment (2004 data) - $MtCO_2$



Note: Assumes that all existing pricing schemes are implemented to the scope of the EU ETS system

6. RESULTS OF THE ANALYSIS

6.1 BORDER ADJUSTMENT DESIGN ELEMENTS

The impact of implementing the various design elements on a Border Adjustment system is presented in relation to the existing GHG emissions trading systems in place in Figure 8. This compares the series of possible Border Adjustment sensitivities against this foreseeable maximum legal benchmark.

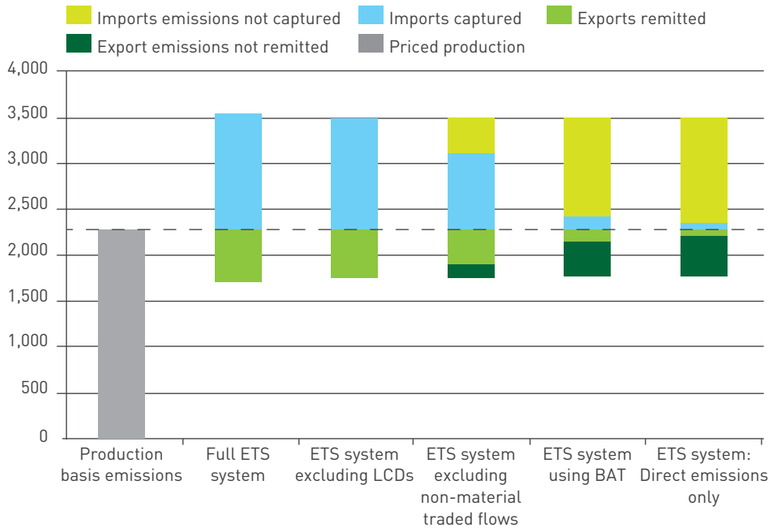
The light blue and green values show the amount of emissions still captured within a Border Adjustment system if that design element were to be introduced. The volumes of emissions not captured due to the introduction of the design element are shown by the yellow and dark green bars.

The results presented in Figure 8 suggest that:

- The impact of excluding LDCs is very small. The embedded emissions from present trade volumes from LDC only represent 1% of imports into priced economies. Therefore, by excluding LDCs there would be very little difference to the effectiveness of the Border Adjustment system, assuming that the aim is to ensure that equivalent GHG emissions are captured in imports that are priced domestically.
- Using BAT emissions intensities has a significant impact on the extent of the Border Adjustment system; only 10% of import emissions and 23% of export emissions would be captured by such a system.
- Excluding non-material traded flows does have more of an impact on the volume of emissions captured; only 65% of benchmark import emissions and 73% of benchmark export emissions would be captured.
- Including only direct emissions would have an even more significant impact on the Border Adjustment system; only 5% of import emissions and 7% of export emissions would be captured by such a system.
- Including direct emissions plus emissions associated with the electricity used in production, however, would increase the extent of the scheme. In this case, 17% of import emissions and 24% of export emissions would be captured.

For both results corresponding to BAT and direct emissions, all traded goods are being captured and influenced by the Border Adjustment; but not to anything near their full extent. Therefore, it might be the case that such a Border Adjustment would be sufficient in tackling some of the issues – such as investment leakage. However, such an un-level system may be resisted by domestic producers within the emissions trading scheme and may be significant in the decision over ending the issuing of free allowances. Such an incomplete system would also not respond to the environmentally motivated desire for consumption reduction as envisaged by a move towards consumption based accounting of CO_2. Whether a BAT system would in fact tackle investment leakage is by no means certain and further research is necessary in this area.

Figure 8: The volume of emissions captured due to Border Adjustment design element – $MtCO_2$



Notes:

- The results are presented as a series of sensitivities. Therefore only one design element is considered at a time.
- The results are for all existing GHG pricing assuming a EU ETS design.
- The results are presented as deviations from the present system (i.e. the territorial production basis) as shown by the grey bar.

7. RECOMMENDATIONS AND FURTHER RESEARCH

The ever increasing embodied emissions in trade is a major concern for national climate policy with the lack of comprehensive global agreement. Considering equitable distributions of the remaining global carbon budget to avoid an above two degree temperature rise, developed countries must take more responsibility than purely their territorial emissions. Therefore, a serious examination of various approaches to extend responsibility from a territorial to a consumption-based approach is required.

In terms of the design of such a mechanism, the results suggest that the impact of excluding LDCs would be small as imports from LDCs only represent 1% emissions embedded in imports. Therefore, from an emissions perspective, it would be appropriate to exclude LDCs from a scheme giving additional room for development. Excluding traded flows considered not to be material has more of an impact, but still 73% of the relevant export emissions would be captured.

The most important design element that would affect the level of emissions captured relates to direct and indirect emissions. Direct emissions refer to the emissions associated with the import of raw materials, such as steel or aluminium, without including any emissions that occur through the supply chain in their production. The reality being that European countries don't import electricity from China but finished products that have emissions from electricity in their production. If the full supply emissions are not included, 95% of emissions are lost, rendering the system ineffective.

The key difficulty is capturing the emissions related to electricity in imports. For example, the EU does not directly import electricity from China, but the supply chain emissions of imported finished goods and services from China have a high proportion of emissions occurring in the electricity sector.

In conclusion, countries attempting to use pricing mechanisms, such as a trading scheme, only capture 50% of the emissions associated with the consumption of the priced commodities. They account for 11% of global emissions; a further 11% is imported that is not captured. It is essential that mechanisms to mitigation these emissions are considered. The responsibility sits firmly with the developed countries from the perspective of cumulative emissions, per capita emissions and the ability to act to achieve emission reduction.

However, by not capturing the embodied emissions through the supply chain associated with finished products, 95% of the emissions embodied in imports would not be included in the scheme. Currently, while there are a number of models that can, with some precision, understand the emissions embodied in imports large product groups, there is no system that can accurately and robustly measure the emissions associated with individual products taking into account global supply chains, individual country efficiencies at a low cost.

Therefore, the design of a complex BCA scheme could be counteractive as it would, most likely, not capture the carbon embodied in imports. The design of a mechanism has to take on some extremely important elements. Primarily, the key message is simplicity. The system must consider how to extend responsibility of developed countries to include embodied emissions without having a full product level knowledge of supply chains.

Such a system could either make a domestic adjustment to an existing scheme. For example, the EU ETS could take a consumption-based approach and add the imported emissions into the scheme without adjusting the cap. This would have the added benefit of driving innovation in low carbon technologies and providing a clear signal to the consumer through a change in price. The additional revenue could be used to fund international climate mitigation schemes that would result in a reduction in emissions of imports.

8. ANNEXES

8.1 THE MRIO MODEL

The EE-MRIO model used in this report features data for the year 2004 extracted from the GTAP version 7 dataset, which is the latest available. This includes 113 regions and 57 sectors generating a supply-side technical coefficients matrix (A) of the dimension 6,441 rows by 6,441 columns. In addition to this matrix, there is a final demand matrix, which is has four categories for each region (households, government, capital formation and variation in stocks).

Accompanying all these matrices is a number of environmental extensions, consisting of total annual GHG emissions for all the 113x57 region-sectors of GTAP 7. CO_2 emissions were calculated according to the Tier 1 method suggested in the revised 1996 IPCC guidelines (Lee, 2008), and by using energy statistics published by the International Energy Agency (IEA). In this sense, emissions are derived from six energy sources or carriers: coal, crude oil, natural gas, petroleum products, electricity and gas distribution. In turn, non-CO_2 data (CH_4, N_2O, and fluorinated gases) were obtained from the US Environmental Protection Agency (USEPA) and calculated by applying growth rates based on near-term projections to 2001 emissions data from GTAP 6. Thus, these figures can vary from the emissions reported by different countries in 2004 (Rose et al., 2010). It is also worth mentioning that CO_2 emissions generated from land change and non-CO_2 emissions from biomass are included in the datasets.

8.1.1 UNCERTAINTIES WITH THE MIRO MODEL

There are a number of uncertainties associated to the GTAP database and to the construction of MRIO models in general. These are related to a number of issues, such as among others: the manipulation required for calibration, balancing and harmonisation; the use of different time periods, currencies, country classifications; and levels of disaggregation, inflation, data errors (Lenzen, 2001; Lenzen et al., 2004; Peters, 2007; Weber, 2008; Lenzen et al., 2010).

Manipulation represents the biggest uncertainty according to Peters (2007). GTAP data is collected from voluntary submissions by individuals or organisations at an international scale in return for the right to use the dataset. Thus, the data is presented in different country classifications and levels of aggregation. Walmsley and Lakatos (2008) have reported that of all the contributed tables, 58 did not contain all 57 sectors, so disaggregation was required. Moreover, data generally corresponds to different years with only a fraction of the entire set of domestic IO tables corresponds to 2004. For example, IO tables for countries, like Cyprus and Malta, date from 1986, while Hong Kong's is from 1988.

Harmonisation is required where data has been submitted expressed in national currencies. Once the data has been transformed to comply with GTAP classifications, it is evaluated by taking into account currency conversions and inflation, so all tables are expressed in a common unit in 2004 prices. Then it is further 'calibrated' and 'balanced', making it suitable to be used in a computable general equilibrium model. It is believed that precise details of these harmonisation, calibration and balancing processes are not transparent as they might be which generate a degree of uncertainty that is hard to estimate.

Giljum et al. (2008) proposes responding to shortcomings in the harmonisation of GTAP data using other sources, such as the OECD. The drawback of this alternative is that domestic IO tables from only OECD countries plus 11 non-member countries are available. Moreover, the organisation does not supply bilateral trade data for the latter group of countries. In this sense, Giljum's MRIO model just takes into account the trade that occurs between OECD members, while the rest of the countries seem not trade between them. This makes it a semi-unidirectional trade MRIO model. Consequently, while it may be more robust in terms of harmonisation, it lacks the ability to take into account the complete effects obtained from a full multilateral model.

Relating to MRIO models in general, Weber (2008) has analysed the most common error types associated with EE-MRIO models compared to the traditional single-region ones. By using IO data from the United States and several of its largest trading partners, he determined that aggregation and concordance to a common sectoral classification, the treatment of the rest-of-world (ROW) region, and monetary exchange rate issues represent the greatest uncertainties. In the particular case of the GTAP EE-MRIO model that is used to produce the results for this report, these problems seem to be also present at a certain extent. Some of these have already been mentioned, but it is worthy to highlight the ROW issue. Although it does not include a ROW region as such, it does possess 18 aggregate regions that comprise 116 nations in total. Due to the reduced size of their economies or the lack of data at a national level, these were aggregated instead of being presented individually. This aggregation, according to Lenzen (2004) and Weber (2008), is likely to result in some errors.

Some other issues further contribute to increase the level of uncertainty that is present in any model of this kind. In general terms, raw macroeconomic and energy data, as is generated by national sources, is already associated with a series of errors. These are seldom estimated by governmental offices of statistics at a national scale, so it is difficult to determine their magnitude. Moreover, data from different sources often varies due to differing definitions or methodologies for data collection. For example, GTAP CO_2 data is calculated by using IEA energy statistics. However, it may vary from 10% to 20% at a national level —and maybe even more at a sectoral level— when compared to other sources (Minx, et al., 2008), such as the Carbon Dioxide Information Analysis Centre (CDIAC). Particularly, significant variations have been found in the case of the United States, China and the EU. In this same respect, Lenzen et al. (2010), while undertaking an uncertainty analysis of the UK's carbon footprint by using an MRIO model, estimated an 89% probability that the footprint might have been significantly larger than originally calculated due to errors related to the carbon multipliers.

In summary, it is almost impossible to know how big the uncertainties are. But, in spite of all these issues, some authors think that the advantages of MRIO models outweigh these problems (Weber, 2008). And regarding GTAP, it still constitutes one of the most reputable sources and its data is currently being used in numerous studies.

8.1.2 EQUATIONS USED IN THE MRIO MODEL

The standard Input-Output analysis considers that the output (X) of sector "i" is given by:

$$X_i = x_{i1} + x_{i2} + \cdots + x_{ij} + y_i \qquad (1)$$

where each xij represents the contributions from the "i-th" sector to "j-th" sector or industry in an economy, and where yi stands for final demand. In other words, the total output of a particular sector is determined by its intermediate and final demand.

If each xij is divided by the total output of its corresponding sector:

$$a_{ij} = \frac{x_{ij}}{X_i} \qquad (2)$$

then, after rearranging (2), equation (1) can be reformulated as:

$$X_i = a_{i1}X_1 + a_{i2}X_2 + \cdots + a_{ij}X_j + y_i \qquad (3)$$

This last equation, in turn, can be expressed in matrix notation as $X=AX+Y$, and after solving for X, it becomes:

$$X = (I-A)^{-1}Y \qquad (4)$$

where X and Y are vectors of total output and final demand, respectively, I is the identity matrix, and A is the technical coefficient matrix, which shows the inter-industry requirements. On the other hand, the first term at the right hand of the equation deserves special attention. $(I-A)^{-1}$ is known as the Leontief inverse (further identified as L). It indicates the inter-industry requirements of the "i-th" sector to deliver a unit of output to final demand.

Under a Multi-Region Input-Output (MRIO) framework, A has to account not only for domestically produced goods and services within the different regions, but also for the trade that takes place between them. In this sense, the sectoral requirements of region "m" are decomposed into a domestic component —which represents inter-industry relationships within the region— and another one that represents imports —which show the inter-industry relationships with other sectors located in the "n-th" region.

$$A_m = A_m^D + \Sigma A_n^I \qquad (5)$$

Hence, A becomes a square composite matrix formed by a number of blocks. The diagonal blocks (i.e. A_{mn}^D, where $m=n$) represent domestic IO matrices, which show the inter-linkages between sectors located within regions. Conversely, the off-diagonal blocks (i.e. A_{mn}^I, where $m \neq n$) represent the sectoral requirements of region "m" from other sectors located in region "n". These are known as the import matrices.

$$A = \begin{Bmatrix} A_{11}^D & A_{12}^I \cdots A_{1n}^I \\ A_{21}^I & A_{22}^D \cdots A_{2n}^I \\ \vdots & \vdots \ddots \vdots \\ A_{m1}^I & A_{m2}^I \cdots A_{mn}^D \end{Bmatrix}$$

Similarly, X and Y must include total output and final demand, respectively, of all sectors located in all regions. Regarding Y, it incorporates all the components of final demand (i.e. private and public consumption, gross capital formation and change in stocks) of domestically produced goods and services (YD) within region "m", as well as of imported products and services (YI) from region "n" to be consumed in "m". Moreover, goods and services produced domestically (E), but consumed in region "n" (i.e. exports) are equally considered to be a part of Y.

$$X = \begin{Bmatrix} X_1 \\ X_2 \\ \vdots \\ X_m \end{Bmatrix} \quad \text{and} \quad Y = \begin{Bmatrix} Y_1 + \Sigma E_{1n} \\ Y_2 + \Sigma E_{2n} \\ \vdots \\ Y_m + \Sigma E_{mn} \end{Bmatrix} \qquad (7)$$

In this sense, in an open economy equation (4) can be rewritten as:

$$X = (A^D + A^I)\,X + Y^D + Y^{I+} + E - M \qquad (8)$$

And since total imports (M) are equal to imports to intermediate demand (AI) plus imports to final consumption (Y^I),

$$M = A^I X + Y^I \qquad (9)$$

then, by substituting (9) in (8), exactly the same form of equation (4) is obtained once again. This implies that it can be used to determine the amount of output (X) from any arbitrary demand.

In the context of an Environmentally Extended MRIO (EE-MRIO) model, environmental impacts are included as an extra vector. This report focuses specifically on GHG emissions, which are assumed to be a function of output. If the emissions (g) generated by sector "i" are divided by the corresponding output (Xi), then a row vector of direct intensities (G) are obtained, just as is expressed by equation (10):

$$G = \frac{g_i}{X_i} \qquad (10)$$

In order to calculate the amount of emissions that would result from a certain level of output, G —known as the direct intensity multipliers— is post-multiplied by X. So by substituting this last variable according to equation (4), the direct emissions (F^d) are determined by:

$$F^d = \hat{G}LY \qquad (11)$$

where the symbol "^" stands for a diagonal vector. G provides a set of weights to the L matrix, forming the total intensity multipliers (GL). Thus, when this new matrix $(\hat{GL})$ is post-multiplied by Y, then direct emissions are obtained.

Another approach is to post-multiply GL by $\hat{Y}$, which allows determining the indirect emissions (F^i) originated from a given level of final demand.

$$F^i = GL\hat{Y} \qquad (12)$$

Both approaches yield the same amount of total emissions. However, they differ in terms of the entities to which they are allocated (Munksgaard and Pedersen, 2001; Gallego and Lenzen, 2005; Lenzen et al., 2007; Peters, 2008). In the first one, these are assigned to the sectors (industries) where the emissions were generated during production. Conversely, in the second one, these are allocated to the final consumers —which can be households, firms or the government— in terms of their final demand.

8.2 TABLES USED WITHIN THE REPORT

This report explores the level of emissions capture under a number of scenarios:

- Hypothetical or idealised future scope for Border Adjustment where all Annex B countries under the Kyoto protocol implemented GHG emission pricing policies for all of their industrial emissions combined with a corresponding Border Adjustment regime.
- Foreseeable scope where the Border Adjustment is restricted to only those economies where pricing schemes are being implemented and assuming further than the Border Adjustment is limited to those sectors covered by the EU ETS.

8.2.1 THE HYPOTHETICAL SCOPE FOR BORDER ADJUSTMENT

Table 2: The hypothetical scope for Border Adjustment – $MtCO_2e$

		CONSUMPTION					
		Consumed in priced economies		Consumed in unpriced economies		Total Production	
		MCO_2	% of Global	MCO_2	% of Global	MCO_2	% of Global
PRODUCTION	Priced production	11,303	35%	3,501	11%	14,804	46%
	Unpriced production	5,882	18%	11,615	36%	17,497	54%
	Total consumption	17,185	53%	15,116	47%	32,301	100%

KEY	Consumed in priced economies	Consumed in unpriced economies
Priced production	Priced economies' consumption of own goods	Remitted exports
Unpriced production	Adjusted imports	Unpriced economies' consumption of own goods

8.2.2 THE FORESEEABLE SCOPE FOR BORDER ADJUSTMENT

Table 3: The foreseeable scope for Border Adjustment – $MtCO_2$

		CONSUMPTION					
		Consumed in priced economies		Consumed in unpriced economies		Total Production	
		MCO_2	% of Global	MCO_2	% of Global	MCO_2	% of Global
PRODUCTION	Priced production	2,381	7%	1,156	4%	3,537	11%
	Unpriced production	2,244	7%	17,133	53%	19,377	60%
	Total consumption	4,625	14%	18,290	57%	22,915	71%

KEY	Consumed in priced economies	Consumed in unpriced economies
Priced production	Priced economies' consumption of own goods	Remitted exports
Unpriced production	Adjusted imports	Unpriced economies' consumption of own goods

8.2.3 RESULTS FROM A SECTORAL PERSPECTIVE

The following sectoral scopes have been explored as sensitivities around the benchmark 'Full ETS system' scope of Border Adjustment:

- **Two sectors** based on recent attempts at exploring Border Adjustment at a sectoral level via voluntary sectoral agreements; most notably the ferrous metal and cement sectors.
- **Six Sectors most at risk** from emissions leakage. The EU considers that all sectors covered by the EU ETS are at risk of emissions leakage. However, the literature typically identifies the following sectors as at most risk: lime and cement; basic iron and steel; refined petroleum; aluminium; inorganic basic chemicals; pulp and paper (Stephenson & Upton 2009, p.8).
- **All Sectors.** This represents the somewhat hypothetical situation that the existing emissions trading systems are extended to all sectors and that a full comprehensive Border Adjustment is introduced.

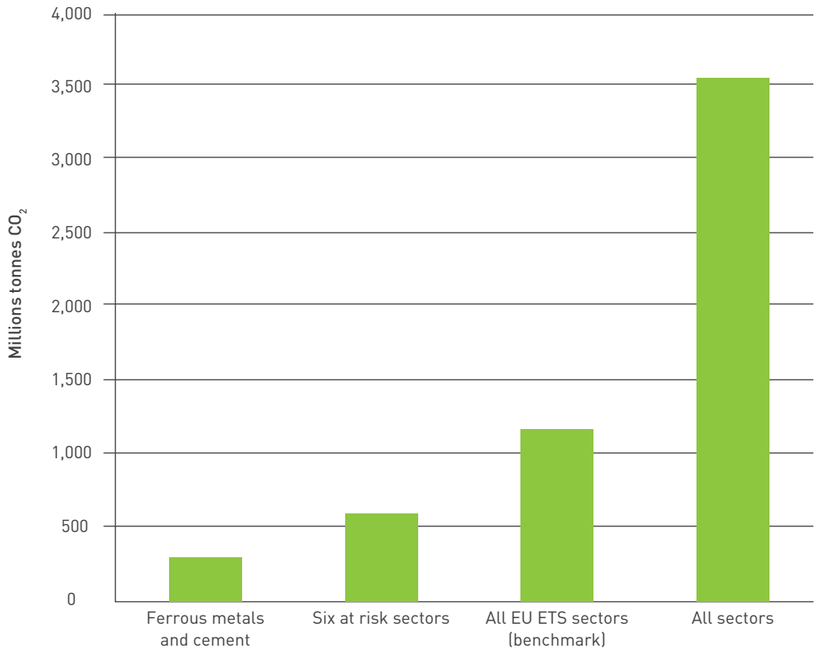
THE RESULTS SHOWN IN FIGURE 9 SUGGEST THAT A BORDER ADJUSTMENT THAT TARGETS LESS THAN THE BENCHMARK SCOPE (I.E. LESS THAN 'ALL EU ETS SECTORS') WOULD BE FOREGOING CONSIDERABLE EMISSIONS CAPTURE. IF ONLY THE FERROUS METALS AND CEMENT SECTORS WERE TO BE TARGETED, ONLY 14% OF THE BENCHMARK WOULD BE CAPTURED. IF THIS WAS EXTENDED TO THE SIX SECTORS AS MOST RISK, 25% OF THE BENCHMARK WOULD BE CAPTURED. THE RESULTS FOR THE 'ALL SECTORS' SENSITIVITY SUGGESTS THAT AN ADDITIONAL 54% OF EMISSIONS WOULD BE CAPTURED BY THE BORDER ADJUSTMENT IF IT (AND THE EMISSIONS TRADING SCHEMES) WERE EXTENDED TO NON-SCHEME SECTORS.

WHIST EXTENDING PRICING TO LESS AT RISK SECTORS WILL PROVIDE A DEMAND-SIDE INCENTIVE; IT IS NOT NECESSARILY THE CASE THAT SUCH SECTORS WERE AT RISK OF INVESTMENT LEAKAGE. THE DEGREE TO WHICH A SECTOR IS AT RISK DEPENDS ON THE LEVEL OF PRICING WITHIN THE EMISSIONS TRADING SCHEME AND THE EXISTENCE OR REMOVAL OF FREE ALLOWANCES.

Table 4: Sensitivity of emission capture due to sectorial scope – $MtCO_2$

	Two sectors (Ferrous metals and cement)	Six sectors at risk	All EU ETS sectors (benchmark)	All sectors
CO_2 emissions captured by existing trading scheme	332	577	1,224	3,537
% EU ETS sectors	27%	47%	100%	289%

Figure 9: Sensitivity of emission capture due to sectorial scope – $MtCO_2$



8.3 TABLES RELATING TO BORDER ADJUSTMENT DESIGN ELEMENTS

8.3.1 ESTIMATION OF BAT

The modelling took BAT to be the average emissions intensity of the EU's 10% least emitting ferrous metals sectors by output in dollars. This was found by ranking the 27 countries by emissions intensity, then calculating the cumulative output in USD until 10% of the output is reached (see table 5). The assumed BAT value was calculated dividing the cumulative emissions at this point by cumulative output as shown in Table 5. This method found BAT to be 134 tCO_2e per US$m.

8.3.2 THE SCOPE OF EMISSIONS INCLUDED

There are four scopes of emission which might be included:

1. Direct: The direct (i.e. on site) emissions associated with the production of products from the relevant sectors.
2. Direct + electricity: The direct (i.e. on site) emissions and the direct emissions associated with the electricity used on and off site.
3. Direct + power sector: The direct (i.e. on site) emissions and the emissions associated with the electricity sector used within all sectors that input into the production process.
4. Embedded (by sectors): The emissions embedded by the all the relevant sectors inputting into the production of the product.

The cumulative process whereby the emissions from the various sectors and trading partners are added to scope of the Border Adjustment system, until the Border Adjustment provides an equivalent scope to the emissions trading scheme (i.e. embedded by sector) is illustrated in Figure 10.

Table 5: Lowest emissions intensities of the EU's ferrous metals sectors

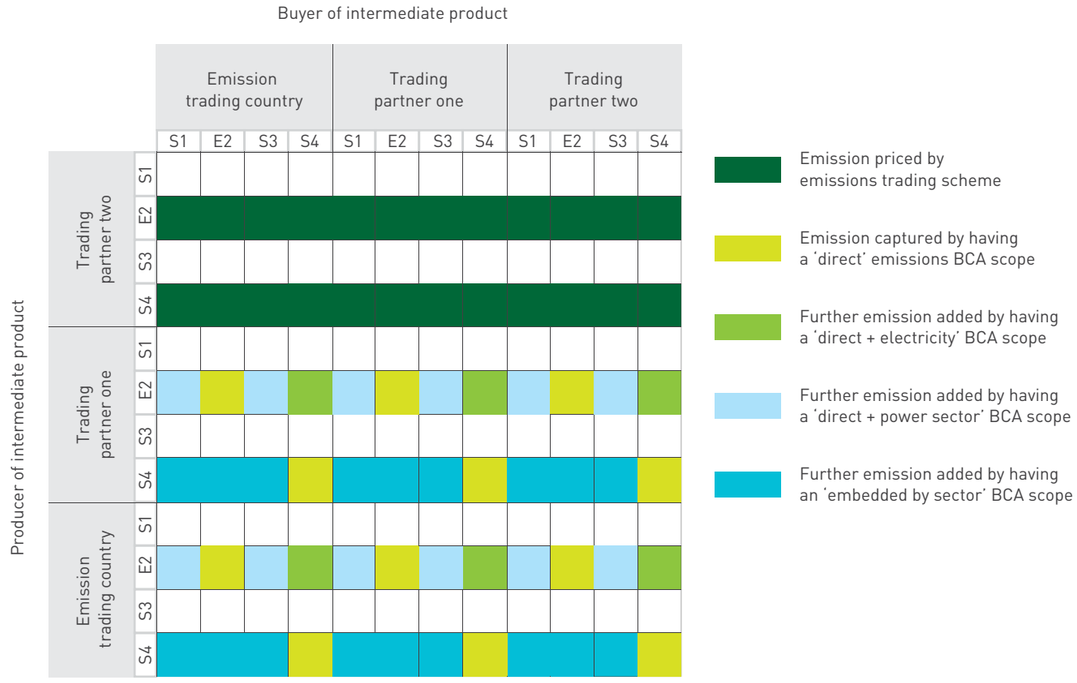
EU 27 Country	Emission intensity (tCO_2e/US$m)	Output (US$m)	Country emissions (tCO_2e)	Cumulative emissions (tCO_2e)	Cumulative output (tCO_2e)	% Cumulative Output	Emission intensity (tCO_2e/US$m)
Malta	0.2	19	3.8	3.8	19	0%	0
Estonia	10	4,410	4,410	4,414	460	0%	10
Lithuania	11	534	5,607	10,021	994	0%	10
Ireland	47	730	34,456	44,477	1,724	1%	26
Denmark	48	2,673	127,235	171,712	4,397	2%	39
Slovenia	64	2,603	167,373	339,085	7,000	2%	48
Greece	68	3,791	257,030	596,114	10,791	4%	55
Portugal	137	1,137	155,542	751,656	11,928	4%	63
France	154	41,316	6,366,796	7,118,452	53,244	18%	134
Slovakia (max)	1,147	3,007	3,448,127	83,414,428	290,369	100%	287

Figure 10 takes three counties (one which has emissions trading scheme in place and two of its trading partners which trade intermediary products both to it and one another) and three sectors (where sector 2 represents the electricity producing sector (E2), sector 4 a sector included in the emissions trading scheme (S4) and sectors 1 and 3 (S1 and S3) are not included in the emissions trading scheme).

Thus, the emission flows are added to the value chain as follows:

- No Border Adjustment (Dark Green) – This represents the present system whereby the emissions flows which are priced due to emission trading scheme are sold onto as inputs into trading partners but their equivalent imports are not.
- Direct scope – Only onsite emissions are included.
- Direct + electricity scope (Light Green) – Same as above, but emissions from the production of electricity which is used in the production of other trading scheme products are included (i.e. the electricity used to make a sector 4 product).
- Direct + power sector scope (Light Blue) – Same as above, but electricity emissions used in any other products are included (i.e. the electricity traded sector so any emissions used to make sector 1, 2 or 3 products are captured).
- Embedded (by sectors) scope (Turqoise) – Included any emissions from scheme sectors embedded in any products.

Figure 10: Illustration of the scope of emissions captured by a Border Adjustment



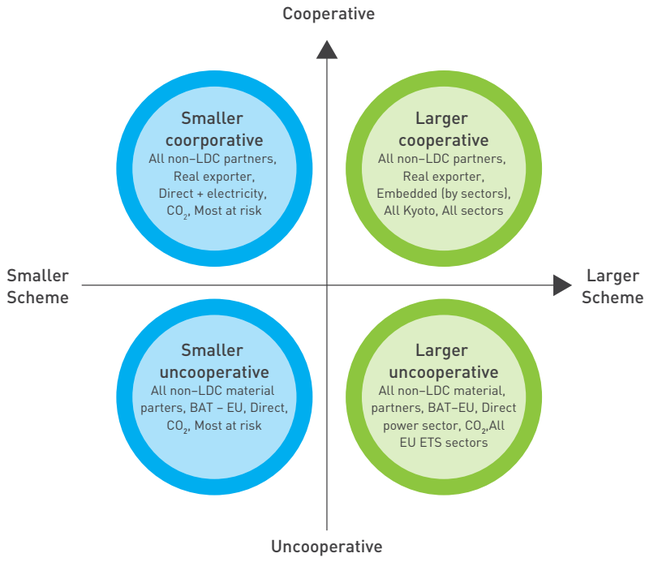
8.4 THE IMPORTANCE OF POLITICAL WILL

These various sensitivities suggest that the design of the Border Adjustment is important to how effective it can be. The potential for a future Border Adjustment to incorporate the most effective design elements depends to a greater or lesser degree on the political Will available to overcome some of the legal and political uncertainties and barriers. Very broadly, the political will required introducing a larger scale Border Adjustment needs to come internally from within the initiating country that has an emissions trading system scheme in place.

The political process required to introduce a Border Adjustment needs to come via corporation with those trading partners who have not got an emissions trading scheme on place.

The project team therefore sought to develop Border Adjustment scenarios based around these two overarching factors (scale of Border Adjustment and level or International Corporation). These are presented in Figure 11 below.

Figure 11: Political Border Adjustment scenarios

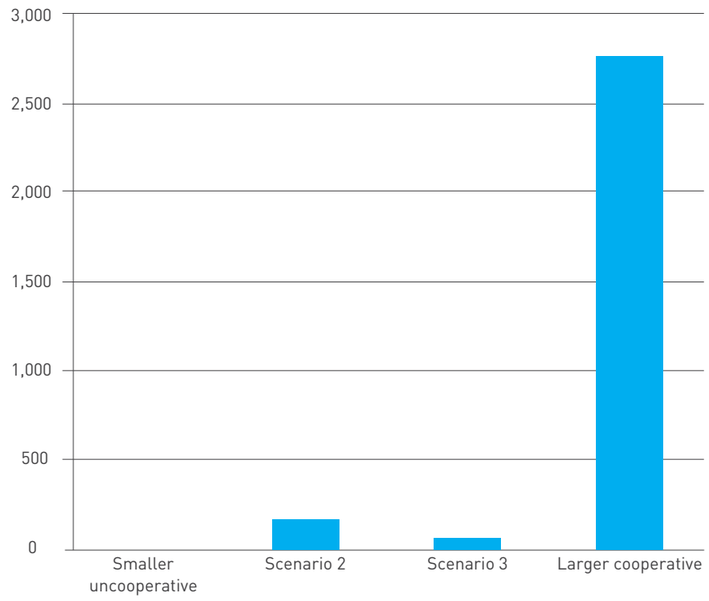


	DESIGN ELEMENT			
Geographical scope of scheme	All	All non-LDCs	All material partners	All non-LDC material partners
Emission intensity	BAT – EU	Average EU	Real – Exporter	–
Scope of emissions included	Direct	Direct + electricity	Direct + power sector	Embedded (by sectors)
GHGs included	CO_2	All Kyoto	–	-
Sectorial scope	Two sectors	Most at risk sectors	All EU ETS sectors	All sectors

Table 6: Emissions captured by political Border Adjustment (BA) scenarios – $MtCO_2e$

	SMALLER UNCOOPERATIVE		SCENARIO 2		SCENARIO 3		LARGER COOPERATIVE	
	TRADING SCHEME	BCA	TRADING SCHEME	BCA	TRADING SCHEME	BCA	TRADING SCHEME	BCA
	$MtCO_2$	$MtCO_2$	$MtCO_2$	$MtCO_2$	$MtCO_2$	$MtCO_2$	$MtCO_2$	$MtCO_2$
Emissions	2,299	2	6,356	100	2,299	17	6,356	2,776
Global total	22,915	22,915	22,915	22,915	22,915	22,915	22,915	22,915
% global total	10%	0.01%	27.7%	0.4%	10%	0.07%	27.7%	12.1%
% of trading scheme		0.1%		2%		1%		44%

Figure 12: Emissions captured by political Border Adjustment scenarios – $MtCO_2e$



THE RESULTS FOR THE POLITICAL SCENARIOS AS SHOWN IN TABLE 6 AND FIGURE 12 HIGHLIGHT THE SIGNIFICANT PART THAT POLITICAL WILL AND COOPERATION WILL PLAY IN INTRODUCING AN EFFECTIVE AND FAR REACHING BORDER ADJUSTMENT. IN TERMS OF PER CENT OF GLOBAL TOTAL GHG EMISSIONS CAPTURED WITHIN THE BORDER ADJUSTMENT, THE SCENARIOS RANGE FROM 0.001% (OR 0.1% OF THE TRADING SCHEMES WHICH IT RELATES) FOR THE SMALLER UNCOOPERATIVE SCENARIO; TO 12.1% (OR 44% OF THE TRADING SCHEMES WHICH IT RELATES) FOR THE LARGER COOPERATIVE SCENARIO. WHILST THE LEVEL OF CAPTURE CANNOT BE RELATED DIRECTLY TO THE EFFECTIVENESS OF A BORDER ADJUSTMENT, THIS RANGE OF CAPTURE LEVELS IS VERY LARGE.

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GLOSSARY

ANNEX B COUNTRIES/REGIONS

These countries are included in the Annex B to the Kyoto Protocol and have set emissions targets: Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland (including Liechtenstein), Ukraine, United Kingdom, United States of America.

ANNEX I COUNTRIES/REGIONS

These countries are party to the United Nations Framework Convention on Climate Change: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, United States of America. These countries committed themselves to the aim of returning individually or jointly to their 1990 levels of GHG emissions by the year 2000. By default, all other countries are referred to as Non-Annex I countries.

BEST AVAILABLE TECHNOLOGY (BAT)

The BAT figure is the average emissions intensity of the cleanest factories in the EU producing the product. The average is taken over the tenth percentile (by output in USD). The 27 countries are ranked by emissions intensity, then the cumulative output of both value, in dollars and emissions in tonnes is found. Ten per cent of the total output in value is calculated then the cumulative emissions at this point are divided by cumulative output to give an estimate of the BAT.

BORDER ADJUSTMENT / BORDER CARBON ADJUSTMENT (BCA) / BORDER TAX ADJUSTMENT (BTA)

A Border Adjustment is the import fees levied by carbon-taxing countries on goods manufactured in non-carbon-taxing countries. If country A exports to country B, who has introduced a Border Tax Adjustment country A will remit any GHG emission taxes they have imposed at their border to ensure a level playing field in international trade.

BORDER EMISSION LEVY (BEL)

A Border Emissions Levy would intend to reply upon GATT Article XX in its defence and therefore exempt adjustments where others have equivalent measures in place. Here, if country A exports to country B, who has introduced a Border Adjustment, country A would respond with an export tax equivalent to the import levy; thus eliminating the case for the import level for its exports. Country A has captured the revenues and can use them as they wish as with any other tax.

CAP

A cap is an upper limit on emissions.

CONSUMPTION BASED EMISSIONS

Allocate emissions to the consumers in each country. There is no standard and internationally agreed methodology to estimate these emissions. A Consumption Based Account measures the emissions required to satisfy final demand in each country. Where-as a Trade Adjusted Emissions Inventory takes production emissions and subtract emissions associated with exports and adds those for imports. This study considers the Consumption Based Account because this method takes account of feedback mechanisms where by emissions from country A that are exported to intermediate demand in country B and made into goods consumed by country A are traced and correctly assigned to country A.

DIRECT EMISSIONS

Direct emissions or 'on-site' emissions are defined at the point in the energy chain where they are released and are attributed to that sector.

DIRECT + ELECTRICITY EMISSIONS

The on-site emissions and the emissions associated with the generation of electricity both on and off site when producing the product. This only includes electricity emissions purchased or produced by the manufacturing outlet.

DIRECT + POWER SECTOR EMISSIONS

The on-site emissions and the emissions associated with electricity used within all sectors that input into the production process. All electricity through the whole supply chain would be captured.

EMBEDDED EMISSIONS

The emissions embedded by all the relevant sectors inputting into the production of the product.

EMISSIONS TRADING SCHEME (ETS)

Emissions trading schemes set emission allowances and allow trading between industrial sectors. At the end of a period of time, some operators may have surplus allowances, below their cap, if they have reduced their emissions. These surpluses can be sold to operators needing to buy more. In effect, an ETS ensures that emissions are capped at a set level.

ENVIRONMENTALLY EXTENDED MULTI-REGIONAL INPUT-OUTPUT (EE-MRIO)

An MRIO model with emissions output per industrial sector data as an extension. This allows calculation of the full global supply chain emissions associated with products to be determined.

EU-EMISSIONS TRADING SCHEME (EU ETS)

Launched in 2005, the EU ETS is an allocation and trading scheme for greenhouse gas emissions allowances within the EU. One allowance is one tonne of carbon dioxide equivalent. The scheme monitors the emissions of over 10,000 installations. A limit or 'cap' is set by Member State's Governments on the total amount of emissions allowed from all the installations and the allowances are then distributed between them. At the end of each year, operators can buy additional allowances (on top of their free allocation) or sell surplus allowances gained from making emissions reductions. The scheme means that emissions are capped across the EU.

EU ETS SECTORS

Phase 1 (2005-2007) of the EUEST covers energy activities, production and processing of ferrous metals, mineral industry (cement clinker, glass and ceramic bricks) and pulp paper and board activities in the EU 27 member states. Phase 2 (2008-2012) includes Norway, Iceland and Liechtenstein and will include aviation emissions from 2012.

EUROPEAN UNION (EU)

The following countries are member states of the EU: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

GENERAL AGREEMENT ON TARIFFS AND TRADE (GATT)

This agreement was first signed in 1947 and is a multilateral agreement regulating trade among countries. In 2012 it regulated trade among 153 countries.

GREENHOUSE GAS (GHG)

GHGs are the gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This causes the greenhouse effect. Water vapour (H_2O), Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O) and Ozone (O_3) are the main GHGs. Entirely human-made GHGs include Hydrofluorocarbons HFCs), Perflurocarbons (PFCs) and Sulphur Hexafluoride (SF_6).

GLOBAL TRADE ANALYSIS PROJECT (GTAP)

The Global Trade Analysis Project (GTAP) is a global network of researchers and policy makers conducting quantitative analysis of international policy issues. GTAP is coordinated by the Centre for Global Trade Analysis in Purdue University's Department of Agricultural Economics. One of the outputs of GTAP is a global data base describing bilateral trade patterns, production, consumption and intermediate use of commodities and services.

INDIRECT EMISSIONS

Indirect emissions refer to the energy use in end-use sectors and account for the emissions associated with the upstream production of the end-use energy. These include the emissions associated with the production of intermediate demands to the manufacturing industry making the product, the product's use and disposal.

LEAST DEVELOPED COUNTRIES (LDC)

According to the United Nations, the following countries are on the list of Least Developed Countries: Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, Djibouti, East Timor, Equatorial Guinea, Eritrea, Ethiopia, Haiti, Gambia, Guinea, Guinea-Bissau, Kiribati, Laos, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, Sao Tome and Principe, Samoa, Senegal, Sierra Leone, Solomon Islands, Somalia, Sudan, Tanzania, Togo, Tuvalu, Uganda, Vanuatu Yemen, Zambia.

MATERIALITY

Some Border Adjustment schemes introduce thresholds that exclude some 'non-material' flows. For this study, flows are excluded if they represent less than 0.5% of the total GHG emissions for that sector total.

MULTI REGIONAL INPUT OUTPUT (MRIO) MODELS

Am MRIO is a model built on economic accounting principles that makes the link between production and final demand. It allows analysis of a product's supply chain showing the increase output response of all industrial sectors to unit increase in demand of a single product.

$MTCO_2$ / MTCO2E

A measure of the weight of carbon dioxide in measured in mega tonnes. If all GHGs are included in the measure, carbon dioxide equivalence is used. This is the amount of carbon dioxide emission that would cause the same amount of radiative forcing as an emitted amount of a well mixed GHG.

PRODUCTION BASED EMISSIONS

Report GHG emission based on the system f economic activities in line with Gross Domestic Product. Under this system, international aviation and shipping are typically allocated to counties based on the operator of the vessel.

STRONG CARBON LEAKAGE

Strong carbon leakage is the increase in GHG emissions outside of country A due to climate policy in A.

SYSTEM LEAKAGE

A flow of emissions to countries where there is no commitment to reduce emissions.

TERRITORIAL BASED EMISSIONS

All emissions emitted from a country's territory. These emissions do not include those related to international aviation and shipping. These inventories are the basis of the UNFCCC regime.

UNFCCC

United Nations Framework Convention on Climate Change is an international environmental treaty signed in Rio in 1992 at the UN's Conference on Environment and Development (UNCED). One of the main outputs of the treaty was the establishment of national GHG inventories.

WEAK CARBON LEAKAGE

Weak carbon leakage is the GHG emissions produced outside of a county A's territory to meet the consumption of country A.

WORLD TRADE ORGANISATION (WTO)

Created in 1995 and implements the GATT. It provides a forum for negotiated additional reduction of trade barriers and for settling policy disputes, and enforces trade rules.

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The Centre for Low Carbon Futures is a collaborative membership organisation that focuses on sustainability for competitive advantage. Founded by the Universities of Hull, Leeds, Sheffield and York, the Centre brings together multidisciplinary and evidence-based research to both inform policy making and to demonstrate low carbon innovations. Our research themes are Smart Infrastructure, Energy Systems and the Circular Economy. Our activities are focused on the needs of business in both the demonstration of innovation and the associated skills development. Registered in the UK at Companies House 29th September 2009 Company No: 7033134.

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