Shipping and climate change: Scope for unilateral action

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1 Executive Summary

This report presents research on international shipping emissions and climate change undertaken at The University of Manchester by the Tyndall Centre for Climate Change Research and the Sustainable Consumption Institute (SCI). The research considers the role that the shipping sector could play in mitigating total global emissions, with a particular focus on assessing the potential for UK unilateral action. The report begins by quantifying the scale of the climate change challenge faced, considers the role of shipping in relation to mitigation, presents and assesses a range of apportionment methods for estimating CO_2 emissions from international shipping at a national scale, and quantifies the UK's emissions using these methods. Finally, the report discusses potential avenues for the UK in pursuing a unilateral mitigation policy aimed at the shipping sector that could compliment global and EU policy, in addition to summarising industry and policy stakeholder views on mitigation within shipping.

1.1 Scale of the challenge

The Copenhagen Accord recognises "global temperatures should not rise by more than 2°C". From a policy perspective, it is necessary to convert this overarching global temperature goal into meaningful emission targets for the purposes of taking appropriate decisions with regard to, for example, infrastructure, technology and society. The long-lived nature of some greenhouse gases requires a focus on cumulative emissions and doing so highlights the importance of taking measures urgently to reduce emissions across all sectors.

By comparing the shipping sector's current and projected emissions with overarching global emission scenarios it is possible to understand the challenge posed by absolute emission reduction. Figure 1.1 presents three sets of global cross-sector mitigation scenarios and compares them with global international shipping scenarios/projections. Under the global mitigation scenarios, the smaller the quantity of cumulative emissions, the greater the probability of avoiding dangerous climate change.

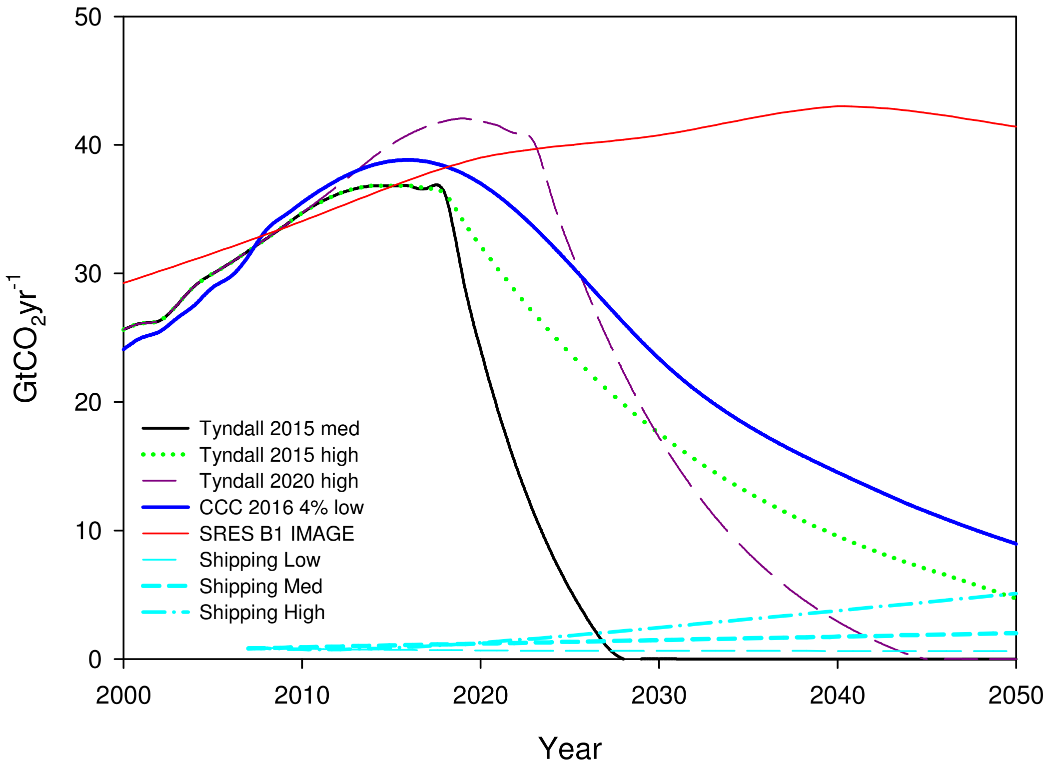


Figure 1-1: Five cross-sector global CO_2 mitigation scenarios plus three scenario/projections for shipping CO_2 emissions. The red scenario is the B1 SRES scenario with a very high probability of exceeding the 2°C future. The blue scenario is produced by the Committee on Climate Change and has the highest probability of not exceeding 2°C of all of their scenarios. The four scenarios other than SRES are characterised as providing a reasonable chance of not exceeding 2ºC.

Figure 1-1 illustrates that the range of shipping emission scenarios/projections either exceed or consume a very significant portion of the available budget by 2050 for all scenarios. Continued growth in CO_2 emissions from shipping is therefore not compatible with the goal of having a reasonable chance of avoiding 'dangerous climate change'. Therefore, a much greater emphasis is required on the short- to medium-term to ensure shipping emissions start to reduce as soon as is feasible. Delving deeper into the interdependencies of players within the shipping sector highlights the barriers faced in achieving the necessary emission reductions:

- The CO_2 emissions released by the shipping sector may already be a larger proportion of the global total than the CO_2 released by the aviation sector
- There is a high degree of uncertainty in global international CO_2 estimates for shipping (varying by over 50% depending on the method chosen)

- A significant shift away from conventional heavy fuel oil is considered unlikely in the short- to medium-term
- The complex, global nature of the shipping industry (see Figure 1-2) poses particular problems in incentivising low-carbon technologies and operational practices

Given this context it is important to explore how mitigation policy could be most effectively implemented. To do so, the broader policy context is considered.

1.2 Mitigation policy for shipping

For greenhouse emission targets set at any sub-global level to be meaningful all emitting sectors must be included or accounted for in some way. The Kyoto Protocol states:

> *"The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO) respectively."*

In other words, national emission inventories and targets do not, within the Protocol, need to include international aviation and shipping, but the ICAO and the IMO are to pursue emission reductions on a global level. However, given that targets such as the UK's 80% reduction target were premised avoiding 'dangerous climate change', they are only valid if they include the aggregate of all sectors. Therefore tackling and quantifying global and sub-global shipping emissions is a necessary element of addressing global climate change.

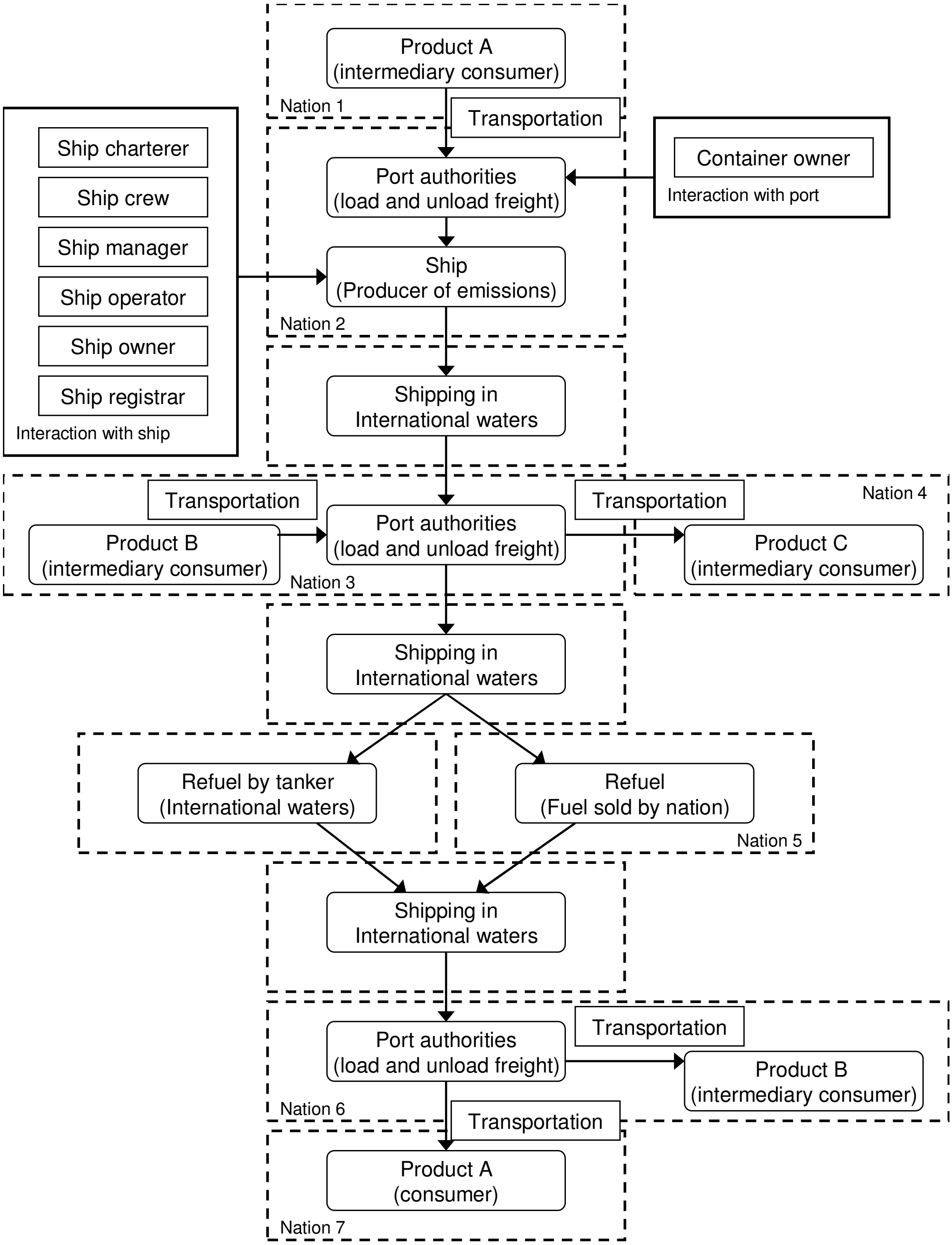


Figure 1-2: A schematic of the shipping system: an example for the shipping of goods between two landlocked nations highlighting the complex nature of shipping

The Marine Environment Protection Committee (MEPC) of the IMO is currently considering two types of measure to limit greenhouse gas emissions from shipping: technical and operational measures; and market-based instruments. The technical and operational measures under consideration are:

- Energy Efficiency Design Index
- Ship Energy Efficiency Management Plan
- Energy Efficiency Operational Indicator

The four market-based mechanisms under consideration by the MEPC are:

- An international fund for greenhouse gas emissions from ships
- An international fund with measures to improve ship efficiency
- A global emissions trading scheme for shipping
- A trading scheme for energy efficiency credits

The UK government has stated that it favours a global emissions trading scheme for shipping (Clark 2009). So too have the shipping chambers of Australia, Belgium, Norway, Sweden and the United Kingdom (Australian Shipowners' Association, Royal Belgian Shipowners' Association et al. 2009).

The EU is currently exploring potential mitigation options for shipping given its intention to include shipping emissions in its reduction commitment if the IMO has not agreed the implementation of a market-based mechanism by 31st December 2011. A recent report by CE Delft (CE Delft 2009) highlights four potential policy instruments that could be used by the EU:

- A cap-and-trade system for maritime transport emissions
- An emissions tax with hypothecated revenues
- A mandatory efficiency limit for ships in EU ports
- A baseline and credit system based on an efficiency index

In relation to UK policy, the Committee on Climate Change (CCC) advised the government that UK carbon budgets should not be tightened to account for shipping emissions (CCC 2008). The CCC's rationale for not making UK unilateral adjustment prior to an EU agreement is:

1. It is not clear how to measure the share of international shipping emissions to include in the adjustment
2. If the UK were to make a unilateral adjustment, resulting in a tightening of its carbon budgets, this could be offset by a relaxation of emission targets in other EU Member States, allowing these states to do less to ensure the EU targets are met. Here, there would be a financial implication for the UK with no environmental benefit

3. If there was a positive environmental impact, whereby other EU Member States did not relax their targets, the environmental benefit from UK unilateral action would only be small

However, in its recent report on controlling greenhouse gas emissions from shipping (EAC 2009a), the Environmental Audit Committee (EAC) argued against the CCC's objections to UK unilateral adjustment of its carbon budget, stating that if the UK were to act in advance of other nations, the UK could help break diplomatic obstacles and encourage other nations to follow suit. Nevertheless, the EAC, CCC and UK Chamber of Shipping advised against the UK taking unilateral action to reduce its international shipping emissions and the government's position was therefore in favour of an international solution, working through the IMO and alongside other EU member states.

This report explores the potential for UK unilateral adjustment of its carbon budgets to reflect its share of international shipping emissions prior to an EU agreement and for UK unilateral action to complement any global or EU schemes to reduce shipping emissions.

1.3 ***Apportionment for shipping***

Viewing current CO_2 scenarios/projections from the shipping sector alongside the four pathways in Figure 1-1 that have the greatest chance of not exceeding a temperature rise of 2°C emphasises the urgency with which shipping needs to adopt mitigation measures to complement those in other sectors. By undertaking UK unilateral action, there is potential to drive the shipping system towards lower-carbon practices in the short- to medium-term, whilst improving port infrastructure, driving UK shipping innovation and giving the UK an advantage as mitigation policies are eventually rolled out elsewhere on a larger spatial scale. However, such unilateral action requires international shipping emissions to be apportioned to enable a nation to: determine its own share of these emissions; compare these emissions with the emissions produced by other sectors; include international shipping within its domestic emission budgets to ensure cross-sector emission reductions remain consistent with overarching targets; monitor its international shipping emissions over time.

Nations currently estimate their share of international shipping emissions based on the bunker fuel sold at their ports and report it as a memo item within the inventories they submit to the UNFCCC. The EAC recently emphasised the inadequacy of apportioning UK shipping emissions on this basis stating that the UK's bunker sales did not represent the UK's share of global emissions. Furthermore, despite data being publicly available, using bunker sales to estimate CO_2 is not comprehensive as not all nations report fuel statistics to the UNFCCC and under-reporting occurs in some nations. Given these factors, alternative methods require consideration to allow the UK to understand its share of international shipping emissions and, if deemed appropriate, to make unilateral adjustment to its carbon budgets and targets even if shipping emissions are included within an EU or global trading scheme.

There are two main practical approaches to apportionment – top-down and bottom-up. Top-down apportionment shares out an annual international shipping emissions estimate using a chosen apportionment methodology. Bottom-up apportionment provides an emissions estimate for a nation, determined within a set location using specific ship movement and ship characteristics data. Potential methods are listed in Table 1-1.

Table 1-1: Apportioning methods proposed within the literature

	Apportionment method	Approach	UNFCCC[a]	Entec[b]	Anderson et al[c]
1	No apportionment		▨		
2	Reported bunker fuel sales	Bottom-up	▨	▨	
3	Reported fuel consumption	Top-down		▨	
4	National emissions (as a proportion of global emissions)	Top-down	▨	▨	
5	Location of emissions (within 12-mile and 200-mile zones)	Bottom-up	▨	▨	
6	Nationality of the transporting company ship registration	Bottom-up	▨	▨	
7	Freight tonnes loaded or unloaded	Top-down		▨	
8	Port of departure or destination of cargo and passenger	Bottom-up	▨	▨	
9	Exporter (producer) or importer (consumer) of the cargo	Bottom-up	▨		
10	Owner of the cargo	Bottom-up	▨		
11	A nation's proportion of global GDP	Top-down			▨

[a] (UNFCCC 1996a), [b] (Entec UK Ltd 2005), [c] (Anderson, Bows et al. 2008)

If a top-down apportionment method is chosen, then the global international shipping emissions to be shared out between nations need to be estimated using one of three approaches:

1. Using global international bunker fuel sales figures
2. Using assumptions regarding global fleet activity
3. Using data on ship movements within a set geographical location

Estimates of CO_2 emissions over the past 40 years taken from selected literature sources are shown in Figure 1-3. As estimates can vary substantially depending on the study and type of model used, this may lead to very different estimates for international ship emissions at a national scale if top-down apportionment is used. This report uses the IMO's annual international shipping emissions activity-based estimate (IMO 2009) to apportion between nations under the proposed top-down apportionment methods.

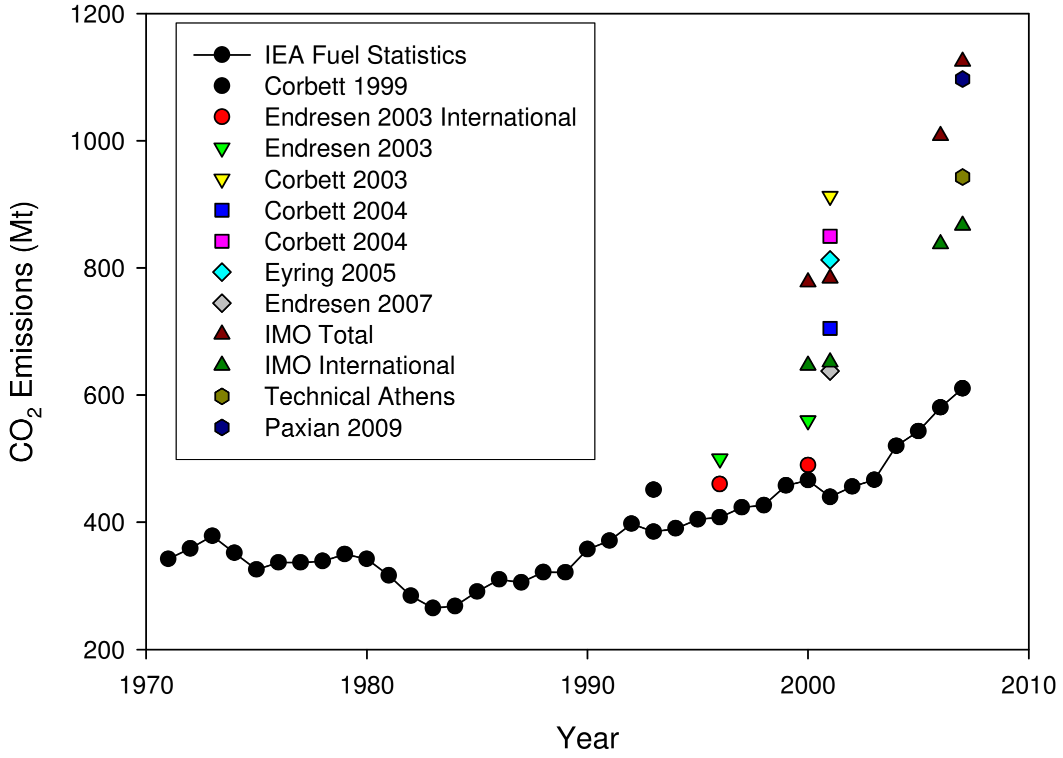


Figure 1-3: Estimated CO_2 release for total and international shipping emissions

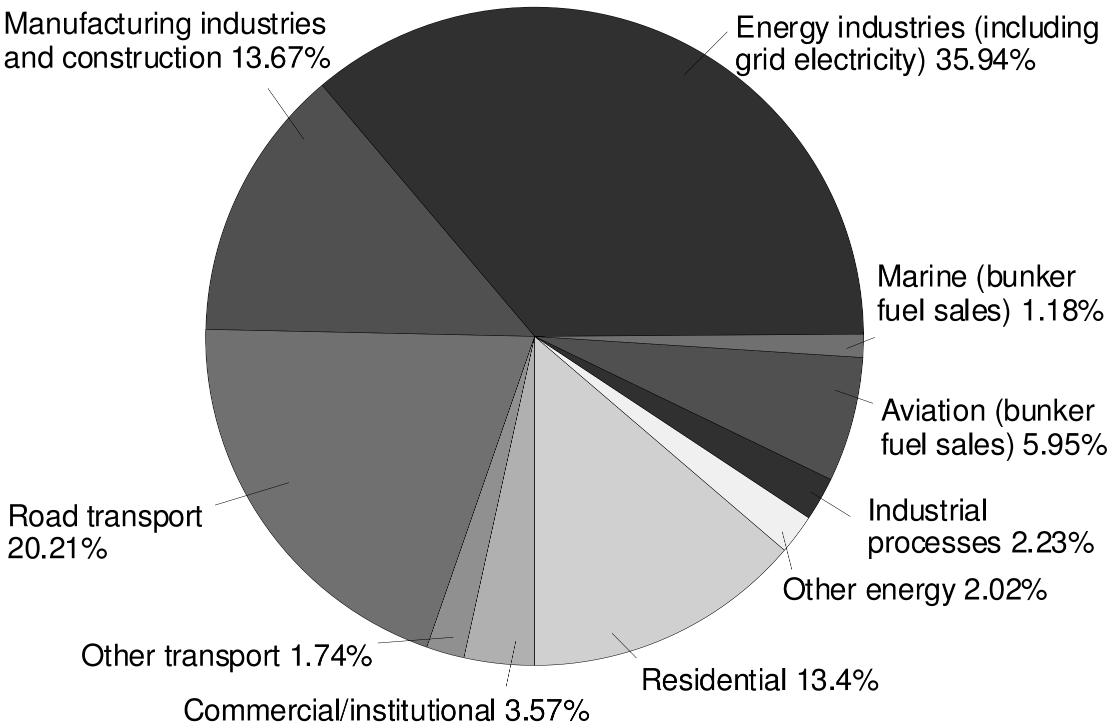
1.4 UK shipping emissions quantification

UK CO_2 emissions from international shipping are estimated and presented in Table 1-2. The methods apportion a share to the UK of the IMO's activity-based estimate of 838 Mt CO_2, using the proposed apportionment methods if possible. The range for 2006 is **7.1 MtCO_2** (method 2, bunker fuel sales) to **42.1 MtCO_2** (method 9a – value of UK imports). As the bunker fuel sales method is the one currently reported as a memo item in the inventory submitted to the UNFCCC, UK shipping emissions could be six times higher than currently estimated.

Table 1-2: Top-down proxy apportionment methods to determine UK's apportionment of CO_2 emissions from international shipping

Apportionment method		UK shipping emissions	
		Per cent of global	Mt CO_2
1	No apportionment		
2	Reported bunker fuel sales		7.05
3	Reported fuel consumption	*Not considered*	
4	National emissions	1.93	16.16
5	Location of emissions	*Bottom-up only*	
6	Flag of ship	1.23	10.30
7a	Freight tonnes loaded	2.95	24.70
7b	Freight tonnes unloaded	4.92	41.26
8	Port of departure or destination of cargo	*Bottom-up only*	
9a	Exporter (producer) of cargo	3.75	31.40
9b	Importer (consumer) of cargo	5.02	42.05
10	Owner of the cargo	*Bottom-up only*	
11	National GDP	4.98	41.76

In 2006, the UK reported national emissions as 554.87 Mt CO_2 to the UNFCCC (excluding land use and land use change) (UNFCCC 2010) and in a separate memo, reported emissions from aviation bunker fuel sales as 35.56 Mt CO_2 (DECC 2010) and emissions from marine bunker fuel sales as 7.05 Mt CO_2 (UNFCCC 2010). If, for reasons of transparency, these emissions from international shipping are included alongside international aviation emissions in the UK's carbon budgeting, then national emissions would increase to 597.48 Mt CO_2. Furthermore, when constructing future budgets and targets consistent with the 2°C goal, the UK would have to include shipping in its carbon reduction strategy. This would require steeper cuts in other sectors, if emissions from aviation and shipping do not fall to the same extent as other sectors[1]. However, using the upper estimate of 42.05 Mt CO_2 (method 9) for the UK's international shipping emissions results in the national emission inventory increasing to 632.48 Mt CO_2 – a 5.9 % increase. Using this apportionment method the UK would need to make even steeper cuts in other sectors, as shipping emissions could be a higher proportion than previously assumed. Continuing this out to 2050, sectors other than international shipping and aviation would need to reduce their emissions by more than 80% to "leave space" for international shipping and aviation emissions. Figure 1-4 shows two pie charts that split the UK's national emission inventory for 2006 into sectors. In the first, international shipping estimates are based on bunker fuel sold and, in the second, on freight imported so as to illustrate the impact of choosing an alternative apportionment method.



[1] Note that the UK would still have to make steeper cuts to other sectors if shipping emissions are included alongside aviation emissions in an EU scheme

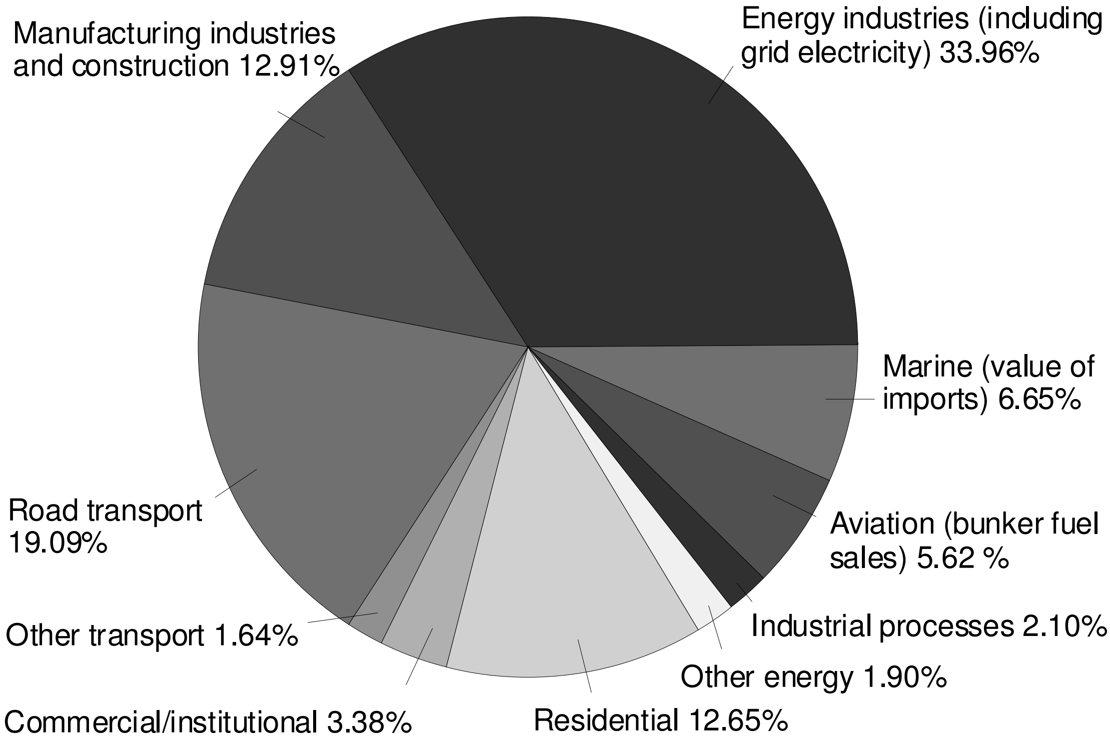


Figure 1-4: UK sector split of CO_2 emissions, apportioning international shipping emissions using bunker fuel sold and value of UK imports

1.5 *Assessing apportionment*

Given the dependence of the UK CO_2 estimate on the chosen apportionment method, each method is assessed in relation to data cost, data quality and fairness in order to understand which might be the most appropriate for the purpose of adjusting carbon budgets to include shipping and developing mitigation policy.

In terms of data quality, bottom-up apportionment methods (including apportioning based on the flag of a ship, location and between importer and exporter) are considered to be more comprehensive and accurate for the individual nations concerned. This is because the emissions are based on the movements and characteristics of individual vessels and their port callings. However, the data required is costly and requires annual updates. If data cost is a pivotal issue for policymakers, then top-down proxies could be favoured for methods using a bottom-up models, or a top-down method could be used instead.

With regard to fairness, this report argues that a fair apportionment method is one that apportions emissions to the nations responsible for those emissions. The current method used to apportion shipping emissions based on bunker fuel sales is not considered to be an appropriate apportionment method on this basis. Although data is readily available for most nations, this method does not fairly represent national shipping activity as it disproportionally allocates responsibility for emissions to conveniently located coastal nations offering relatively cheap fuel. Likewise, apportionment methods based on flag of ship and location of emissions were also considered to be unfair.

If shipping is viewed as a complex system consisting of a number of interdependent players then it is plausible to suggest that consumers of shipped goods, perhaps in combination with producers of these goods, are the dominant players within the system and therefore most responsible for emissions. To reflect this dominance, emissions would need to be apportioned on the basis of national imports or exports (method 9). This method and the other methods considered to be most 'fair' in this report, all tend towards the upper estimates for the UK's share of international shipping emissions (all >30MtCO_2 or > 5% of UK CO_2).

Although apportioning emissions on the basis of imports or exports may be the most equitable in theory, implementing it in practice requires data on the weight of goods exported (produced) and imported (consumed) by each nation, the distance that goods are shipped and ship efficiency/carbon intensity, and such data is not readily available. Thus, as stated earlier, top-down proxies can be used instead. However, only when consideration is given to how the method can be implemented in order to monitor the success or otherwise of a mitigation policy, does it become clear that not all of the top-down proxies will be adequate. For example, a top-down proxy based on value or weight of imports and exports could be used for method 9, but it will not be able to capture any improvements in, for example, the efficiency of ship routes/distance, ship carbon intensity and port congestion. Furthermore, as profit is not necessarily proportional to shipping emissions and, for the same reasons, neither is the value of imports or exports, the value proxy also has limited use. If a proxy is to be used, it must include a measure of the tonne-kilometres (tkm) moved between nations (based on goods traded between nations and the distance between the nations by sea) and the emission factors for vessels on an annual basis in CO_2/tkm. The proxy would capture improvements to the efficiency of shipping routes, the distance travelled, congestion etc.

An alternative to choosing one apportionment regime is to combine two or more to reflect responsibility being spread among a number of players within the shipping system. This raises issues of determining which entities should be classified as players and, assuming ranking is possible, the appropriate method(s) to use for appropriately ranking their responsibility. The idea of using a hybrid of methods is explored in relation to practical policy implementation.

1.6 Policy implications of particular apportionment methods

The complex nature of the global shipping sector, with its numerous players spread across the globe, makes shaping appropriate policy particularly difficult. Shipping requires a step-change in policy to begin the urgent process of decarbonisation. With influence over its imports and exports of shipped goods, waters and bunker fuel sold, the UK has the potential to take a unilateral approach to reduce its shipping emissions. However, policies tackling one part of the system must not induce rebound effects elsewhere. It is therefore important to consider what is to be incentivised/penalised (for example, low-carbon fuels, fuel efficiency, consumption) and where in the system this can best be achieved.

To develop strategies to successfully mitigate shipping emissions, UK policymakers first need to consider what aspect of the shipping system they can reasonably influence and then understand the magnitude of the UK's international shipping emissions compared to both global shipping emissions and other UK sectors. The UK can influence:

- Port operations (methods 5, 7, 8, 9)
- Quantity of imports/exports (methods 7, 8, 9)
- Amount by value of imports/exports (methods 7, 9)
- Ultimate destination or origin of imports/exports (methods 8, 9)
- Ownership of goods (method 10)
- Type of fuel sold (method 2)
- UK waters (methods 5, 7, 8, 9)

It has limited unilateral influence over the shipping emissions associated with:

- The flag or registration of a vessel (method 6)

- The construction or type of vessel (method 6)
- The quantity of fuel sold for international shipping (method 2)
- Ownership of goods if non-UK residents (method 10)
- Scaled national emissions (method 4)
- Scaled GDP emissions (method 11)

Given the combined assessment of data cost, quality, fairness and practical implications of the apportionment regimes, the most promising to be able to monitor and influence emissions through unilateral policy are likely to involve a hybrid of approaches. Methods 4 (national emissions), 6 (flag of ship) and 11 (GDP) are therefore omitted on the basis that they can not provide any measure of impact. Moreover, although method 6 (flag of ship) could be used to monitor and influence improvements in ship design, unilateral national policies are unlikely to bring this about, with global regulations and legislation preferable. Method 2 is also rejected for its lack of measurable impact, if it is the quantity of fuel sold that is to be monitored and influenced. However, it is viable to use method 2 if it is the type of fuel, rather than the quantity, that is targeted. The apportionment methods that offer the most promise for further consideration can be grouped together as those linked to the movement of goods (7,8,9,10), then location of emissions (method 5) and fuel sales (method 2). The implications of UK unilateral policy, plus the data and fairness assessments are summarised for each apportionment method in Table 1-3.

Table 1-3: Summary of the consequences of UK unilateral influence over the shipping system in relation to all the apportionment regimes.

Method	Data Assessment	Fairness	Positive consequences of unilateral action	Negative consequences of unilateral action
1 (No apportionment)				
2 (Fuel sales)	Publicly available; straightforward assessment requiring accurate national estimate for total bunker fuel sold	Not ultimately responsible for supply and demand of shipping; gains profit from selling fuel; coastal nations penalised but additional costs due to imposed taxes could be passed on; unrepresentative of shipping activity driven by consumption or production	If incentivised to produce alternative or low carbon fuel, could lead way in reducing CO_2 from ships	If taxed, ships would refuel elsewhere (in the absence of an EU scheme)

Table 1-3 continued.

3 (Fuel consumed)	Depends on choice of which actor is 'responsible' for the activity; data may be costly but available	Depends on 'activity' chosen.	Depends on 'activity' chosen.	Depends on 'activity' chosen.
4 (National emissions scalar)	Publicly available; straightforward top-down assessment requiring accurate estimate for CO_2 emissions from international shipping	Unfair given the influence of population and wealth on this figure (poor populous nations may have high emissions but low shipping activity)	Partially incentivises a reduction in national emissions	Changes in shipping efficiency, alternative fuels, technology improvements would not be reflected when using this method, therefore it does not directly incentivise the shipping sector
5 (Location of emissions)	Available but costly, bottom up model required	Omits emissions outside of national waters. If additional international emissions are pro-rated on the basis of a nation's proportion of emissions within its waters, this could unfairly allocate a high proportion to coastal nations or nations with highly active shipping routes.	Could incentivise less congestion and operational practices in UK waters, reducing fuel consumption for users; UK importers may choose more efficient shipping routes to reduce costs	May discourage ships passing the UK refuelling in the UK and may result in ships unloading in Rotterdam and transporting goods by land (in the absence of an EU scheme)
6 (Flag of ship)	Publicly available (if using a top-down estimate); requires additional data (bottom-up model)	Unfairly reflects a nation's shipping activity and not dominant in the system	UK registered ships become more efficient or use lower carbon fuels	Ships register elsewhere to avoid regulation
7 (Goods loaded/unloaded by value or weight)	Publicly available (if using a top-down estimate)	Ignores landlocked nations, journey lengths and only accounts for 'goods handled'	Encourages lower consumption of goods arriving by ship, either in terms of weight or value	Pushes loading, and transhipment unloading to unregulated ports and encourages higher carbon land-based transfer of goods
8 (Port of departure [or destination] of cargo)	Requires additional expensive voyage data (bottom-up model)	Ignores landlocked nations and type/final destination of goods traded, but considers journey length and ship type	Incentivises lower congestion and lower-carbon operational practices around UK ports; encourages efficient travelling to destination; drives innovation; incentivises shorter journeys; incentivises cold ironing	Pushes freight onto land-based modes (assuming no regulation on land-based freight)

Table 1-3 continued.

9a (Exporter/producer of cargo)	Top down on the basis of value, data publicly available. Could also be top-down based on tonnes but no data. Bottom-up considering length of voyage and nation of consumption (and developing the relationship between the two); data expensive	Assumes producer is either ultimately responsible for shipping or most responsible; omits journey length unless using a bottom-up approach; includes landlocked nations	If using a bottom-up approach, incentivises lower congestion and lower-carbon operational practices around UK ports; encourages efficient travelling to destination; drives innovation; incentivises shorter journeys; cold ironing to reduce fuel use	Raises costs of exporting. Top-down proxy would fail to capture improvements made using the bottom-up approach
9b (Importer /consumer of cargo)	Top down on the basis of value, data publicly available. Could also be top-down based on tonnes but no data. Bottom-up considering length of voyage and nation of consumption (and developing the relationship between the two); data expensive	Assumes consumer is either ultimately responsible for shipping or most responsible; omits journey length unless using a bottom-up approach; includes landlocked nations	If using a bottom-up approach, incentivises lower congestion and lower-carbon operational practices around UK ports; encourages efficient travelling to destination; drives innovation; incentivises shorter journeys; cold ironing	Pushes freight onto land-based modes (assuming no regulation on land-based freight). Top-down proxy would fail to capture improvements made using the bottom-up approach
10 (Owner of the cargo)	Bottom-up considering length of voyage and owner of the cargo which may change during transportation; data expensive	Assumes the cargo owner is either ultimately responsible or most responsible; includes landlocked nations; overly reliant on time of change in ownership	Incentivises lower congestion and lower-carbon operational practices around UK ports; encourages efficient travelling to destination; drives innovation; incentivises shorter journeys; cold ironing	A country may seek to change ownership prior to shipping; pushes freight onto land-based modes
11 (GDP scalar)	Publicly available; straightforward top-down assessment requiring accurate estimate for CO_2 emissions from international shipping	Given most goods imported either arrive by, or involve shipping at some stage, this could fairly represent shipping if consumption is considered to be the main driver of shipping emissions	Partially incentivises a reduction in national GDP which could, as long as the fossil-fuel economy remained, lead to lower national emissions	Changes in shipping efficiency, alternative fuels, technology improvements would not be reflected, thus does not incentivise shipping sector, but incentivises a nation to lower its GDP

Global policy measures are preferable for influencing some aspects of the shipping system, for example ship design. However, if complementary unilateral mitigation policies were put in place, the most promising appear to be those that would tackle:

1) Goods imported/exported: policies could be implemented that could lower congestion, incentivise lower-carbon operational practices, drive innovation, incentivise shorter journeys, encourage more local consumption/production and

lower overall consumption, but could also push freight onto land-base modes (assuming no accompanying regulation).

2) Location of emissions: could result in lower congestion at UK ports or incentivise more efficient routing, but may result in ships loading/unloading at nearby ports and moving freight by land.

3) Fuel sales: could incentivise low-carbon fuels, but any higher fuel cost could result in ships simply purchasing fuel elsewhere.

Thus a hybrid of methods, as opposed to choosing one in isolation, may be the most appropriate for developing and monitoring unilateral policy measures. For example, one hybrid method could incorporate emissions associated with a proportion of imports and exports and monitor its progress using a top-down proxy (method 9a and b) with additional bottom-up estimated geographical trade information. Another could target emissions in the UK's waters and monitor its progress by apportioning emissions using a bottom-up model of emissions released in national waters (method 5), then allocate the remaining global shipping emissions to nations on the basis of a top-down proxy for value of imports. Further research will explore the potential of such hybrid approaches for policymaking in relation to shipping.

1.7 Stakeholder views

On 1 March 2010, the Tyndall Centre and the SCI hosted a shipping workshop in London attended by 26 experts from the UK and European shipping sector. The workshop discussed the issues highlighted in this report. Although participants were keen to tackle shipping's contribution to climate change, they suggested that there was little appetite in many parts of the shipping sector for greenhouse gas emissions reduction, particularly as the release of sulphur emissions by ships is known to have a cooling effect. Furthermore, stakeholders highlighted that shipping contributes a small percentage of global CO_2 emissions, and therefore some participants considered that the attention paid to shipping was unwarranted especially as global trade and the economy strongly depend on shipping.

Overall, there was little support from stakeholders for UK unilateral action on controlling shipping emissions. For example, they considered that a carbon tax on fuel would result in a negligible reduction in emissions given the UK could only impact a minor proportion of the total international shipping emissions. Reducing congestion in ports through regulatory instruments was viewed as a good idea, but difficult to achieve in practice.

Participants expressed differing views with regard to apportionment. Some participants favoured apportionment as a means of emphasising the urgent need for the shipping sector to control its emissions and allowing nations to monitor their shipping. However, the majority of stakeholders opposed the idea of apportionment, and instead argued that all international shipping emissions should be controlled through a sector-based emissions trading scheme. If nations wish to establish what their share of international emissions are, then a simple method of apportioning, such as on the basis of GDP or fuel sales was considered by some stakeholders to be sufficient.

Apportioning shipping emissions to the exporter (producer) and importer (consumer) of shipped goods was supported by some participants as a fair approach. However, an alternative view expressed by some of the stakeholders was that the ships themselves were ultimately responsible for the emissions and therefore emissions should be apportioned on this basis (method 2).

Prior to addressing mitigation policy instruments, participants were asked to identify measures that could be taken by the UK acting unilaterally to tackle shipping emissions. In the first instance, many examples were given, although some stakeholders were of the view that there was little point to even discussing unilateral action. The measures identified can be summarised as follows:

i. Carbon tax on fuel for shipping
ii. Support and infrastructure for cold ironing
iii. Improved port infrastructure and operational management
iv. Measures to address ship speed both in relation to emissions within UK waters and deliver times
v. Carbon labelling for goods to include all freight modes
vi. Funding for RD&D
vii. Improved fuel and emission reporting techniques

Summary

Global policies for tackling shipping emissions are appropriate and necessary for mitigating the greenhouse gases associated with shipping. However, given the urgency with which emissions must start to reduce on aggregate, this report has explored complementary unilateral national mitigation policies aimed at the shipping system. Combining an assessment of data quality, cost and fairness of the various apportionment methods appropriate for monitoring unilateral policy measures, this project concludes that the fairest and most practical unilateral measures require a hybrid of apportionment methods. Further research will explore the potential for a hybrid of apportionment methods to support unilateral policy measures in terms of mitigation potential and determine the potential for unilateral policy to complement global mitigation measures to urgently tackle shipping emissions.

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2 Introduction

This report summarises research undertaken at The University of Manchester by the Tyndall Centre for Climate Change Research and the Sustainable Consumption Institute (SCI) on international shipping emissions and climate change during early 2010. The research explores the implications of global climate change and associated emission pathways for UK shipping mitigation policy.

Along with the aviation sector, shipping is one of the fastest growth sectors in terms of greenhouse gas emissions. In 2007, international shipping emissions were estimated to be 2.7% of global carbon dioxide (CO_2) emissions (IMO 2009). The global community recognises the need to reduce global emissions in order to limit the chance of experiencing dangerous climate change (taken here to constitute an increase in global average pre-industrial temperature of 2℃ or more). Given this context, Section 3 of this report discusses what global emissions pathways should be adopted to ensure a reasonable chance of not exceeding the 2°C threshold associated with 'dangerous climate change' as well as what implications these will have for the shipping sector.

The International Maritime Organization (IMO) is currently considering various policy measures for reducing shipping emissions. Furthermore, the European Union (EU) has stated that if no international agreement on the reduction of international shipping emissions is reached, either through the IMO or United Nations Framework Convention on Climate Change (UNFCCC), by the end of 2011, then the EU should aim to implement a policy measure of its own by 2013 to tackle EU shipping emissions. Section 4 provides a brief summary of discussions on international policy measures to reduce emissions from international shipping and provides the current UK policy position.

If EU or UK policy measures are introduced to control shipping emissions then there will need to be an understanding of how responsibility for global shipping emissions will be shared. Apportionment of annual international shipping emissions is defined as the assigning of a share of these emissions between all nations. In its recent report on greenhouse gas emissions from shipping, the UK's Environmental Audit Committee (EAC) emphasised the inadequacy of apportioning shipping emissions on the basis of bunker fuel sales. But at the same time, the EAC and the Committee on

Climate Change have highlighted the challenges in formulating an appropriate alternative apportionment methodology. Section 4 offers a definition of apportionment, presents and assesses a range of apportionment methods for estimating CO_2 emissions from international shipping at a national scale, and quantifies the UK's emissions using these methods. Finally, it discusses potential avenues for the UK in pursuing a unilateral mitigation policy aimed at the shipping sector that could compliment global and EU policy.

On 1 March 2010, the Tyndall Centre and SCI hosted a shipping workshop in London, attended by around 25 stakeholders from the UK and European shipping sector. Section 6 provides a summary of the workshop and the views expressed by participants on the topics discussed in this report and Section 7 concludes the report.

3 Shipping and Climate Change

The Copenhagen Accord (UNFCCC 2009) recognises "global temperatures should not rise by more than 2°C". Although it is not clear in the Accord what this temperature rise is in reference to, it is generally accepted that a 2°C rise above pre-industrial levels is associated with a threshold between 'acceptable' and 'dangerous' climate change, and therefore it is this 2°C rise that global efforts are focused on avoiding. There is a considerable body of research exploring the potential impacts a 2°C temperature rise could have on global ecosystems and society, which is brought together within the Intergovernmental Panel on Climate Change's (IPCC's) fourth assessment report (ARD) on Impacts, Adaptation and Vulnerability (IPCC 2007). Some of the key likely impacts brought about by such a rise in temperature (1.2°C above current global temperatures) include:

- the destruction of the vast majority of coral reefs;
- millions of people becoming vulnerable to flooding and drought;
- the potential of the land becoming a source rather than a sink of carbon and;
- the increasing likelihood of reaching a climate 'tipping point'.

Furthermore, research published since the IPCC AR4 report suggests many of these impacts have been underestimated (Smith, Schneider et al. 2009), which further underlines the critical importance of avoiding this 2°C threshold.

From a policy perspective, it is necessary to convert this overarching global temperature goal into meaningful emission targets for the purposes of taking appropriate decisions with regard to infrastructure, technology and society. Historically, the framing of these emission targets has tended towards the longer-term: UK's 80% reduction in greenhouse gases by 2050; the EU's 60-80% reduction in greenhouse gases by 2050; the 50% global reduction in greenhouse gases discussed in Bali. However, the long-lived nature of some of the greenhouse gases, particularly N_2O and CO_2, renders these long-term targets inappropriate, as it is the cumulative emissions of those gases, rather than the point they reach in 2050, that is of crucial importance. This alternative framing has underpinned much of Tyndall's energy-related research to date (Bows, Mander et al. 2006; Anderson et al. 2008; Bows, Anderson et al. 2009) and has added weight to the argument that short-term and urgent measures to reduce emissions pay significant dividends in the longer-term (Anderson and Bows 2008; Meinshausen, Meinshausen et al. 2009; Macintosh 2010).

It is from the cumulative emissions framework that this project addresses the shipping sector. Rather than assuming that technological solutions available in the longer-term will deliver adequate emissions savings for the shipping sector, this framework addresses the following questions:

1. By how much is it currently assumed the shipping sector's emissions will grow in the future?
2. How does this compare with the 'necessary' action required to mitigate to avoid a 2°C temperature rise above pre-industrial levels?
3. Can shipping emissions be accounted for on a sub-global scale?
4. What urgent and step-change measures can be taken to deliver short-term emission reductions from the shipping sector?

3.1 Whole systems analysis

For greenhouse emission targets set at any sub-global level to be meaningful with regard to a desired temperature goal, all emitting sectors must be included or accounted for in some way. However, one of the legacies of the Kyoto Protocol in relation to international aviation and shipping is that they are frequently omitted from national targets and budgets. This is because within the Protocol, it was stated that:

> *"The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO) respectively."*

In other words, national emission targets did not need to include international aviation and shipping, but the ICAO and the IMO would pursue emission reductions on a global scale. However, given that targets such as the UK's 80% reduction target were premised on not exceeding a 2°C temperature rise above pre-industrial levels and that this temperature was associated with a particular stabilisation level of global greenhouse gases in the atmosphere, this target would only be valid if it included the aggregate of all sectors. By choosing to omit international aviation and shipping, the emission reduction target becomes disconnected from the overarching temperature goal (Anderson and Bows 2007). Furthermore, international aviation and shipping have in recent decades grown more rapidly than most other sectors both in terms of activity and in terms of their emissions (Anderson, Shackley et al. 2005). Therefore, tackling and quantifying global and sub-global shipping emissions is a necessary element of addressing global climate change.

3.2 Challenges for the shipping industry

A considerable body of research has now built up around assessing the potential and barriers to mitigation for the aviation sector (e.g. Greener by Design 2005; Bows, Anderson et al. 2006; Cairns and Newson 2006; Bows et al. 2009). Research on the equivalent barriers and potential for the shipping sector tends to be more recent (Eyring, Kohler et al. 2005b; IMO 2009; Eyring, Isaksen et al. 2010) as previously the focus was largely on non-greenhouse gases emitted by ships, including sulphur dioxide. This research aims to add to this body of research addressing the challenges faced by the shipping industry in tackling climate change.

3.2.1 Data uncertainty

During this research endeavour, interviews with industry stakeholders identified a number of key mitigation challenges for shipping. Firstly, despite being the most fuel-efficient mode of transport in terms of tonne-km moved, the CO_2 emissions released by the shipping sector may already be a larger proportion of the global total than the CO_2 released by the aviation sector. The relevance of this is not so much in the comparison with aviation, but in relation to the very high levels of uncertainty in the total global CO_2 emission burden from shipping. Figure 5-1 illustrates this point clearly – with estimates varying from 402 $MtCO_2$ per year to 1097 $MtCO_2$ per year – well over a 50% increase depending on the data source and method used. Exploring the implications for sub-global policy of a better understanding of these levels of uncertainty forms a central element of this project.

3.2.2 Fuel use

The fuels used within shipping pose conflicting challenges depending on the environmental point of view taken. The use of heavy fuel oil produces high levels of local pollutants that must be controlled in port. In the mid-1990s, MARPOL Annex 6 brought in legislation stipulating that ships were not allowed to burn more than 4.5%

sulphur injected fuel on a worldwide basis[2]. Legislation then went further in 2006 to introduce Sulphur Emission Control Areas (SECAs) around ports with a limit of 1.5% sulphur content. Consequently, ships switch to lighter, cleaner fuels when loading and unloading. Cleaning up the fuel used is desirable from a local pollution perspective, but the energy penalty of opting for cleaner fuel can release additional CO_2. Moreover, being able to provide an adequate global supply of cleaner distillate (diesel) fuel for the shipping industry is considered by some to be too great a challenge in itself. As one stakeholder interviewed put it:

> *"The problem is that there is just not enough diesel around, and it's not in the right places."*

To resolve this shortfall, new units would need to be built onto the sides of existing refineries, but given the exceptionally high temperatures and pressures involved in such a process, there are only a few locations in the world where this would be viable. Thus, a significant shift away from conventional heavy fuel oil is currently considered to be unlikely in the short- to medium-term.

3.2.3 Truly global infrastructure

The global nature of the shipping industry is an extremely challenging barrier to address in relation to mitigating greenhouse gas emissions. Currently many nations – non-Annex I nations – do not have binding targets under the Kyoto agreement, and thus there are no incentives provided by such nations to decarbonise their international aviation or shipping industries, other than through the ICAO and the IMO. Shipyards tend to be in areas of the world least concerned with global climate change from a mitigation perspective, hence there are few drivers to innovate radically towards low-carbon technologies in shipbuilding. Compounding this, prior to the global economic downturn, there was a very high demand for new ships.

> *"There is plenty of work for shipbuilders and engine manufacturers." (stakeholder)*

The simple truth is that novel and innovative ship designs are likely to carry additional costs and are therefore less likely to get built.

[2] Incidentally, this was a level that was rarely emitted, thus the legislation was not perceived as hard-hitting.

> *"Ships look the way they look because they are as efficient as the current designs stipulated by the regulations. This is not to say that you can't do more, but that you need to change the focus." (stakeholder)*

The shipping sector's complexity in relation to other global sectors can be illustrated when comparing it with the aviation sector. Although flights depart and arrive in different nations, there are only a few major manufacturers, most customers are leisure and business flyers, and nations have, in general, clearly defined national carriers.

> *"As far as airlines are concerned, we could probably come up with all the main players in a couple of hours. We would struggle in shipping – it is a truly global industry." (stakeholder)*

By comparison, the shipping sector has numerous ship builders, charterers, customers, logistics organisations, owners etc. Furthermore, the routes taken by ships are not limited to 2 or 3 nations, but, depending on the type of service, they can 'tramp' around the seas to pick up cargo or be chartered to pick up and drop off cargo at a number of ports en route. Relatively few services will be limited to one or two ports, with timetabled liner services one exception. Even cruise ships take in many ports along the way. This multi-port activity poses problems when considering how to apportion emissions to reflect responsibility. Within air travel, it is clear that a flight between the UK and Italy could attribute 50% of the emissions to the UK and 50% to Italy. Such an approach is not viable for many types of shipping voyage. The apportionment of international shipping emissions is discussed further in Section 0 and the complexity of the shipping sector is outlined in Figure 3-1.

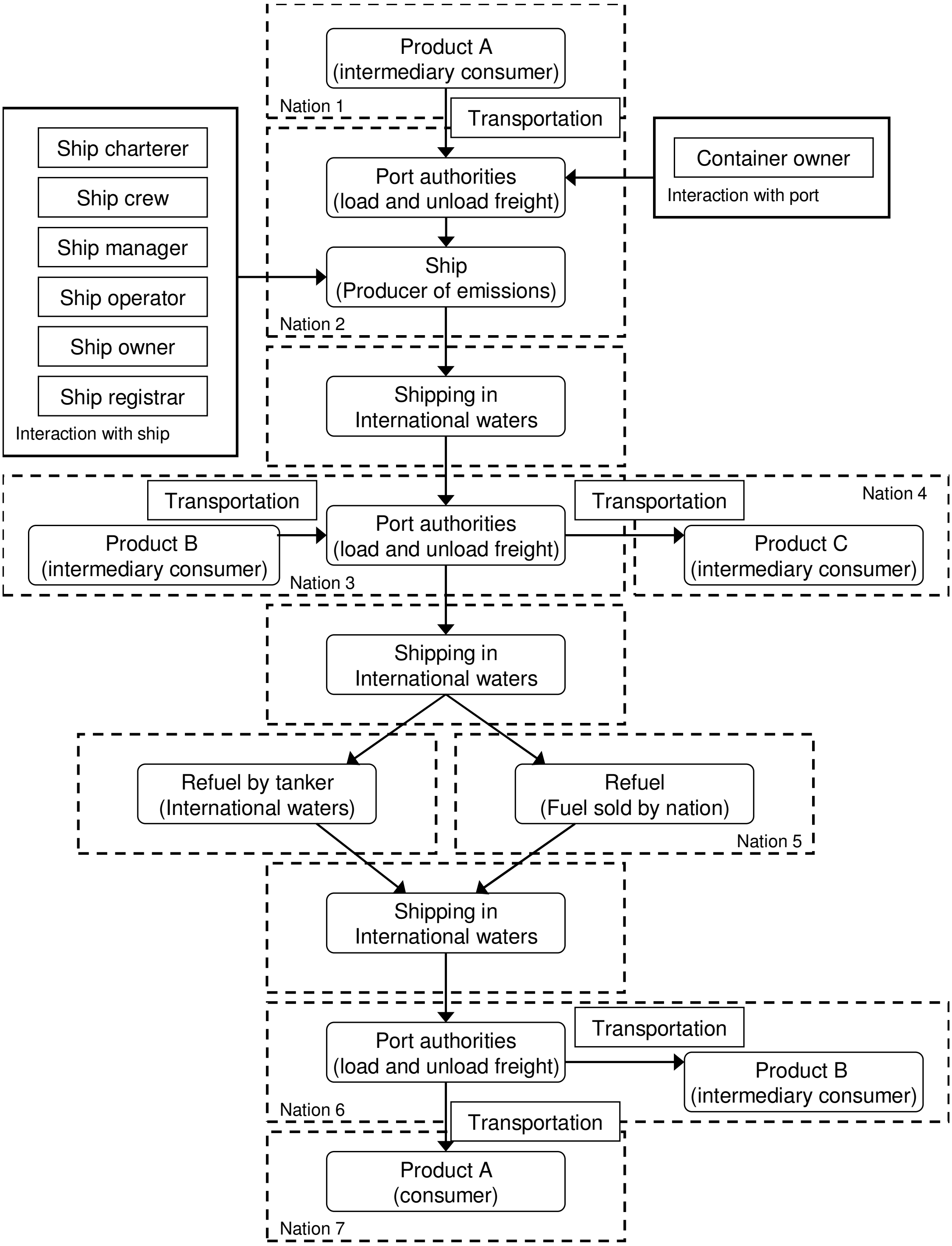


Figure 3-1: A schematic of the shipping system: an example for the shipping of goods between two landlocked nations highlighting the complex nature of shipping

3.2.4 Incentivising fuel efficiency

With a likely continued use of high-carbon fuels within shipping for some time to come, incentivising additional fuel efficiency improvements is clearly a desirable option in relation to mitigation. Yet this is one of the biggest barriers of all to reducing greenhouse gas emissions from ships. Already the shipping industry can boast that it is the most fuel-efficient mode of transport and that it has made great gains over time in terms of engine efficiency. Nevertheless, stakeholders highlighted considerable scope for improving efficiency through measures including: advanced engine technology on new ships or retrofitted onto older ships; optimising the speed of sailing; improving port congestion; redesigning ships; and better supply chain management. Technological and operational improvements are outlined in the IMO's recent report on climate change and shipping (IMO 2009). However, without clear policies with direct incentives to bring about such changes, they are unlikely to occur. Although the IMO clearly has a role to play here in incentivising and driving change, pace of progress has to date been slow compared with the urgency of the climate change issue.

> *"If the way the IMO works is the way other UN things work, then the cockroaches will win the day… it's shocking trying to get people to agree on even the most simple things." (stakeholder)*

To complement the global reach of the IMO, alternative mechanisms through national or regional jurisdiction could be put into action. The problem then is who should be incentivised, and how, particularly given ship bases are essentially transient. A fleet can be registered to a nation, but if that nation imposes a regulation that is unpopular with the fleet, then the fleet will choose to be registered elsewhere. Indeed a ship can be owned by someone in one country but have a flag belonging to another. If the fleet or flag owner can not be incentivised, how about the person who charters the ship? The variation in how ships are chartered provides an insight into some of the difficulties in incentivising alternative technology choice and routing decisions.

> **Bare boat chartering***: the owner of the ship charters it to a shipping company and hands it over without any people or any stores, and the charterer runs it as if it was their own ship. The charterer pays for the fuel.*

> **Ship owner/operator***: the owner has commissioned the ship to be built, then owns and operates it. The ship owner pays for the fuel.*

> **Time chartering:** *a shipping company charters additional ships (including people and stores) to add to their existing fleet to provide a particular amount of*

tonnage for a set number of years. The ship is then at the beck and call of the charterer, not the ship owner. The time charterer pays for the fuel.

Spot chartering: *if a company needs a ship for a voyage or two, it can charter one to take something from A to B on an ad-hoc basis. The ship owner, not the charterer, pays for the fuel.*

Therefore, a bare boat charterer does not have a say on the ship design/type, but could incentivise or organise how the boat is used. A ship owner/operator has the most control of the ship and its activities. Again, a time charter is not run by the owner, therefore the shipping activity is organised by the charterer, similarly for a spot charter. In both cases, the staff on board are directly answerable to the ship owner, and therefore their practices are unlikely to be influenced by the charterer for that particular voyage. Without the responsibility of paying for fuel, there is little incentive for a spot charterer to reduce speed or optimise efficiency through operations. In any case, the value of the cargo often far exceeds the cost of the fuel, further reducing incentives to reduce fuel consumption.

"With tankers, the value of the cargo is so huge compared to the value of the fuel, that the traders and operators don't give a hoot what the price of fuel is. In the length of time we have had a conversation about fuel, they could have done another trade, so why waste time talking about fuel efficiency." *(stakeholder)*

It is against this backdrop of high carbon fuel use, difficulties in incentivising the various players in the system and shipping's truly global nature, that this project has explored the mitigation potential at a UK level.

3.3 Future scenario comparison

Only by comparing the shipping sector's current and future projected emissions with overarching global emission scenarios, is it possible to understand the challenge faced in terms of absolute emission reduction. To do this, three sets of global emission scenarios for all sectors are presented below. The purpose of illustrating these scenarios is to convey two particular points:

1. The more stringent the emission pathway chosen, the greater the probability of avoiding 'dangerous climate change'

2. The more stringent the emission pathway chosen, the higher the proportion of global emissions will be attributable to ships in the future.

One pitfall for stakeholders and policymakers in assessing the potential impact of one sector in relation to future global emissions, is to inadvertently choose a high carbon future with which to compare. This has been done frequently when assessing the aviation sector's likely future impact (Bows 2010). Such comparisons provide a false sense of security in relation to what is materially required to avoid 'dangerous climate change'. Figure 3-2 illustrates a suite of scenarios developed by the IPCC and published in a Special Report on Emission Scenarios (SRES) for the CO_2 emissions for the aggregate of all sectors.

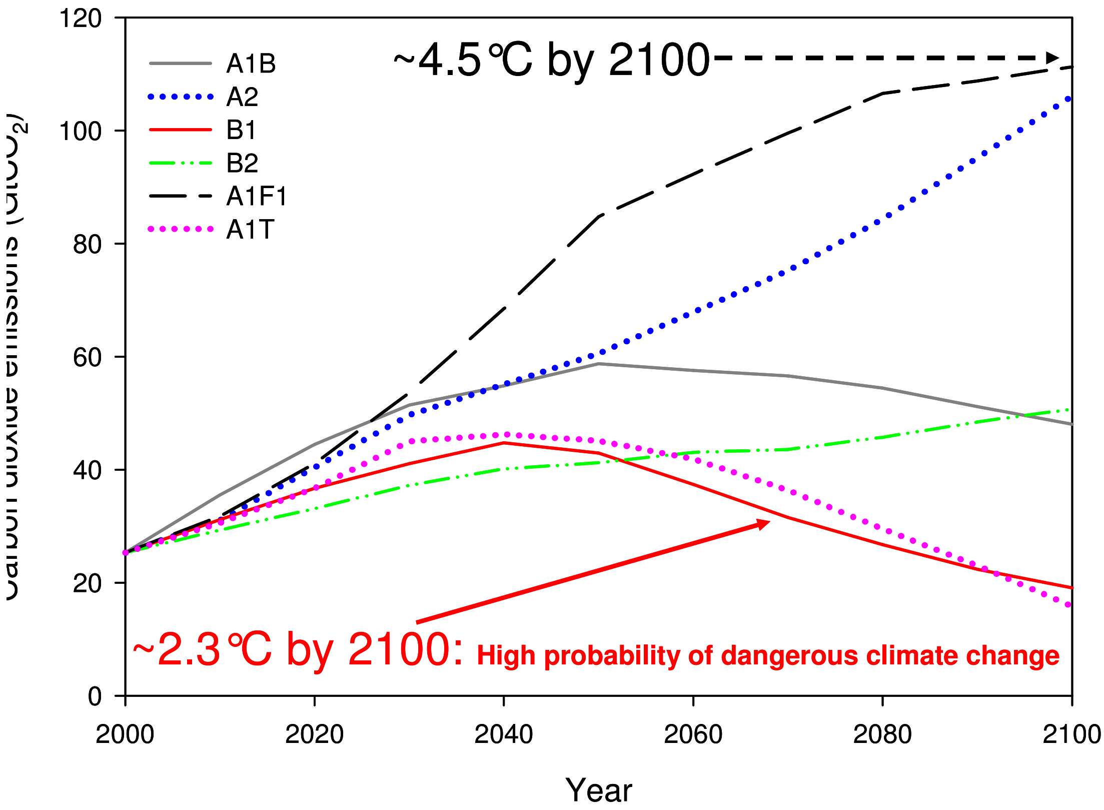


Figure 3-2: IPCC SRES global cross-sector emission scenarios

These scenarios range from futures with an estimated 2.3℃ of warming compared with pre-industrial times by 2100 (B1) to 4.5℃ of warming by 2100 (A1F1). Clearly, the B1 scenario illustrated is the more desirable in terms of climate change impact, yet even this scenario has a very high probability of exceeding the level of warming associated with 'dangerous climate change'.

Figure 3-3 presents a similar picture, but for scenarios developed by the UK's Committee on Climate Change (CCC) (CCC 2008). These scenarios do not span the range illustrated within Figure 3-2, however their highest emission scenario (2028: 1.5%) has a 95% probability of exceeding the 2°C threshold associated with 'dangerous climate change'. Their lowest emission scenario (2016: 4% low) has an estimated 53% chance of exceeding the 2°C threshold. The date within their scenario titles refers to the peak date in global emissions; the percentage reduction figure refers to the reduction rate following the peak date.

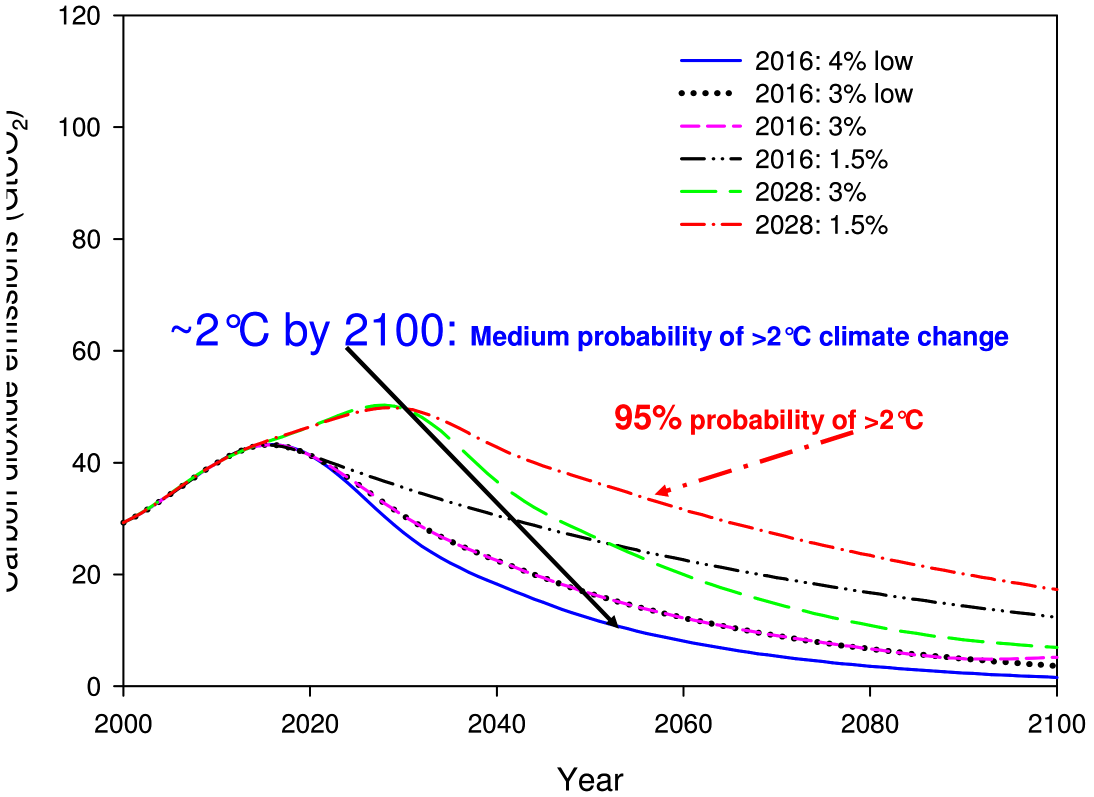


Figure 3-3: UK Committee on Climate Change global emission scenarios for CO_2

The final suite of scenarios are those produced by Anderson and Bows (2008) that aim for a 'reasonable' probability of not exceeding the 2°C threshold. These scenarios vary in relation to the date chosen for global emissions to peak, in addition to assumptions regarding the range of cumulative emissions viable for the 2°C threshold. More details regarding the underlying assumptions can be found in Anderson and Bows (2008) and details of how these sets of scenarios compare can be found in Bows (2010).

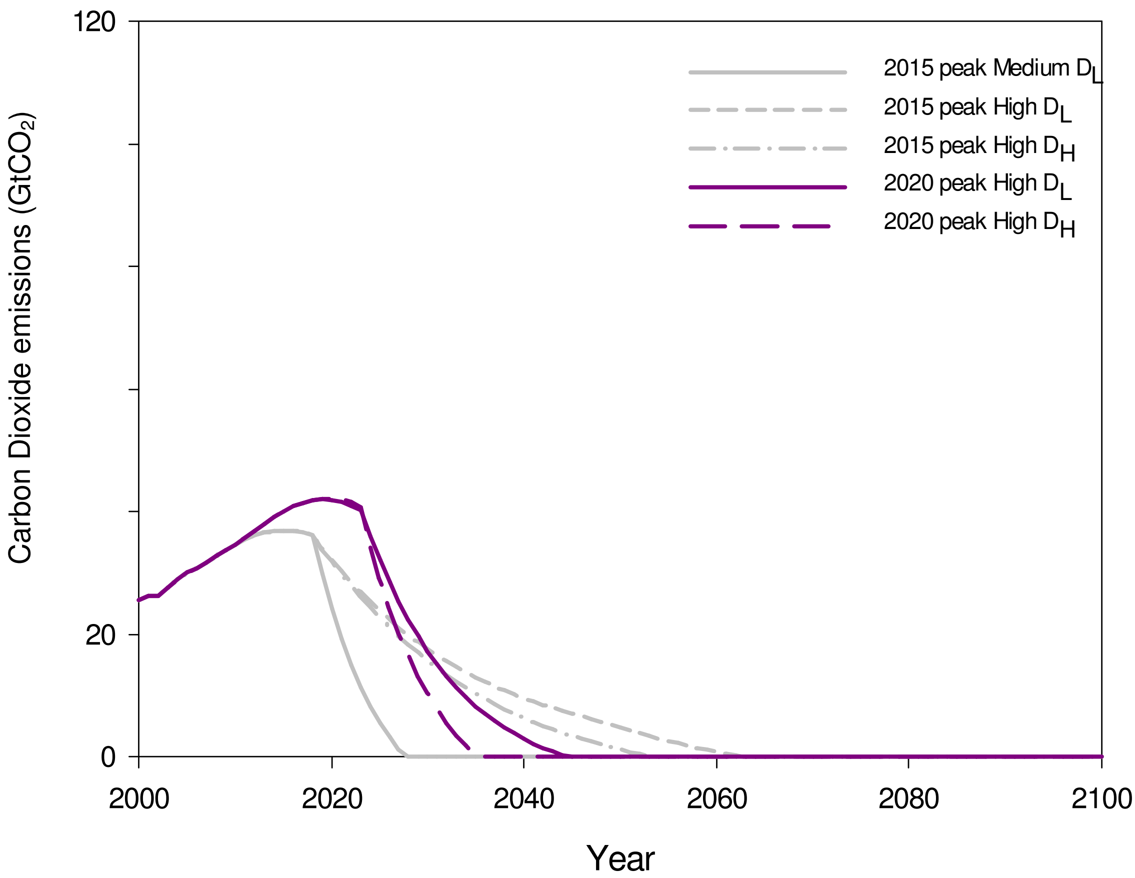


Figure 3-4: Anderson and Bows (2008) scenarios for a 'reasonable' probability of not exceeding the 2°C threshold

To illustrate how the scenarios compare with one another, Figure 3-5 pulls out just those scenarios commensurate or broadly commensurate with the 2°C goal. Arguably, the lowest SRES scenario has too high a probability to avoid 2°C given it does not include the effect of carbon cycle feedbacks. CCC's '2016:4% low' is most similar to Tyndall's '2015 high'. This particular Tyndall scenario assumes global emissions can peak in 2015. However, such an early peaking date is considered to be highly optimistic, despite offering significantly more desirable emission reduction rates in the future.

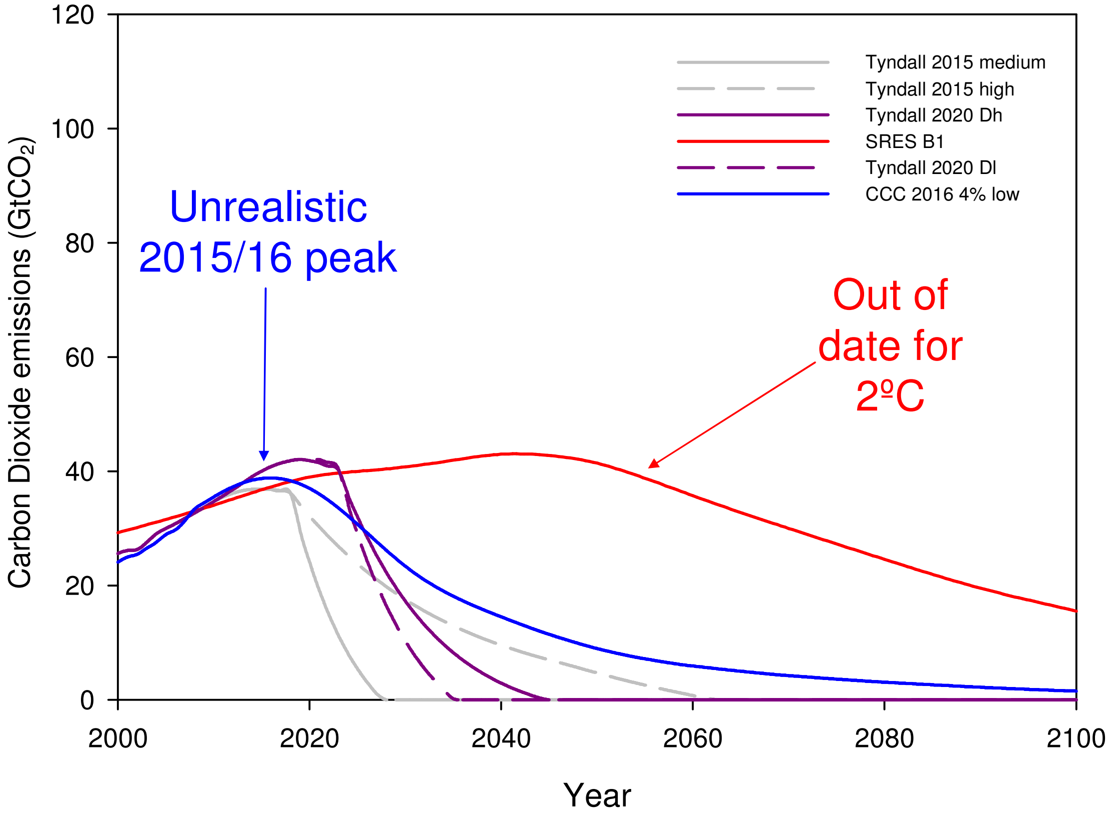


Figure 3-5: Emission scenarios from the three sets presented in Figure 3-2 to Figure 3-4 selected for their relatively low future climate impacts

3.3.1 Relevance for the shipping sector

To make a comparison of projected shipping CO_2 emissions with the global emission scenarios presented in Figure 3-5, recent CO_2 projections for shipping are considered. Figure 3-6 presents a selection of these scenarios.

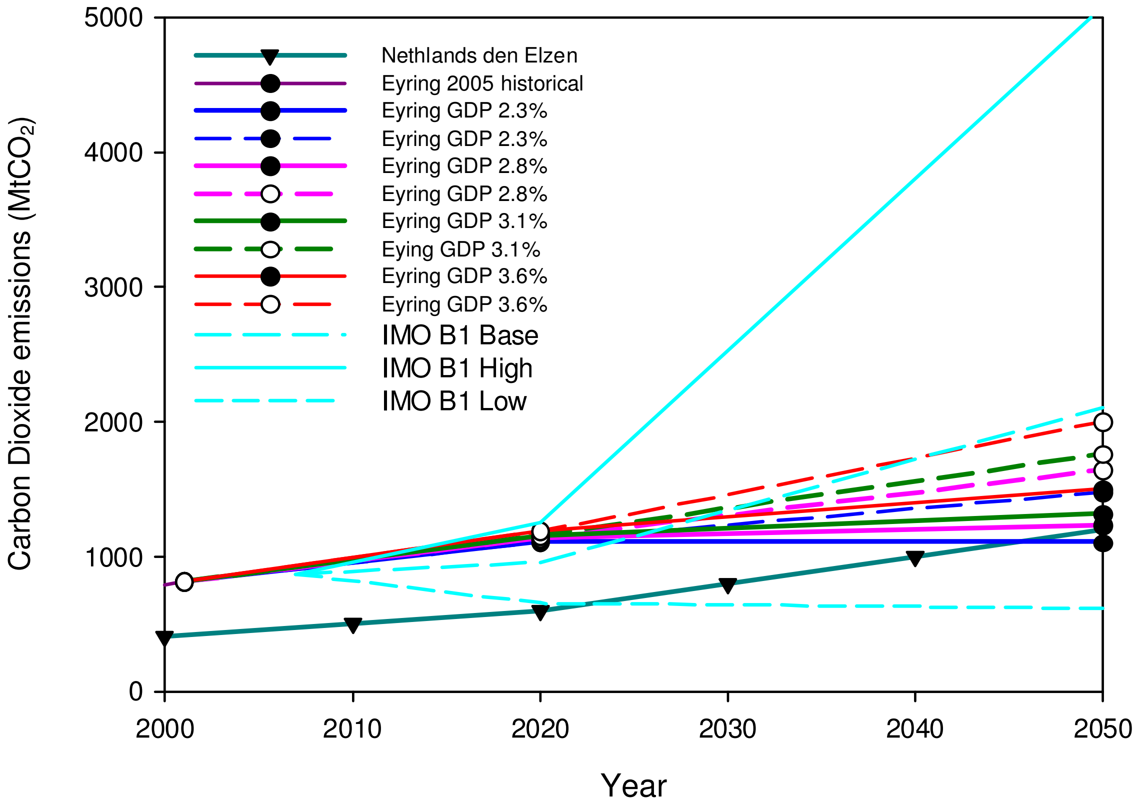


Figure 3-6: Global CO_2 emission projections/scenarios for the shipping sector (Eyring et al. 2005b; IMO 2009)

Although the IMO have produced several emission scenarios, these are all informed and driven by the SRES assumptions. In other words, they relate to each of the scenarios presented in Figure 3-2. Thus, many are driven within a global context with high climate change impacts in the future. To make sure that the shipping scenarios used are fairly compared with the appropriate global cross-sectoral scenarios, only the B1 scenarios have been selected from the IMO suite. The full suite of Eyring scenarios are presented here representing a wide range of growth assumptions into the future. The most salient point to note from Figure 3-6 is that, bar one scenario, none assume emissions will be lower in 2050 than they are currently. Given global emissions are required to reduce very significantly, potentially to zero by 2030-2050 in terms of the CO_2 emissions from energy, emission growth from the shipping sector is incompatible with avoiding ‘dangerous climate change.’

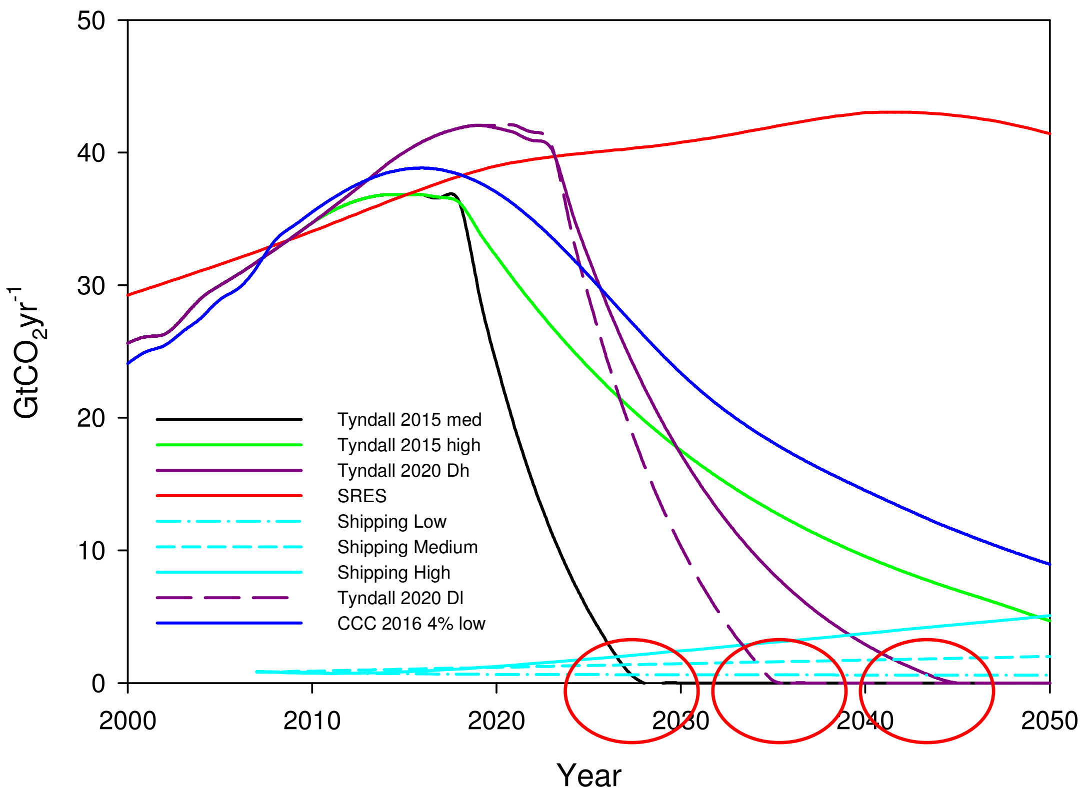


Figure 3-7: Comparison of a selection of low, medium and high emission scenarios for shipping with global 2°C emission scenarios

To illustrate the importance of the future emission pathway with which a particular sector is being compared, Figure 3-7 presents a selection of 'low', 'medium' and 'high' emission scenarios for shipping taken from the selection presented in Figure 3-6, and compares them with the previous global cross-sectoral emission scenarios.

Emissions by 2050 from the shipping sector would appear to compare favourably with the B1 scenario. Shipping emissions are a relatively low proportion of the global future total, and there would be room to trade with other sectors to mitigate those emissions. However, this scenario has a very high probability of 'dangerous climate change' and is thus disregarded from here onwards.

Over half of the 2050 budget is consumed by the highest of the shipping scenarios when compared with the CCC's most optimistic scenario, while the medium scenario consumes around a quarter. This is a very large proportion for one sector to consume, but with emissions trading, it is not unreasonable to assume that the shipping sector would be able to purchase rights to emit to this level under this scenario. However, this scenario has a more than 50% chance of exceeding the threshold associated with 'dangerous climate change' and an unrealistically optimistic global peak date – particularly following the lack of binding targets set in Copenhagen in 2009.

Comparing the shipping scenarios with the Anderson and Bows scenarios, emissions from CO_2 need to reduce to zero prior to 2050. Thus for those cross-sector scenarios with a more realistic peak date for global emissions, the red circles indicate complete decarbonisation. To achieve such complete decarbonisation for a sector such as shipping it is clear that in the medium- to longer-term, emissions trading will not be adequate to mitigate emissions, and a decarbonisation of the fuel used within shipping will be necessary, in addition to a range of other short-term measures.

Shipping, along with other major economic sectors, will need to significantly reduce emissions from their current level if a prevention of a 2°C temperature rise remains the goal. In considering how such a reduction might be brought about, the next section of this report reviews current EU and international policies and how these could potentially dovetail with more nationally-focused measures.

4 Current progress controlling shipping emissions

As discussed in Section 3.1, emissions from international shipping are excluded from national emissions and budgets, and therefore Annex 1 nations are expected to seek to control the release of greenhouse gas emissions through the IMO. The international policy measures that may be adopted by the IMO to control greenhouse gas emissions from shipping are briefly discussed here.

4.1 International measures

Total greenhouse gas emissions from shipping are a function of:

1. The efficiency of ship design and operation
2. The carbon intensity of the fuel used
3. The percentage of gases removed prior to the release to atmosphere and
4. The total shipping demand.

Technical and operational options relating to points 1-3 are summarised in the recent reports for the IMO (IMO 2009)[3] and for the EU (CE Delft 2009). Various authors have developed scenarios for future shipping demand (see IMO 2009).

The Marine Environment Protection Committee (MEPC) of the IMO is currently considering two types of measure to limit greenhouse gas emissions from shipping: technical and operational measures; and market-based instruments.

The technical and operational measures under consideration are:

- Energy Efficiency Design Index
- Ship Energy Efficiency Management Plan
- Energy Efficiency Operational Indicator

The Energy Efficiency Design Index (EEDI) will set a minimum energy efficiency level for new ships and aims to stimulate continued technical development of all elements relating to the fuel efficiency of ships. The EEDI aims to separate technical and design-based measures from operational measures (see below) and to enable a comparison of the energy efficiency of similar ships moving the same cargo. According to the IMO:

[3] With regard to (3), the IMO report states that "Although it is possible to remove CO_2 from exhaust gases, e.g., by chemical conversion, this is not considered feasible" [p70].

> *"The EEDI is developed for the larger segments of the world merchant fleet and would cover 87% of emissions from new ships covering the following ship types: oil and gas tankers, bulk carriers, general cargo and container ships, ro-ro (roll-on-roll-off) carriers and passenger ships. However, due to the long economic life of merchant ships, it would take about 20 years to reach this coverage without additional incentives."* (IMO 2009)

It is expected that the EEDI will become mandatory in 2010. According to the IMO, the Ship Energy Efficiency Management Plan (SEEMP) aims to:

> *"establish a mechanism for a company and/or a ship to improve the energy efficiency of ship operations. Preferably, the ship-specific SEEMP is linked to a broader corporate energy management policy for the company that owns, operates or controls the ship, recognizing that no two shipping companies or shipowners are the same. It should also be recognized that the international fleet of merchant vessels comprises a wide range of ship types and sizes that differ significantly in their design and purpose, and that ships operate under a broad variety of different conditions."* (IMO 2009)

A 20% reduction in greenhouse gas emissions per tonne-mile is possible through operational measures alone at current fuel prices (IMO 2009) and the SEEMP aims to assist the shipping industry in achieving this potential. The Energy Efficiency Operational Indicator (EEOI) has been designed for use as a monitoring tool within the SEEMP and enables continued monitoring of an individual ship in operation and the results of any changes made to its operation. Note that whilst the EEDI will be mandatory, the SEEMP and EEOI offer guidance only.

Four market-based mechanisms under consideration by the MEPC are:

An international fund for greenhouse gas emissions from ships: The fund consists of contributions paid on bunker fuel sales which are then used to purchase emissions offsets in developing nations.

An international fund with measures to improve ship efficiency: A variation on the fund idea is that some of the revenue, instead of being used to purchase offsets, is returned to a proportion of the fleet that is most energy efficient. This method incentivises and thereby accelerates improved energy efficiency (measured using the EEDI and EEOI).

A global emissions trading scheme for shipping: The trading scheme proposed is one under which emissions rights are allocated by auction and the revenue used for mitigation and adaptation purposes in developing countries.

A trading scheme for energy efficiency credits: Rather than a scheme for trading emissions rights, this is a scheme for trading energy efficiency credits, with the aim of cost-effectively improving ship efficiency.

The UK government has stated that it favours a global emissions trading scheme for shipping (Clark 2009). So too, in a recent report have the shipping chambers of Australia, Belgium, Norway, Sweden and the United Kingdom (Australian Shipowners' Association et al. 2009).

4.2 European measures

The EU's position on shipping emissions is as follows:

> *"In the event that no international agreement which includes international maritime emissions in its reduction targets through the International Maritime Organisation has been approved by the Member States or no such agreement through the UNFCCC has been approved by the Community by 31 December 2011, the Commission should make a proposal to include international maritime emissions in the Community reduction commitment with the aim of the proposed act entering into force by 2013. Such a proposal should minimise any negative impact on the Community's competitiveness while taking into account the potential environmental benefits." (European Parliament and Council 2009)*

A recent report for the EU (CE Delft 2009) discusses four potential instruments that could be used by the EU.

1. A cap-and-trade system for maritime transport emissions
2. An emissions tax with hypothecated revenues
3. A mandatory efficiency limit for ships in EU ports
4. A baseline and credit system based on an efficiency index

Under the second instrument, it is proposed that the tax revenue be used for emissions reduction in developing nations. The proposed instruments 1, 2 and 4 are similar to those discussed by the MEPC.

4.3 UK measures

Giving evidence to the EAC in 2006 (EAC, 2009a), the then Secretary of State for Transport, Douglas Alexander, stated that the Government's position was that its efforts should be directed at securing an international agreement to reduce international shipping emissions rather than the UK taking unilateral action to reduce its share of these emissions due to the practical difficulties of such unilateral action. The CCC also raised concern with the significant administrative duties involved when considering shipping in the UK framework (CCC 2008). Given these difficulties, the draft Climate Change Bill did not include international shipping (or aviation) emissions within the UK's carbon budgets. Nevertheless, under the section *'other supplementary provisions'* a clause was included to ensure the Secretary of State considers international shipping and aviation, indirectly covered under the EU's 20 % and 30 % targets, when setting UK carbon budgets (EAC 2009a), to ensure that other sectors do not have to make steeper cuts if emissions from these sectors continue to rise. This was adopted for aviation emissions however, the CCC recommended that the UK should not unilaterally tighten its carbon budgets to account for shipping emissions until they are included in the EU's greenhouse gas targets and instead, should only report annually, the proportion of international shipping emissions that could be attributed to the UK (CCC 2008). The CCC's rationale for not making UK unilateral adjustment prior to an EU agreement is:

1. It is not clear how to measure the share of international shipping emissions to include in the adjustment
2. If the UK were to make a unilateral adjustment resulting in a tightening of carbon budgets, this could be offset by a relaxation of targets for other EU Member States that may ensue in negotiations over burden sharing of the 20% and 30% greenhouse gas targets. In this event, there would be a financial implication for the UK with no environmental benefit
3. If there were to be a positive environmental impact (i.e. if other Member States were not to relax targets in response to UK unilateral action), this would be small based on UK action alone. In order to leverage inclusion at the UK level, international shipping should be included at the EU level

The EAC responded to the CCC as follows:

> *"We are not entirely convinced by the CCC's objections to unilateral action [to adjusting carbon budgets], either that the UK would suffer financially for no net environmental benefit, or that the environmental benefit would only be small. Crucially, the CCC seems to be ignoring the possibility that, by acting in advance of other nations, the UK could help to break diplomatic logjams and encourage other countries to follow suit."* (EAC, 2009a)

Whilst the EAC disagreed with the CCC about UK unilateral adjustment of its carbon budgets, it agreed with them that the UK should not undertake unilateral action to reduce its international shipping emissions, leaving the UK's latest position on reducing international shipping emissions as follows:

> *"We will work actively in the UNFCCC, with a view to getting an agreement to a target which will be taken forward in the IMO… We will continue to act in close cooperation with other EU Member States… We also will continue to work within the European Union to give shape to the measures, which the Commission will bring forward in the event that the international process does not deliver an agreed solution to the problem of greenhouse gas emissions from ships. However, we want an international solution."* (EAC 2009b)

With regard to the UK's share of international shipping emissions, two policy questions have been debated:

1. Should the UK's international shipping emissions be reflected in UK carbon budgets prior to an EU agreement?
2. Should the UK take unilateral action to reduce its share of international shipping emissions?

Within this report, the same position is explored as with the EAC, in that the UK should make unilateral adjustment of its carbon budgets to incorporate shipping prior to an EU agreement. The next section outlines methodologies to apportion international shipping emissions to the UK, quantifies the emissions under the various apportionment methods and assesses them with regard to data quality and cost, fairness and practical implementation. These recommendations could then assist UK policymakers in better understanding the UK's contribution to international shipping emissions, comparing it with other sectors and to assist when making unilateral adjustment of its carbon budget to be commensurate with 2°C. However, even if international shipping is included in an EU agreement, the UK should, for transparency reasons, still explicitly include its share of international shipping emissions in its carbon budgets and future targets, for consistency with its 2°C goal.

The report also explores the potential of UK unilateral action for reducing the UK's shipping emissions by: briefly outlining market-based instruments that could be adopted; defining shipping activity that the UK could influence and; exploring the relationship between this activity and the apportionment methods. This provides a means by which the UK could implement policy prior and in addition to any global or EU agreement and to monitor these unilateral mitigation efforts through apportionment.

5 Emission Apportionment for Shipping

Comparing current CO_2 projections from the shipping sector alongside those pathways that have the greatest chance of not exceeding a temperature rise of 2℃, emphasises the urgency with which shipping needs to adopt mitigation measures to complement those in other sectors. If this is to be carried out at any sub-global scale, issues of emission reporting and apportionment require consideration. The following section introduces how emissions are currently reported and explores the notion of emission apportionment with a particular focus on international shipping.

5.1 What is apportionment?

Article 4 of the United Nations Framework Convention (UNFCCC 1992) on Climate Change requires that Parties to the Convention submit greenhouse gas inventories to the UNFCCC and Article 7 of the Kyoto Protocol (UNFCCC 1997) requires that Annex 1 nations submit inventories annually. At the invitation of the UNFCCC, the IPCC has produced guidelines that provide internationally agreed methodologies on inventory preparation (Eggleston, Buendia et al. 2006a). According to this guidance

> *"National inventories should include greenhouse gas emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction. There are, however, some specific issues to be taken into account…*
>
> *…Emissions from fuel for use on ships or aircraft engaged in international transport should not be included in national totals. To ensure global completeness, these emissions should be reported separately." (Eggleston, Buendia et al. 2006a)*

This approach to compiling inventories is sometimes referred to as the producer-based approach as emissions are allocated to the nation in which they are produced. The IPCC's guidance defines international shipping emissions as:

> *"Emissions from fuels used by vessels of all flags that are engaged in international water-borne navigation. The international navigation may take place at sea, on inland lakes and waterways and in coastal waters. Includes*

emissions from journeys that depart in one country and arrive in a different country…" (Eggleston, Buendia et al. 2006b)

In contrast, domestic shipping emissions are defined as:

"Emissions from fuels used by vessels of all flags that depart and arrive in the same country…". (Eggleston et al. 2006b)

Given that international shipping emissions do not figure in national emission totals within inventories submitted to the UNFCCC, the apportionment of international shipping emissions to nations for a given year is here understood to constitute the assigning of a share (which may include a zero share) of the emissions in that year to each of the world's nations.

The international policy measures considered by the IMO were briefly discussed in Section 4.1. One instrument that can be used to control greenhouse gas emissions is emissions trading. Under emissions trading schemes, emissions are controlled by allocating emissions rights to designated participants. Thus, whilst emissions trading schemes share out rights to *future* emissions, the apportionment discussed here involves the sharing out of *past* emissions.

5.2 Why is there a need for apportionment?

Apportionment enables a nation to determine its share of global shipping emissions, compare this with the emissions produced by other sectors, enable a nation to consider shipping within its carbon budgets and targets and monitor a nation's international shipping emissions over time. This may be particularly important if a nation is seeking to undertake unilateral action to reduce its shipping emissions by incentivising or regulating a particular player or players within the shipping system. The following section outlines the potential role of apportionment in emissions trading.

5.2.1 Apportioning to control total global emissions

It should be noted that, while the allocation of emissions rights may be dependent on the apportionment of shipping emissions, this is not necessarily the case. Two contrasting examples follow:

(i) Contraction and Convergence (C&C) is a proposal for allocating the rights to emissions between nations based upon their current share of total global emissions. Under C&C, the allocation of rights thus requires establishing what nations' current total emissions are. As a nation's shipping emissions are part of its total emissions, establishing its total emissions requires the apportionment of international shipping emissions between nations. Thus, in this case, apportionment plays a necessary role in enabling allocation under C&C.

(ii) The national ship owner associations of Australia, Belgium, Norway, Sweden and the United Kingdom have recently proposed a sectoral emissions trading scheme for international shipping emissions (Australian Shipowners' Association et al. 2009). Assume that such a sectoral scheme is in place and that a similar scheme is also in place for the international aviation emissions, the other category of emissions that, under UNFCCC guidelines, do not figure in national emissions totals. Assume, too, that rights to all remaining emissions are to be allocated to nations on the basis of C&C. As rights under C&C are allocated on the basis of current emissions, and as the rights to be allocated would not include rights covering international shipping and aviation emissions, then it can be argued that the calculation of nations' current emissions should not include their international shipping and aviation emissions. If this is so, then apportionment of international shipping and aviation emissions is not necessary for the allocation of rights under C&C.

However, even if sector trading schemes were in place for international shipping and aviation emissions, it is probable that nations would still wish to establish what their total emissions are and, to do so, it would be necessary to apportion international shipping and aviation emissions between nations. Thus, even in instances where apportionment is not necessary for allocation, it remains important in order to establish total national emissions.

5.2.2 Apportionment from a UK perspective

In a recent report on greenhouse gas emissions from shipping (EAC 2009a), the EAC emphasised the inadequacy of apportioning UK shipping emissions on the basis of bunker fuel sales[4] and furthermore, it stated that bunker sales do not represent the UK's share of global emissions.

> *"The current methodology for calculating international shipping emissions underestimates actual emissions. The government must produce a more accurate estimate, and state what effect this would have on total UK CO_2 emissions were it to be taken into account. We recommend that the Government consult on the methodology it should use to calculate the UK's share of international shipping emissions."* (EAC 2009a)

At the same time, the EAC and also the UK's CCC have highlighted the challenge in formulating an appropriate apportionment methodology (CCC 2008). This report makes a start on taking up this challenge by identifying the various apportionment methodologies available, assessing them according to particular criteria and then quantifying the UK's share of international shipping emissions using the various apportionment methodologies.

5.3 Apportionment methods

Apportionment methods for shipping emissions were first discussed in 1996 at the fourth session of the UNFCCC's Subsidiary Body for Scientific and Technological Advice (SBSTA) (UNFCCC 1996a; UNFCCC 1996b; Kågeson 2007). They have subsequently been discussed in a report for the European Commission by Entec UK Ltd (Entec UK Ltd 2005), and at international conferences by staff from CE Delft (Faber 2007) and Lloyd's Marine Intelligence Unit (Wright 2008).

There are two main practical approaches to apportionment – top-down and bottom-up. Top-down apportionment shares out an annual international shipping emissions estimate using a chosen apportionment methodology. This annual emissions estimate is discussed in Section 5.3.1. Bottom-up apportionment provides an emissions estimate for a nation, determined within a set location using specific ship

[4] This was further emphasised by the UK government in its response to the report by the UK's EAC (EAC 2009b).

movement and ship characteristics data. The benefits and implications of these types of apportionment are also discussed in Section 5.3.1.

This Section provides a description of the different apportionment methods derived by the UNFCCC and Entec UK Ltd and a further method proposed by Anderson et al (Anderson et al. 2008).

Table 5-1: Apportioning methods proposed within the literature

	Apportionment method	Approach	UNFCCC[a]	Entec[b]	Anderson et al[c]
1	No apportionment		■		
2	Reported bunker fuel sales	Bottom-up	■	■	
3	Reported fuel consumption	Top-down		■	
4	National emissions (as a proportion of global emissions)	Top-down	■	■	
5	Location of emissions (within 12-mile and 200-mile zones)	Bottom-up	■	■	
6	Nationality of the transporting company ship registration	Bottom-up	■	■	
7	Freight tonnes loaded or unloaded	Top-down		■	
8	Port of departure or destination of cargo and passenger	Bottom-up	■	■	
9	Exporter (producer) or importer (consumer) of cargo[5]	Bottom-up	■		
10	Owner of the cargo[6]	Bottom-up	■		
11	A nation's proportion of global GDP	Top-down			■

[a] (UNFCCC 1996a), [b] (Entec UK Ltd 2005), [c] (Anderson et al. 2008)

Method 1 – No apportionment

The UNFCCC's SBSTA says the following

> *"As in the case of aviation bunkers, this option represents the status quo, that is reporting of emissions by Parties in a separate category. In the case of no allocation, the emissions from international marine bunkers would still need to be considered in relation to Article 4.2 of the Convention. In this case, IMO may be able to be of assistance."* (UNFCCC 1996a)

[5] In the UNFCCC report, method 9 is referred to as the country of departure or destination of the cargo or passenger

[6] In the UNFCCC report, method 10 is referred to as the country that owns the cargo or origin of the passenger

This text suggests that whilst nations should still report their bunker fuel sales, they should not be used for the purposes of apportionment to control emissions and hence consider other mitigation policy options.

Method 2 – Reported bunker fuel sales

This bottom-up method apportions emissions according to where the bunker fuel is sold using a nation's recorded fuel sales.

Method 3 – Reported fuel consumption

This top-down method apportions emissions based on the ratio between the reported annual fuel consumed by each country and the annual international fuel consumption.

Method 4 – A nation's proportion of global emissions

This top-down method apportions annual international CO_2 emissions based on a nation's contributions to global emissions.

Method 5 – Location of emissions

This bottom-up apportionment method calculates emissions based on vessel type and the activities of these vessels at sea, in ports and in inland waterways. As in the accountancy guidelines (Eggleston et al. 2006a), this is equivalent to the methodology used in other sectors, where emissions are apportioned to a nation based on where they occur. In the Entec UK Ltd study (Entec UK Ltd 2005), two location boundaries are defined: the 12 mile zone that equates to a region's territorial waters and the 200 mile zone that equates to the region's exclusive economic zone (EEZ). This methodology does not cover shipping emissions in international waters.

Method 6 – Nationality of the transporting company or ship registration

This bottom-up method apportions emissions based on the flag of a ship. However, as described in Section 3.2.4, the flag of ship can be characterised through a set of complex relationships, so according to the UNFCCC's SBSTA (UNFCCC 1996a), determining which party is accountable is complex:

> *"A ship can be owned by a company in one country, which itself is owned by other companies in other countries, registered in another, operated by a ship management company in a third country and crewed from a manning agency in a forth country with nationals from yet other countries."* (UNFCCC 1996a)

In this report, emissions are only determined based on where the ship is registered (represented by the flag of the ship).

Method 7 – Freight tonnes loaded or unloaded

This top-down method apportions the annual international shipping emissions to a nation using the ratio of a country's freight tonnes loaded and unloaded to the total global seafaring trade. This methodology does not account for non-freight shipping, such as passenger ferries. However, as passenger ferries only account for a very small proportion of international seafaring activities, their emissions are assumed to be negligible in this case.

Method 8 – Port of departure or destination of cargo/passenger

This bottom-up method apportions emissions to the nations of departure or destination. Within the model, the apportionment is made using data for the specific ship movements between the port of departure and destination. This method takes into account the distance travelled by ship, unlike method 7.

Method 9 – Exporter (producer) or importer (consumer) of cargo

This bottom-up method apportions emissions to nations that produce (export) or consume (import) the goods.

Method 10 – Owner of the cargo

This bottom-up method apportions emissions to nations that own the goods. It differs to method 9 as the emissions are apportioned to the cargo owner and not to where the cargo is exported from. The cargo owner may change prior to/during/after transportation.

Method 11 – A nation's proportion of global GDP

This top-down method would apportion annual international CO_2 emissions, based on a nation's contributions to global GDP – an assumption very similar to the 2009 IMO study, which presented a relationship between global fuel consumption, seafaring trade and GDP (IMO 2009).

5.3.1 Methods for estimating global shipping emissions

If a top-down apportionment method is chosen, then the global international shipping emissions to be shared out between nations need to be estimated, also using either top-down or bottom-up calculations. There are three main approaches to estimate annual global international shipping emissions:

1. Using global international bunker fuel sales figures
2. Using assumptions regarding global fleet activity
3. Using data on ship movements within a set geographical location[7]

For the first two approaches, the location of the emissions are not considered, with fuel consumption estimated on the basis of global bunker fuel sales or by typical power production and then multiplied by a standard emissions factor to calculate CO_2 emissions.

The first approach uses the total fuel consumption from global marine bunker fuel sales, based on fuel statistics reported to the UNFCCC. Therefore, at a regional or national scale, an estimate for the total sold within a particular nation can be straightforward to obtain. However, according to previous research (Corbett and Koehler 2003; Endresen, Sorgard et al. 2003; CE Delft 2009) such data incorporates limited coverage and underreporting, particularly as not all nations report bunker sales to the UNFCCC. Moreover, some vessels travelling for domestic purposes may refuel by purchasing bunker fuels intended for international voyages to avoid paying the tax that is levied on fuel for domestic use. As a result, estimates of fuel consumption based on bunker fuel statistics have a high degree of uncertainty (Olivier and Peters 1999; Corbett et al. 2003; Entec UK Ltd 2005; Eyring, Kohler et al. 2005a; Eyring et al. 2005b; Endresen, Sorgard et al. 2007; Eyring et al. 2010).

The second approach to estimate fuel consumption uses an activity-based model incorporating fleet activity aggregated by vessel type (Eyring et al. 2010). Fuel consumption is based on the installed engine power for each vessel type, the typical engine characteristics and the estimated operating time of these vessels. The global emissions are then calculated by combining the modelled fuel consumption with vessel specific emissions factors.

[7] This is different to the bottom-up apportionment methodology described in Section 5.3. The bottom-up estimate provides an estimate for annual international shipping emissions whilst the bottom-up apportionment methodology is a method to apportion shipping emissions to nations based on ship movements and ship characteristics.

The deviation found between emission estimates using activity-based models, as shown in Figure 5-1, result from the use of differing averaged input parameters for the selected vessel types (CE Delft 2009). For instance, assumptions are made with respect to the average number of days ships are considered to be at sea (Endresen et al. 2007) and other parameters, including engine load factor, fuel consumption rate and emissions factors, which can vary due to vessel size, age, fuel type and market situation (CE Delft 2009).

The third approach to estimate international shipping emissions estimates fuel consumption and emissions within a set geographical location using locally reported data. The emission estimates are vessel and route specific, based on vessel movements, vessel characteristics and specific emission factors (CE Delft 2009). At a global scale, these 'bottom-up' models can have a high degree of uncertainty (Eyring et al. 2010) due to assumptions made in relation to engine workload, ship speed (CE Delft 2009) and more significantly, the ship trajectories between two ports, as they do not usually follow a straight line due to weather conditions etc (Eyring et al. 2010). In addition to this, the models can also be expensive to run, as annual data is costly to purchase. For example, to estimate international shipping emissions associated with EU ship movements, the CE Delft study for the EU (CE Delft 2009) could only purchase data for 6 months during 2006 and so extrapolated to estimate annual totals.

5.3.2 Global shipping emissions estimates

Estimates of CO_2 emissions over the past 40 years taken from selected literature sources are shown in Figure 5-1. The estimates can vary substantially depending on the study and type of model used. The International Energy Agency (IEA) fuel statistics use the first approach described in the previous section (bunker fuel sales), and all others sources use the second approach (activity-based models) apart from the Paxian 2009 estimate which uses the third approach (bottom-up geographically specific model).

With such variance in the global estimate for shipping emissions, the total emissions value that can be apportioned between individual nations under any proposed top-down apportionment method necessarily varies. It is this variance that the UK policymakers need to be aware of, as it can have implications for a nation's carbon budget and national emissions totals. In this report, the IMO's annual international shipping emissions activity-based estimate (IMO 2009) is selected as the best estimate to apportion between nations under the proposed top-down apportionment methods. They involved key academics in their study, their model is considered to be the most rigorous and up-to-date and it was also regarded as the most appropriate choice by the stakeholders at the 'Tyndall//SCI Expert Shipping Workshop'.

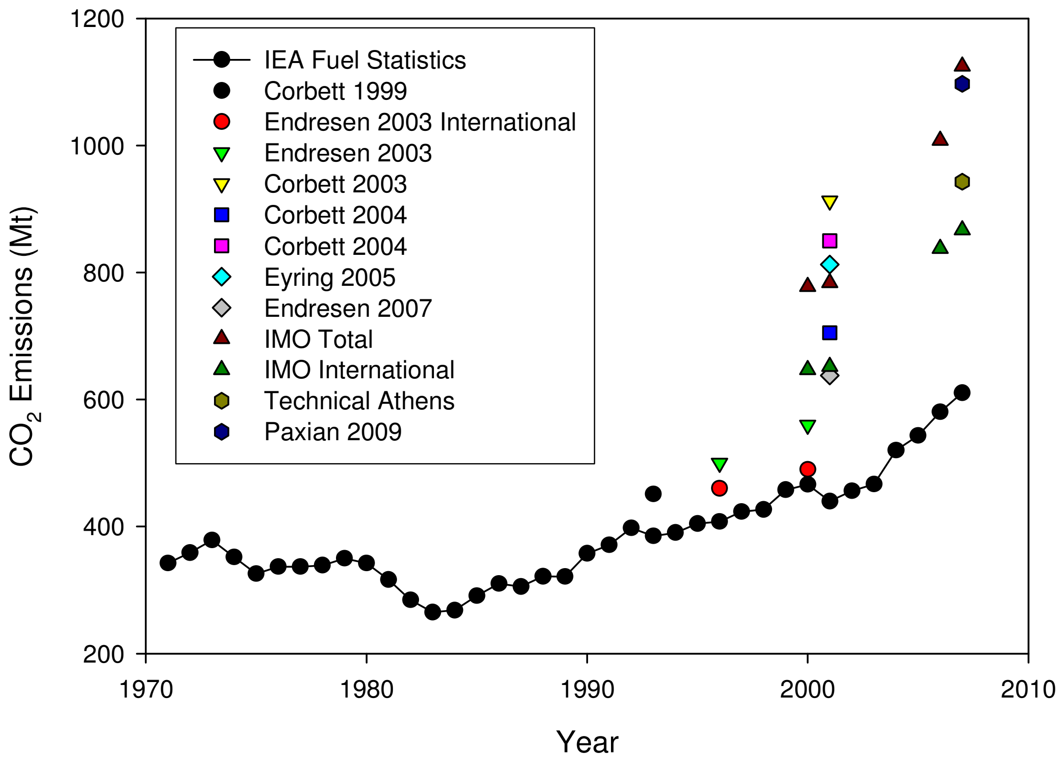


Figure 5-1: Estimated CO_2 release for total and international shipping emissions

5.4 Criteria for assessing each apportionment method

If apportionment of international shipping emissions is to be used by policymakers to develop mitigation strategies and to include emissions in national inventories, then the method chosen needs to be comprehensive and transparent. The method also needs to be repeatable, so that all nations could adopt it to monitor future emission reductions. It is argued in this study that, all other things being equal, the most appropriate method of apportionment is that which is fairest or most equitable. However, comprehensive data is not available for each method and, for some methods, obtaining the relevant data incurs very considerable monetary and time costs.

Criteria to assess the apportionment of shipping emissions have been developed by UNFCCC's SBSTA (UNFCCC 1996a), Entec UK Ltd (Entec UK Ltd 2005) and Wright (LMIU) (Wright 2008)[8] and criteria for the apportionment of UK international aviation emissions to UK regions was developed by Wood et al (2010). Three criteria used in this report are:

1. Data quality (availability, comprehensiveness and accuracy)
2. Data cost
3. Fairness

Data comprehensiveness and cost are discussed in Section 5.5.1 and this is followed by estimates of UK shipping emissions using the top-down apportionment methods in Section 5.5.2. Fairness is then assessed in Section 5.5.3. Apportionment could be used to influence future emissions if the right policy levers that impacted on the apportioned emissions are implemented; this is briefly discussed in Section 5.5.4. In addition, as argued by Wood et al (Wood et al. 2010), the selected method should be consistent when reporting national inventories to the UNFCCC, without double counting or omitting any emissions.

5.5 Assessment of apportionment method(s)

5.5.1 Assessment of data availability and data cost

Reported bunker fuel sales (Method 2)[9]

Data for international fuel sales is publicly available from UNFCCC (UNFCCC 2010) and IEA (IEA Statistics 2009) and the resultant apportionment is a straight-forward and cost-effective task, as the only variables are the nations fuel sales and the relative emission factor. However, as described in Section 5.3.1, at present not all nations report fuel statistics to the UNFCCC (IEA Statistics 2009; UN Comtrade 2010) and, in addition, some nations are known to under-report (CE Delft 2009).

Reported fuel consumption (Method 3)

The issue regarding the extent the fuel consumed 'belongs' to a country and who is then 'responsible' for the emissions, requires an additional variable to allow for apportionment – this is discussed in Section 5.5.3. This could, for example, be the

[8] The full assessment criteria used in each of these studies is located in Appendix A.

[9] Note Method 1 involves no apportionment and therefore is not discussed here.

flag of a ship or ship movement and is therefore addressed when assessing the remaining apportionment methods.

A nation's proportion of global emissions or the global economy (Methods 4 and 11)

The top-down apportionment based on the ratio of a nation's national CO_2 emissions estimate to global CO_2 emission estimate can use publicly available data within the UNFCCC database (UNFCCC 2010)[10].

The relationship between fuel consumption and GDP is shown in the IMO 2009 study (IMO 2009) and by Eyring et al (Eyring et al. 2005a; Eyring et al. 2010). When apportioning emissions according to GDP, accurate data is publicly available from the World Bank (World Bank 2009) or the International Monetary Fund (IMF 2009).

Location of emissions (Method 5)

Estimating emissions based on ship movements within a set location - either within a country's 12 or 200 mile zone (Entec UK Ltd 2005), could provide a more accurate representation of emissions compared to a top-down approach. However, this apportionment methodology does not cover the shipping emissions in international waters outside of the 200 mile zone, thus the globally aggregated figure would not represent the total amount of greenhouse gases released by the shipping sector.

For Method 5, data is expensive making it costly to implement[11] and update annually. It can be argued that it is more appropriate to use a top-down proxy with publicly available data.

If bottom-up data was to be purchased, Lloyd's Marine Intelligence Unit (LMIU) is able to supply data for vessel movement and vessel characteristics for *all* the bottom-up apportionment methods assessed in this section.

Nationality of the reporting company or ship registration (Method 6)

[10] In this study, CO_2 equivalent, land use and land use change are not taken into account in the CO_2 emissions estimates.

[11] As well as not developing a model to estimate annual international shipping emissions, the development of a bottom-up apportionment method is also not in the scope of this study. This study aims to derive appropriate apportionment methods, the criteria by which to assess them and to identify areas of ongoing research at Tyndall Manchester.

This bottom-up method apportions emissions to a nation based on the emissions released by the vessels registered to it. Depending on the level of comprehensiveness required, a top-down proxy could be used as an alternative to apportion the IMO's annual international emissions estimate using the ratio of a nation's registered vessels to total number of registered vessels, although this would omit information on how far the ships travelled. Data for maritime trade is publicly available online from the United Nations Conference on Trade and Development (UNCTAD) (UNCTAD 2007; UNCTAD 2008) and the apportionment is straightforward to implement.

Freight loaded or unloaded (Method 7)

In terms of data availability and cost, this top-down apportionment based method is straightforward to implement. Data is publicly available for tonnes loaded/unloaded by individual nations from Eurostat and the UN and total global seafaring trade is available from the UNCTAD. This method would not allocate any emissions to landlocked nations and would allocate more emissions to nations that have a considerable amount of trans-shipment[12], such as the Netherlands, (see Section 5.5.3).

Port of departure or destination of cargo/passenger (Method 8)

Depending on the level of detail required and the amount of funding available, a bottom-up proxy could be developed based on the port of departure and destination. This method could work for the UK, but as with Method 7, it would not allocate any emissions to landlocked nations. However, at a regional level, this was the apportionment method adopted by CE Delft in their report to the European Commission (CE Delft 2009) and was based on the SeaKlim algorithm (bottom-up model) by Paxian et al (Paxian, Eyring et al. 2010).

Exporter (producer) or importer (consumer) of cargo (Method 9)

This method is the most costly method to apportion emissions and concerns all trading nations. In particular, it includes the landlocked nations as well as the nations where freight is loaded and unloaded onto vessels. Using a bottom-up model, the apportionment is made by firstly determining the emissions associated with ship movements between port of departure and destination (generated using LMIU data).

[12] For example, freight is frequently loaded and unloaded at Dutch ports onto vessels transporting goods to and from continental Europe using the Rhine.

These emissions are then apportioned to the exporter (producer) and importer (consumer) of the freight that is being shipped (this could then include trade between landlocked nations that has been loaded or unloaded at the coastal ports). This therefore requires additional understanding of the relationship between the ship movements and the freight that is being shipped.

Wright at LMIU has previously favoured the apportionment between exporter (producer) and importer (consumer) (Wright 2008), but has highlighted issues related to developing the relationship between ship movements and seafaring trade. For data on ship movements, Wright suggested that there is a need for bottom-up models over top-down proxies to determine accurate mileage of shipping between ports. However, apportionment then becomes difficult when considering the transport routes for landlocked nations and the Suez/Cape trades. When considering the data available for seafaring trade, Wright argued that the exporter (producer) and importer (consumer) report different levels of trade, which leads to gaps in the data. This is exacerbated by the large amount of freight that is currently traded annually (4 million ship movements per year).

When examining data for ship movements, the last port of call may not reflect where the freight was loaded – it could have originated in a landlocked country or could have been loaded onto the vessel at a port other than its last port of call. Furthermore, it is likely that vessels such as containers will experience multiple loading/discharging on route. Therefore, from a data perspective, it becomes increasingly difficult to apportion the emissions between the exporters (producers) and importers (consumers), if the responsibility for the emissions released by the vessels changes depending on the freight that the vessel loads and unloads at each port.

Nevertheless, for tankers, bulk and cargo vessels, a 50:50 spilt could be made, as it could be assumed that there would be the only one drop-off made by the vessels (excluding additional port callings to refuel). Research at the Tyndall Centre and the SCI is investigating this type of apportionment (method 9) for the UK in the first instance, to develop a methodology that could be adopted by other nations. The World Trade Organization’s annual International Trade Statistics report (WTO 2007) and the annual UNCTAD report (UNCTAD 2007) are currently being considered as reference points to develop the relationship between ship movements and trade.

Summary of proxies for method 9

Depending on the compromise required between data cost and data quality, this report outlines a bottom-up proxy and several top-down proxy methods that could be implemented instead of the detailed bottom-up methods outlined above.

A bottom-up proxy applicable for method 9 could consider the weight and distance of the freight transported by sea, to apportion based on a nation's tonne-km shipped, as described by CE Delft in their recent report for the European Commission (CE Delft 2009). To apply this method requires data for shipped trade between nations, per vessel category and the distances between the trading nations to provide the total amount of goods transported, per vessel category, in tonne-km (tkm). Using the averaged CO_2 emissions factors for the vessel categories per tkm, the CO_2 emission factors for each nation can be determined. This acknowledges the impact of transporting heavy freight a long distance and light freight a short distance.

Apportionment to nations could also be made on the basis of a nation's contribution of total global trade in terms of value. However, double counting could occur if the apportionment is made by aggregating the UK's imports and exports. It would also include trade moved by other modes of transport. To avoid double-counting, the top-down apportionment is made for trade imported and trade exported separately. Although this is one appropriate top-down proxy for method 9, there are additional proxies available, such as the weight of goods. Furthermore, if data is obtained for *global* shipping trade in terms of imports and exports per nation (by volume or weight), then a quantitative top-down proxy could be made by apportioning emissions on the basis of a nation's trade that is seafaring[13]. These top-down proxy methods, along with the other apportionment methods, are discussed in terms of equity in Section 5.5.3. Ongoing research will examine the variation in the UK's international shipping emission estimates between the bottom-up approaches and the outlined proxies to characterise any relationships between them. It is likely that if data cost is a pivotal issue for policymakers, then the top-down methods would be favoured. By

[13] This would be in addition to method 7, which assumes goods loaded and unloaded. Method 7 does not take into account whether the goods loaded/unloaded are for that particular nation. They may be then transported to other nations or moved on to a different vessel and re-shipped.

providing future advice for policymakers, this ongoing research will identify the appropriate proxy to use.

Owner of the cargo (Method 10)

This bottom-up method would require the same methodology as method 8 to determine the emissions of a journey between the port of departure and destination. Then, similarly to method 9, it requires supplementary data on the owner of the cargo, to apportion these emissions accordingly. This would be done by understanding the relationship between the ship movements and global trade activity (as in method 9) and then determining an additional link between the exporter of the cargo and the owner of the cargo as: they may reside in different nations and the owner of the cargo may change prior to/during/after transportation. From a data quality and cost perspective, method 10 would therefore be very difficult to achieve and it would also have the same logistical and double counting issues as method 9.

5.5.2 UK CO_2 emissions under selected apportionment methods

Given the assumptions regarding data availability for the top-down apportionment methods outlined in Section 5.5.1, UK CO_2 emissions from international shipping are estimated and presented in Table 5-2. The methods apportion the IMO's activity-based estimate for CO_2 emissions of 838 Mt CO_2 to the UK using the proposed apportionment methods. Using the top-down proxies, international shipping emissions apportioned to the UK range from 6.77 Mt CO_2 (0.81 % of global international shipping emissions) and 42.05 Mt CO_2 (5.02 % of global international shipping emissions).

In 2006, the UK reported national emissions as 554.87 Mt CO_2 to the UNFCCC (excluding land use and land use change) (UNFCCC 2010) and in a separate memo, reported emissions from aviation bunker fuel sales as 35.56 Mt CO_2 (DECC 2010) and emissions from marine bunker fuel sales as 7.05 Mt CO_2 (UNFCCC 2010). If, for reasons of transparency, these emissions from international shipping are included alongside international aviation emissions in the UK's carbon budgeting, then national emissions would increase to 597.48 Mt CO_2. Furthermore, when constructing future budgets and targets consistent with the 2°C goal, the UK would have to include shipping in its carbon reduction strategy. This would require steeper cuts in other sectors, if emissions from aviation and shipping do not fall to the same extent as other sectors[14].

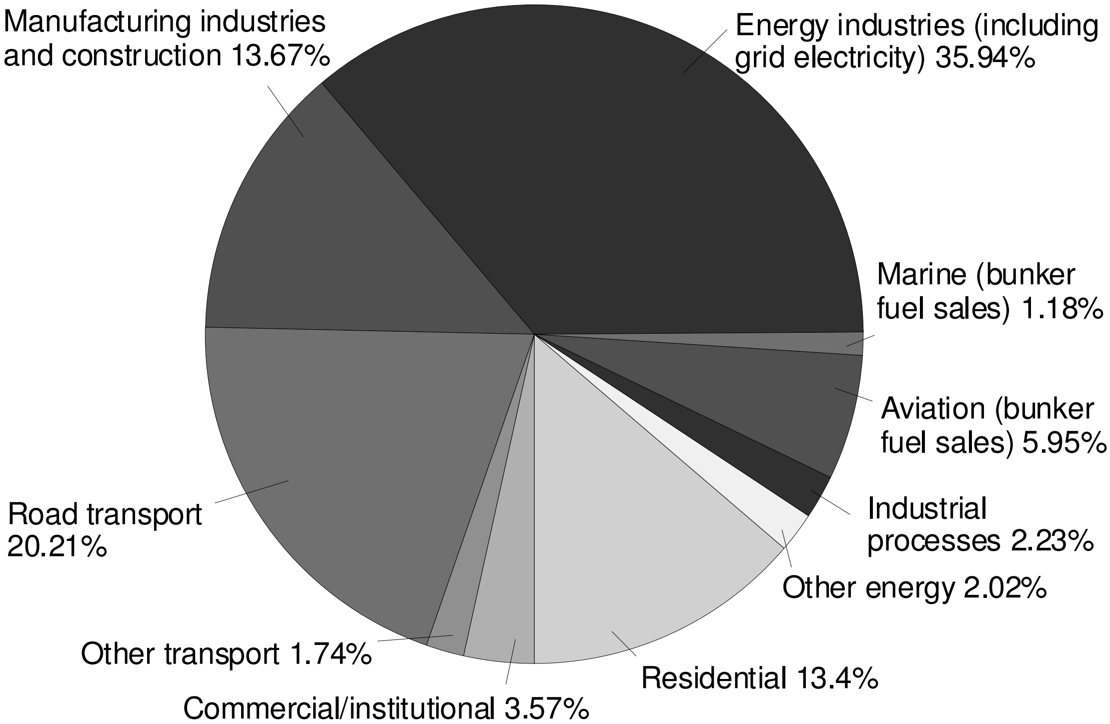
Using the upper estimate of 42.05 Mt CO_2 (method 9) for the UK's international shipping emissions results in the national emission inventory increasing to 632.48 Mt CO_2 – a 5.9 % increase. Using this apportionment method the UK would need to make even steeper cuts in other sectors, as shipping emissions could be a higher proportion than previously assumed. Continuing this out to 2050, sectors other than international shipping and aviation would need to reduce their emissions by more than 80% to "leave space" for international shipping and aviation emissions.

Figure 5-2 shows two pie charts that split the UK's national emission inventory for 2006, as reported to the UNFCCC, into sectors and includes international shipping estimates based on bunker fuel sold and freight imported to illustrate the impact of choosing an alternative apportionment method. The potential impact on the UK's national emissions inventory is explored further as ongoing work at the Tyndall Centre and the SCI.

[14] Note that the UK would still have to make steeper cuts to other sectors if shipping emissions are included alongside aviation emissions in an EU scheme

Table 5-2: Top-down proxy apportionment methods to determine UK's apportionment of CO_2 emissions from international shipping

Apportionment method		Indicator option			UK shipping emissions		Source
		Description	UK	Global	% of global	Mt CO_2	
1	No apportionment	n/a					
2	Reported bunker fuel sales	UNFCCC bunker fuel sales	7.05 Mt CO_2			7.05	(UNFCCC 2010)
3	Reported fuel consumption	No data available					
4	National emissions	UK and global CO2 emissions excluding land use, land use change	557.86 Mt CO_2	28928.12 Mt CO_2	1.93	16.16	(UNSTATS 2009)
5	Location of emissions	Bottom-up model only					
6	Flag of ship	Registered vessels	12810 dwt (1000)	1042351 dwt (1000)	1.23	10.30	(UNCTAD 2007)
7a	Freight tonnes loaded	Freight loaded by UK and global seafaring trade	218.63 Mt	7416 Mt	2.95	24.70	(EUROSTAT 2010) (UNCTAD 2007)
7b	Freight tonnes unloaded	Freight unloaded by UK	365.11 Mt	7416 Mt	4.92	41.26	
8	Port of departure or destination of cargo	See Method 7 plus ship movements					
9a	Exporter (producer) of cargo	Trade exported by UK in US Dollars	444 US $ bn	11861 US $ bn	3.75	31.40	(UN Comtrade 2010)
9b	Importer (consumer) of cargo	Trade imported by the UK in US Dollars	606 US $ bn	12084US $ bn	5.02	42.05	
10	Owner of the cargo	Bottom-up model only					
11	National GDP	UK GDP	2436 US $ bn	48882 US $ bn	4.98	41.76	(IMF 2009)



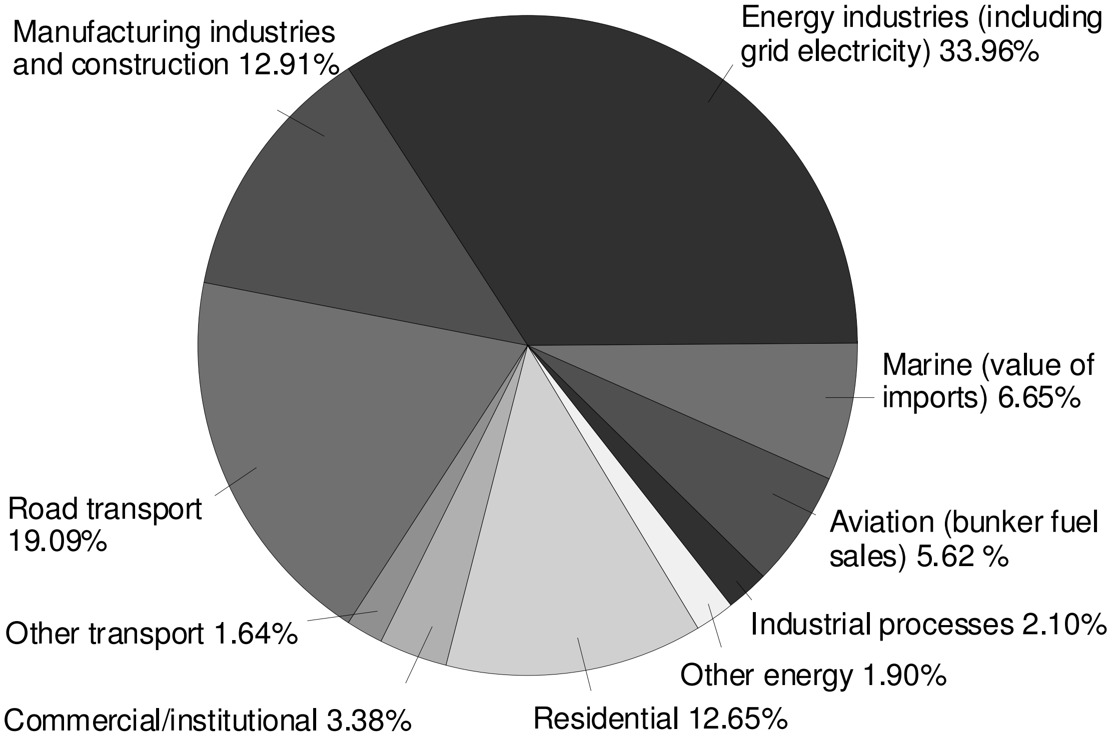


Figure 5-2: UK sectoral split of CO_2 emissions, apportioning international shipping emissions using bunker fuel sold and value of UK imports

5.5.3 Assessment of fairness

This section takes as its starting point the proposition that a fair or equitable method of apportioning international shipping emissions is one that apportions between nations on the basis of their *responsibility* for these emissions. Before discussing the notion of responsibility for international shipping emissions, it is important to recognise that the shipping sector is a complex system composed of various interdependent players (see Figure 3-1).

The section begins by briefly considering differing perspectives on the distribution of responsibility within the shipping system and goes on to briefly explore the relationship between responsibility and benefit. It then reviews the equity of each of the apportionment methods described in Section 5.3 and concludes with a discussion of the issues raised and potential future work.

Ultimate or shared responsibility

Under the producer-based approach to apportionment discussed in Section 5.1, a nation is responsible only for those emissions released within its territory. In contrast, under the consumer-based approach, a nation is ultimately responsible for the emissions released in the production and transport of all the goods it consumes (Munksgaard and Pedersen 2001; Lenzen, Murray et al. 2007). Under this approach, a nation is therefore deemed ultimately responsible for the emissions released in shipping the goods consumed by its population.

Alternatively, as shipping is a system, it might be argued that ultimate responsibility for international shipping emissions cannot be assigned to consumers or, indeed, any one part of the system and that responsibility is shared between all players. There are two recognised methods for sharing this responsibility. The first involves ranking the responsibility of all relevant players, while the second shares emissions equally[15].

If it is assumed that responsibility can be ranked, then emissions could be apportioned based on the activities and rankings of all involved. A simpler alternative

[15] Wood et al note the close relationship between responsibility and benefit. It is perhaps not surprising that the various players are responsible for international shipping emissions as a result of their participation in the shipping system and they participate in the system in the expectation of experiencing benefit. (For consumers of shipped goods, their benefit often consists of the satisfaction derived from consumption of the shipped goods whilst, for other players, their benefit ultimately often the form of profit). How exactly responsibility and benefit interrelate will be explored in future research.

would be to apportion on the basis of the activities of highest ranked player or players i.e. the main driver or drivers of shipping emissions (see Appendix B).

Note that the apportionment methods described in Section 5.3 that are based on activity (Methods 2, 6-9) are based on the activity of only a *single* player. From the above discussion, it can be seen that there are only two arguments for apportioning on the basis of the activity of a single player. The first is that the particular player is *ultimately* responsible for international shipping emissions, and the second is that, whilst not ultimately responsible, the player is the highest ranked or *most* responsible and that emissions should be apportioned solely on the basis of being the most responsible.

Reported bunker fuel sales (Method 2)[16]

The current method of apportioning international shipping emissions is based on bunker fuel sales. Although this method is used by the UNFCCC, the bunker sales recorded are not part of the national inventory, but a memo item submitted with the inventory.

Whilst the combustion of bunker fuels gives rise to emissions from ships, bunker fuel sales are clearly not the principal driver of shipping emissions. Rather, it seems more accurate to suggest that bunker fuel sales facilitate that exchange of shipped goods between exporters (producers) and importers (consumers). On the other hand, the fuel seller gains economically through the sale of the fuel and could have influence over the type of fuel provided. The cost of fuel, in addition to the geographical convenience of a fuel sale depot, significantly influences the amount of fuel sold by a particular nation – as evidenced by the UK and Netherlands bunker fuel sales figures with 1.2 % of global reported fuel sales attributable to the UK and 9.7 % of global reported fuel sales attributable to the Netherlands.

If it were argued that gaining benefit accrues some level of responsibility, then, landlocked nations engaged in importing or exporting should be held directly responsible for some emissions. However, under this ‘fuel sales’ apportionment regime, no responsibility is attributed to such nations, and hence their contribution to emissions from shipping is assumed to be zero.

[16] Note Method 1 involves no apportionment and therefore is not discussed here.

Reported fuel consumption (Method 3)

Fuel consumed on a voyage can be used as a basis for apportioning shipping emissions to nations, based on, for example, where a ship is registered (its ‘flag’); value of imports or exports; mass of imports or exports etc. Arguments in relation to fairness for this regime depend chiefly on which apportionment method is chosen.

A nation’s proportion of global emissions or the global economy (Methods 4 and 11)

Using a proxy to estimate shipping emissions relies on the assumption that whatever is considered to be a nation’s ‘fair’ proportion of international shipping can be reasonably linked to that proxy. What constitutes a fair proportion of international shipping is the subject of discussion under many of the other methods and comes back to what nations should be responsible for. To assess the suitability of the proxy, (either the nation’s proportion of global emissions or GDP), it is useful to consider what the proxy most closely represents.

National emissions are related to national wealth and a nation’s carbon intensity. GDP is linked to both population and wealth but reveals nothing about the country’s energy system. It is therefore possible for a nation to have a high population, low national wealth and a high carbon intensity resulting in a high allocation of international shipping emissions using the ‘national emissions’ proxy, despite having low imports and exports. If the GDP proxy were used, then it is less likely that this type of mismatch could occur and is therefore fairer than the national emissions proxy.

If GDP were the chosen proxy, it would most closely reflect a nation’s importing and exporting activity (as illustrated in Table 4-2), but if it is considered fairer to avoid allocating emissions to landlocked nations, or allocate to the fuel seller, then this proxy would be less appropriate.

Location of emissions (Method 5)

Drawing a spatial boundary around a nation and estimating emissions associated with ships arriving, departing and passing through waters within the boundary could provide a method for apportioning emissions. A nation would, under this apportionment regime, be taking responsibility for ‘its waters’ or patch of sea and landlocked nations would not be apportioned any emissions. Including ships passing through local waters risks unfairly skewing emissions towards those nations who waters include popular shipping routes. More importantly, this regime does not consider the full voyage, so aggregating for all nations does not account for all emissions. It would be relatively straightforward to pro-rata total shipping emissions on the basis of relative 'local emissions' from shipping or using another of the apportionment methods presented. However, this would still apportion to landlocked nations and also would not differentiate between geographically different coast lines (e.g. fjords versus more direct port access).

Nationality of the reporting company or ship registration (Method 6)

It is possible to apportion emissions to the nation that a ship is either registered in or in which the owner/operator resides. If the activities of the registrar, owner or operator are the main drivers for the emissions or these players are likely to gain the most benefit (including economic and reputation), this method could be considered fair. However, while registration and ownership certainly confers some benefit to the respective nations, it evidently represents only a small proportion of the overall benefits of shipping. For example, according to the UNFCCC's SBSTA (UNFCCC 1996a), the UK, USA and Japan have large export markets facilitated by ships registered, owned and/or operated by other nations.[17] At the same time, nations such as Greece and Norway are rarely visited by ships of their own 'flag', as they are engaged in 'cross trading'. Consequently, although it would be possible to develop a bottom-up model to apportion on the basis of ship movement and activity for the deadweight tonnage of UK registered vessels, or to instead use a top-down proxy to apportion emissions, this regime does not satisfy any reasonable criteria of fairness.

Freight loaded or unloaded (Method 7)

Freight loaded and unloaded reflects the goods handled at ports, even if the port facilitates the movement of goods from one vessel to another (trans-shipped). It does not necessarily reflect imports and exports and does not take into account the distance the ship has travelled. Thus, emissions would be apportioned to coastal nations, and not to landlocked nations and, in addition, those apportioned to coastal nations could misrepresent the actual fuel consumed by ships if one nation tends to import/export more locally than another. The main argument for using this method is that responsibility for shipping emissions lies with port activity (as the ports primarily gain economic benefit).

[17] It is worth noting that the top three nations/regions to register ships in 2007 were Panama, Liberia and Bahamas (UNCTAD 2007) – all of which have relatively small import/export markets.

Port of departure or destination of cargo/passenger (Method 8)

The port of departure and/or destination of the cargo (method 8) is a bottom-up approach that takes into consideration the length of voyage, based on comprehensive data regarding ship movement, ship engine characteristics and overall fuel consumption. In an ideal scenario, this method could apportion all of the emissions associated with a voyage from A to B, to either nation A, nation B or a 50% split, in a similar way to methods used to measure aviation emissions (Watterson, Walker et al. 2004). This method does take a fairer approach than method 7 in so much as it uses the length of voyage and therefore benefits nations choosing to import and export goods by sea more locally to reduce emissions. Complications arise, however, when considering the number of intermediary ports involved in any transfer of goods from one nation to another and this not insignificant issue would need to be overcome as referred to in Section 4.5.1. Even though the port of departure and destination gain economic benefit, it may be considered unfair to assume that responsibility for shipping emissions lies here, as it could be argued that main drivers for port activity are the importers (consumers) and exporters (producers) of the goods.

Exporter (producer) or importer (consumer) of the cargo (Method 9)

Ideally, this method would use a bottom-up approach to estimate the shipping emissions released on a voyage that related to the consumption of particular goods, or the shipping emissions released on a voyage that related to the production of particular goods. Compared with methods 7 and 8, this method therefore directly assigns responsibility to the consumer or producer, whether or not they reside in a landlocked nation, laying responsibility for shipping emissions entirely at the door of either the consumer or the producer of the goods.

Owner of the cargo (Method 10)

This bottom-up approach would apportion emissions released during the journey to the nation where the owner of the cargo resides. If the cargo is owned by the nation where it is produced, then the emissions are apportioned to the exporter of the cargo, as in method 9a. However, the cargo owner may reside in a different nation and furthermore, the cargo owner may change prior to/during/after the goods are shipped, potentially resulting in the emissions being apportioned to the nation importing the cargo. By apportioning using method 10, the dominant driver is likely to be the owner of the cargo. It seems unfair to apportion the emissions to a nation depending on the time of the transaction of cargo.

Discussion

It is plausible to suggest that producers and consumers of shipped goods are the dominant drivers within the shipping system, as all shipping activity is a means to facilitate the market exchange between these two players. Given that producers and consumers are the dominant drivers, it would be possible to introduce a hybrid apportionment method incorporating both the producers and consumers.

Accuracy of proxies: Although Method 9 may be the most equitable in theory, implementing it in practice requires data on the weight of goods exported (produced) and imported (consumed) by each nation, the distance that goods are shipped and ship efficiency/carbon intensity. As noted in Section 5.3, such data is not readily available. Thus in Table 5-2, the values of total goods imported and exported are used as top-down proxies. As discussed, profit is not necessarily proportional to shipping emissions and, for the same reasons, neither is the value of imports or exports. Thus, these proxies will have limited use.

Multiple players: Of the apportionment methods discussed, those based on shipping activity apportion on the basis of the activity of only one player. However, there is scope for future research to explore apportionment on the basis of multiple players using a hybrid of apportionment methods. This raises issues of determining which entities should be classified as players within the shipping system and, assuming ranking is possible, the appropriate method(s) to use for ranking the responsibility of various players.

Responsibility and systems: The notion of responsibility is complex and one that has not been explored to any great degree in this report. Thus, there may also be scope for drawing on the work on responsibility in the legal and philosophical literature to see what it can contribute to discussions of apportionment. Similarly, given that shipping can usefully be viewed as a system, there may be scope for drawing on the extensive literature on systems thinking to inform discussions of apportionment.

5.5.4 Policy implications

Having discussed various apportionment methods, this section briefly considers the relationship between these methods and policy instruments aimed at the UK reducing emissions from international shipping to complement any global or EU scheme.

For UK policymakers developing strategies to successfully mitigate their share of shipping emissions, they first need to understand the magnitude of the UK's international shipping emissions compared both with global shipping emissions and other UK sectors and also consider what aspect of the shipping system they can reasonably influence. The objective of this report is not to offer policymakers the definitive apportionment regime for this purpose or to define the market-based instruments that could then be put in place. Instead it opens out the discussion by:

- Illustrating the wide range of estimates for the UK's share of international shipping emissions using available apportionment methods and assessing these apportionment methods with regard to data quality, cost and fairness
- Determining how this may affect the UK's carbon reduction strategy if cumulative emissions from shipping are included alongside aviation when formulating the UK's carbon budget

The remainder of this report will also add to the debate by:

- Highlighting the importance of shipping as a complex system and those aspects of the system that the UK could influence (including potential rebound effects);
- Exploring the potential for the UK to take unilateral mitigation measures and to monitor their success through apportionment

Some examples of potential policy instruments for UK unilateral action to control shipping emissions are summarised in Table 5-3[18]. These instruments were put forward to participants at the Tyndall/SCI Expert Shipping Workshop and are explored in more detail in Sections 6 of this report.

Table 5-3: Suggestions for instruments to be implemented unilaterally

[18] Note that detailed analysis of these policies to determine the feasibility of their implementation is not in the scope of this report. Instead, the positive and negative consequences of UK unilateral action are explored in relation to influencing specific players in the shipping system.

Policy Type	Potential instruments to reduce UK shipping emissions
Fiscal	Carbon tax on ships using UK ports (in the absence of any EU scheme) Revenue used to promote RD&D in UK Incentives to operate efficiently in UK waters
Regulatory Instruments	Standard for congestion management in UK ports Standards for setting proportions of alternative fuels
Research, Development & Demonstration (RD&D)	Aim to make UK a world leader in RD&D
Policy Process and Outreach	Consumer label indicating goods transported by ship “Buy British” campaign – reduce demand for shipped goods

The numerous players within the shipping system, as highlighted in Figure 3-1 and discussed in Section 3.1, demonstrate the challenge faced in developing and implementing influential mitigation policy. For example, policies tackling one part of the system must not induce rebound effects elsewhere. For unilateral UK policy to be viable and to complement any multinational scheme, it must address those aspects of the shipping system that the UK is able to influence, consider potential rebound effects and, in addition, use an apportionment method that allows a measurable assessment of whether or not the mitigation policy is successful. The UK has influence and can quantify the emissions associated with:

- Port operations (methods 5, 7, 8, 9)
- Quantity of imports/exports (methods 7, 8, 9)
- Amount by value of imports/exports (methods 7, 9)
- Ultimate destination or origin of imports/exports (methods 8, 9)
- Owner of goods (method 10)
- Type of fuel sold (method 2)
- UK waters (methods 5, 7, 8, 9)

It has limited unilateral influence over the shipping emissions associated with:

- The flag or registration of a vessel (method 6)
- The construction or type of vessel (method 6)
- The quantity of fuel sold (method 2)
- Owner of goods if non-UK resident (method 10)
- Scaled national emissions (method 4)
- Scaled GDP emissions (method 11)

Table 5-4 summarises the consequences of UK unilateral influence over the shipping system in relation to each apportionment regime.

Table 5-4: Summary of the apportionment methods and their consequence for UK unilateral action

Method	Data Assessment	Fairness	Positive consequences of unilateral action	Negative consequences of unilateral action
1 (No apportionment)				
2 (Fuel sales)	Publicly available; straightforward assessment requiring accurate national estimate for total bunker fuel sold	Not ultimately responsible for supply and demand of shipping; gains profit from selling fuel; coastal nations penalised but additional costs due to imposed taxes could be passed on; unrepresentative of shipping activity driven by consumption or production	If incentivised to produce alternative or low carbon fuel, could lead way in reducing CO_2 from ships	If taxed, ships would refuel elsewhere (in the absence of an EU scheme)
3 (Fuel consumed)	Depends on choice of who is 'responsible' for the activity; data may be costly but available	Depends on 'activity' chosen.	Depends on 'activity' chosen.	Depends on 'activity' chosen.
4 (National emissions scalar)	Publicly available; straightforward top-down assessment requiring accurate estimate for CO_2 emissions from international shipping	Unfair given the influence of population and wealth on this figure (poor populous nations may have high emissions but low shipping activity)	Partially incentivises a reduction in national emissions	Changes in shipping efficiency, alternative fuels, technology improvements would not be reflected when using this method, therefore it does not directly incentivise the shipping sector
5 (Location of emissions)	Available but costly, bottom up model required	Omits emissions outside of national waters. If additional international emissions are pro-rated on the basis of a nation's proportion of emissions within its waters, this could unfairly allocate a high proportion to coastal nations or nations with highly active shipping routes.	Could incentivise less congestion and operational practices in UK waters, reducing fuel consumption for users; UK importers may choose more efficient shipping routes to reduce costs	May discourage ships passing the UK refuelling in the UK and may result in ships unloading in Rotterdam and transporting goods by land (in the absence of an EU scheme)

Table 5-3 continued

6 (Flag of ship)	Publicly available (if using a top-down estimate); requires additional data (bottom-up model)	Unfairly reflects a nation's shipping activity and not dominant in the system	UK registered ships become more efficient, are built more efficiently or use lower carbon fuels	Ships register elsewhere to avoid regulation, thus global intervention is preferable to unilateral intervention
7 (Goods loaded/unloaded by value or weight)	Publicly available (if using a top-down estimate)	Ignores landlocked nations, journey lengths and only accounts for 'goods handled'	Encourages lower consumption of goods arriving by ship, either in terms of weight or value	Pushes loading, and transhipment unloading to unregulated ports and encourages higher carbon land-based transfer of goods
8 (Port of departure [or destination] of cargo)	Requires additional expensive voyage data (bottom-up model)	Ignores landlocked nations and type/final destination of goods traded, but considers journey length and ship type	Incentivises lower congestion and lower-carbon operational practices around UK ports; encourages efficient travelling to destination; drives innovation; incentivises shorter journeys; incentivises cold ironing	Pushes freight onto land-based modes (assuming no regulation on land-based freight)
9a (Exporter/producer of cargo)	Top down on the basis of value, data publicly available. Could also be top-down based on tonnes but no data. Bottom-up considering length of voyage and nation of consumption (and developing the relationship between the two); data expensive	Assumes exporter is either ultimately responsible for shipping or most responsible; omits journey length unless using a bottom-up approach; includes landlocked nations	If using a bottom-up approach, incentivises lower congestion and lower-carbon operational practices around UK ports; encourages efficient travelling to destination; drives innovation; incentivises shorter journeys; cold ironing to reduce fuel use	Raises costs of exporting. Top-down proxy would fail to capture improvements made using the bottom-up approach
9b (Importer /consumer of cargo)	Top down on the basis of value, data publicly available. Could also be top-down based on tonnes but no data. Bottom-up considering length of voyage and nation of consumption (and developing the relationship between the two); data expensive	Assumes importer is either ultimately responsible for shipping or most responsible; omits journey length unless using a bottom-up approach; includes landlocked nations	If using a bottom-up approach, incentivises lower congestion and lower-carbon operational practices around UK ports; encourages efficient travelling to destination; drives innovation; incentivises shorter journeys; cold ironing	Pushes freight onto land-based modes (assuming no regulation on land-based freight). Top-down proxy would fail to capture improvements made using the bottom-up approach

Table 5-3 continued

10 (Owner of the cargo)	Bottom-up considering length of voyage and owner of the cargo which may change during transportation; data expensive	Assumes the cargo owner is either ultimately responsible or most responsible; includes landlocked nations; overly reliant on time of change in ownership	If using a bottom-up approach, incentivises lower congestion and lower-carbon operational practices around UK ports; encourages efficient travelling to destination; drives innovation; incentivises shorter journeys; cold ironing	A country may seek to change ownership prior to shipping; pushes freight onto land-based modes
11 (GDP scalar)	Publicly available; straightforward top-down assessment requiring accurate estimate for CO_2 emissions from international shipping	Given most goods imported either arrive by, or involve shipping at some stage, this could fairly represent shipping if consumption is considered to be the main driver of shipping emissions	Partially incentivises a reduction in national GDP which could, as long as the fossil-fuel economy remained, lead to lower national emissions	Changes in shipping efficiency, alternative fuels, technology improvements would not be reflected when using this method, therefore it does not incentivise the shipping sector, but incentivises a nation to lower its GDP

Given the combined assessment of data cost, quality, fairness and practical implications of the apportionment regimes, the most promising to be able to monitor and influence unilateral policy are likely to involve a hybrid of approaches that can provide a measure of policy impact. Methods 4 (national emissions), 6 (flag of ship) and 11 (GDP) are therefore omitted on the basis that they can not provide any measure of impact. Moreover, although method 6 (flag of ship) could be used to monitor and influence improvements in ship design, unilateral national policies are unlikely to bring this about, with global regulations and legislation preferable. Method 2 is also rejected for its lack of measurable impact, if it is the quantity of fuel sold that is to be monitored and influenced. However, it is viable to use method 2 if it is the type of fuel, rather than the quantity, that is targeted. The apportionment methods that offer the most promise for further consideration can be grouped together as those linked to the movement of goods (7,8,9,10), then location of emissions (method 5) and fuel sales (method 2).

Movement of goods

A regulation that tackled only the goods loaded and unloaded at ports (monitored using method 7) could result in higher costs being passed down the supply chain to increase the cost of imports and exports to landlocked nations, but ignores the journey distance. A policy tackling the transit between ports would account for journey distance but would not directly influence landlocked nations' emissions (monitored using method 8). Although a policy that targets the cargo owner (monitored using method 10) captures one of the dominant drivers in the shipping system, it would in practice be extremely complex to implement and in terms of fairness be overly reliant on the time of transaction.

A policy that captures imports and/or exports and is influenced and monitored through apportionment method 9 is considered to be the fairest and most comprehensive. However, this apportionment method has costly data requirements for implementing and would necessitate the use of a proxy. Top-down proxies for *total* value or weight of goods traded are straightforward to obtain, but they ignore the length of journey travelled, any detail on the vessels and, furthermore, they do not segregate trade by mode of transport. Therefore, any mitigation policy that aimed to influence distance travelled and was monitored using this top-down proxy, efficiency of voyage, ship technology or alternative fuels would not be measurable.

An alternative proxy to monitor and influence this policy, as outlined in Section 5.5.1, estimates the tonne-km moved by ship from trade data and distances (by sea) between trading nations, and uses estimated emission factors (in CO_2/tkm) to determine a nation's international shipping emissions for particular categories of vessel by element of the journey (i.e. a different emission factor is applicable in port compared with on the high seas). If this data is updated on an annual basis, it can capture changes in distances travelled (from tonne-km data), efficiency of voyage, ship technology and alternative fuels. As such, the apportionment method could monitor the policy to drive lower congestion, incentivise lower-carbon operational practices, drive innovation, incentivise shorter journeys, encourage local consumption/production and lower overall consumption, but it could push freight onto land-base modes (assuming that there was no accompanying regulation to prevent this).

Location of emissions

Although the method that apportions based on where the emissions are located omits emissions on the high seas, the ability for it to monitor incentives for better port congestion and operational practices makes it attractive if the remaining global shipping emissions could be apportioned using an alternative method. For example, if the UK could seek to reduce its share of international shipping emissions by implementing a tax on emissions released within its waters or by rewarding efficient shipping within its waters, by also apportioning based on emissions released in the waters (method 5) it could directly monitor and influence these policies.

Fuel sales

Developing policies on the basis of fuel sales and monitoring mitigation efforts using such an apportionment method (method 2) appears unattractive when first considered given the inherent inequities. Also, depending on the stringency of the policy, targeting policies at the fuel seller may or may not yield substantive changes to fuel consumption given the complexity of shipping's 'consumption-production' system. However, in addition to a conventional fuel tax, whereby costs imposed are often passed down the supply chain to the customer (indirectly impacting landlocked nations), new business models could be developed where money is made from incentivising lower carbon fuel purchases (e.g. introducing the equivalent of renewable obligation certificates to encourage alternative fuel production/sales). Fuel sellers would be rewarded for incentivising lower CO_2 emissions or be able to market the idea to their customers that they are a desirable choice, thereby gaining competitive advantage.

However, wider sustainability concerns surrounding the most obvious fuel at present – biofuel – suggest that this is not viable in the very short-term. Moreover, the complicated nature of the shipping system may hinder the uptake of such incentives, as those responsible for purchasing the fuel are sometimes not those actually paying for it and under these circumstances would preferably require multinational schemes. In addition to the relative 'unfairness' of apportioning on the basis of fuel sales, the opportunities for policies to encourage low carbon shipping are very limited. The fuel seller may be the most appropriate agent to incentivise alternative low-carbon fuels, but other parts of the shipping sector could be more important to incentivise lower absolute emissions.

Rather than choosing one area to target for unilateral policy, a hybrid of methods may be the most appropriate for developing and monitoring unilateral policy measures. For example, one hybrid method could incorporate emissions associated with a proportion of imports and exports and monitor its progress using a top-down proxy (method 9a and b) with additional bottom-up estimated geographical trade information. Another could target emissions in the UK's waters and monitor its progress by apportioning emissions using a bottom-up model of emissions released in national waters (method 5), then allocate the remaining global shipping emissions to nations on the basis of a top-down proxy for value of imports. Further research will explore the potential of such hybrids for policymaking in relation to shipping.

6 Tyndall/SCI Expert Shipping Workshop

On 1 March 2010, the Tyndall Centre for Climate Change Research and the Sustainable Consumption Institute (SCI) hosted an expert workshop to discuss the reduction of greenhouse gas emissions from shipping. The workshop was attended by 26 experts from various sectors of the shipping industry and from government, academia, NGOs and consultancies.

The workshop was divided into three sessions. Each session consisted of a presentation by a Tyndall/SCI researcher followed by a discussion. Session 1 examined the role that emissions reductions in the shipping sector could and should play in the reduction of total global emissions. Session 2 discussed whether there was scope for the UK to take unilateral action to reduce its shipping emissions and Session 3 explored various issues relating to the apportionment of shipping emissions. The presentation and discussion in each of the three sessions is summarised below.

6.1 Session 1: Climate change and carbon budgets: implications for shipping

Presentation

Dangerous climate change is generally accepted as an increase in pre-industrial global average surface temperature of greater than 2°C. In her presentation, Alice Bows (SCI) explained that achieving a lower probability of experiencing dangerous climate change requires constraining the global emissions budget over the next century and went on to show that under a budget resulting in a 50% probability of experiencing dangerous climate change, carbon dioxide (CO_2) emissions from the energy sector would be required to fall to zero by around 2030-40. Dr Bows then showed how such a requirement is incompatible with even the lowest level of CO_2 emissions from shipping under the scenarios produced by the IMO (around 0.65 $GtCO_2$ in 2020 and 0.6 $GtCO_2$ in 2050). These IMO scenarios assume no policy action to mitigate greenhouse gas emissions and their incompatibility with the emissions pathways illustrated by Dr Bows emphasised the need for policy intervention in the shipping sector.

Discussion

Although participants were positive about tackling shipping's contribution to climate change, it was suggested there was little appetite in many parts of the shipping industry for emission reduction or even emissions trading, with some parts of the industry equating mitigation with job losses, paying a premium for being environmentally friendly and loss of market share due to modal shift. Furthermore, given that shipping is considered to contribute only a small percentage of global CO_2 emissions (2.7% was the figure mentioned), a number of the participants stated that the attention paid to shipping was unwarranted given the industry's fuel efficiency and the lack of pressure placed on road transport. This concern was re-emphasised several times despite the presentation illustrating the steep carbon reductions in the short to medium term necessary to avert dangerous climate change.

Aviation and shipping are often discussed within the same arenas due to their similar treatment within the Kyoto agreement. The implications of such treatment, it was argued, has led aviation and shipping towards exploring the potential of global emissions trading ahead of other sectors. Yet others suggested that bringing aviation and shipping together in this way is problematic, as they perform different functions and are dissimilar institutionally. It was pointed out that, whilst grounding all aircraft would have little impact on global trade, berthing all ships would bring global trade to a standstill – an issue poorly recognised outside of the shipping industry. Yet in relation to climate policy, the fact that global trading would involve nations currently omitted from Kyoto obligations is common to both aviation and shipping. As one participant explained:

> "*the IMO has to steer a difficult course between the 'common but differentiated responsibilities' under the UNFCCC and the IMO's requirement of 'no more favourable treatment'."*

Considering shipping emissions, one stakeholder stressed that within the wider industry, focus on local pollutants was more dominant than greenhouse gas emissions, particularly as particulate emissions from ships have a cooling effect and are associated with health risks. Furthermore, it was pointed out that if main engines switched to distillate fuel, which produces far less particulates, this could in turn produce greater greenhouse gas emissions when assessed over its life cycle due to the refining process. It was argued, however, that debate over distillate fuel was largely irrelevant in the climate arena, given that the main objection to heavy fuel oil is related to coastal/port pollution while the majority of shipping activity is spent on the high seas.

The diversity within the shipping sector was considered to be both a barrier and an opportunity for mitigation measures. As there are many different types of ship, voyage and cargo, mitigation options would be more fruitful if they were more appropriately targeted. It was estimated by one expert that 80% of emissions are generated by 20-50% of all ships (50% of emissions from intra-EU); therefore, low-carbon measures could be targeted at particular routes or types of activity.

The shipping industry transports large quantities of waste material. If, for example, the ore could be refined in the country in which it was mined, much less material would need to be shipped, although it was recognised that not all countries in which ores were mined had, or could easily develop, the refining infrastructure. If a more targeted mitigation strategy was applied to all freight, the lowest carbon option may well be an increase in short-sea shipping given its low carbon intensity compared with road freight.

General discussion regarding how climate change mitigation is communicated focused on its negative framing and absence of a vision to inspire new opportunities or tackle issues of energy security. To overcome this, the stakeholders explored the opportunities for shipping over the coming decades. In terms of immediate potential implementation, more efficient ships, slow steaming (30% reduction in the engine load as exemplified by Maersk), hull paints and scrubbing debris collected on hulls were presented as examples. All were considered to be economically-driven although changes tend to be incremental. With regard to a revolutionary step-change, the stakeholders present were less optimistic for the short-term. 2030 was the first date before which newly built or designed ships would substantially penetrate the fleet, similarly for widespread use of alternative propulsion technologies such as wind and wave power.

Specific barriers to implementing policy that were mentioned at the workshop reinforced the empirical data from the interviews (Section 3) that highlighted that ship ownership, port infrastructure and shipping’s generally global nature must all be addressed. Yet it was recognised that the EU may take a regional approach to tackling emissions if no global solution has come to the force by 2013.

6.2 Session 2: Unilateral action to reduce greenhouse gas emissions from shipping: some preliminary thoughts

Presentation

In his presentation, Richard Starkey (Tyndall Centre) noted the discussions taking place within the IMO with regard to implementing a global market-based measure to reduce shipping emissions and the EU's commitment to implement a regional market-based measure, should no global agreement be reached by the end of 2011. However, given the steep reduction in global emissions required to avoid a high probability of experiencing dangerous climate change, the question was raised as to whether it might be appropriate for the UK to unilaterally put in place measures to tackle UK shipping emissions prior to the implementation of a global or EU market-based measure.

The Organization for Economic Cooperation and Development (OECD) classifies policy instruments into six types (Table 6-1). It was suggested that it did not seem feasible for the UK to unilaterally implement an emissions trading scheme and that something more than voluntary agreements were required. Thus, instruments from the remaining four policy types were suggested (Table 6-2).

Table 6-1: OECD policy types

Policy Type	Classification
Fiscal	Taxes (tax, tax exemption, tax reduction, tax credit) Fees/charges, Refund systems Subsidies (transfers, grants, preferential loans)
Tradable Permits	Emissions trading Green certificates Project-based programmes (including CDM and JI)
Regulatory Instruments	Mandates/standards Regulatory reform
Voluntary Agreements	"Strong" "Weak"
Research, Development & Demonstration (RD&D)	Research programmes Technology development Demonstration projects Technology information dissemination
Policy Process and Outreach	Advice/aid in implementation Consultation Outreach/information dissemination Strategic planning Institutional development

Source: (IEA 2001)

Table 6-2: Suggestions for instruments to be implemented unilaterally

Policy Type	Instruments to reduce UK shipping emissions
Fiscal	Carbon tax on ships using UK ports Revenue used to promote RD&D in UK
Regulatory Instruments	Standard for congestion management in UK Ports
Research, Development & Demonstration (RD&D)	Aim to make UK a world leader in RD&D
Policy Process and Outreach	Consumer label indicating goods transported by ship "Buy British" campaign – reduce demand for shipped goods

Discussion

Prior to addressing mitigation policy implementation, participants were asked to identify measures that could be taken by the UK acting unilaterally to tackle shipping emissions. In the first instance, many examples were given, although some stakeholders were of the view that there was little point to even discussing unilateral action. The measures identified can be summarised as follows:

i. Carbon tax on fuel for shipping
ii. Support and infrastructure for cold ironing
iii. Improved port infrastructure and operational management
iv. Measures to address ship speed both in relation to emissions within UK waters and deliver times
v. Carbon labelling for goods to include all freight modes
vi. Funding for RD&D
vii. Improved fuel and emission reporting techniques

Most of these measures were then discussed in the broader context of barriers and opportunities for the implementation of policy.

(i) Carbon tax

There was little support amongst participants for the proposed carbon tax. It was argued that international shipping emissions are currently less than 3 % of the global total and that a UK tax would, even if successful, impact only a small fraction of this 3 %. In addition, participants said that, in practice, a UK government would have little interest in implementing an instrument, which, if an EU scheme was incepted in 2013, would only be operational for a few years. Furthermore, it was argued that, if the tax was, for example, levied on emissions released since the last port of call, shipping operators would seek to avoid or minimise payment through trans-shipping or trans-loading e.g. unloading cargo at Rotterdam and then transporting goods to the UK by either feeder ships or road.

(ii) Support and infrastructure for cold ironing

In terms of providing renewable energy at ports for cold ironing, the question of who pays for the infrastructure was raised. The ship owner could benefit if it reduced combined fuel costs, but they would not fund such development. The costs of the fuel burned whilst docked compared with necessary electricity requirements would need to be weighed up. One participant suggested that as shipping is outside of the Kyoto agreement, it can not currently generate clean development credits to carry out clean port development.

On the other hand, stakeholders recognised the strategic risk of a high carbon price and how this may influence the desirability of plugging into low-carbon electricity at the port. However, for many types of shipping activity, the proportion of fuel cost for shipping is not high, as the value is often in the cargo. Although this of more relevance to the person owning the cargo and not necessarily the ship operator who will be purchasing the fuel. Moreover, tankers would not be able to take advantage of cold ironing as the largest of the vessels would require as much as 25MW per ship – the total output of around five of the largest off-shore wind turbines. Again participants argued the need for international agreement to reduce fuel use through cold ironing, to ensure connector types were internationally viable.

(iii) Improved port infrastructure and operations

Participants agreed that reducing congestion in ports was a good idea in theory, but there was disagreement about how great a reduction could be achieved in practice given port energy use is poorly understood. This uncertainty applied not only to the energy used by the ports directly, but additionally to the wasted fuel from ships waiting to dock. However, estimating the energy lost in delays due to port congestion would need to take into consideration the very different types of shipping activity. For example, liners pay for slots and are therefore granted priority for docking.

The issue of slot payment and difficulties in identifying exactly who is responsible for port congestion opened up a broader discussion on the potential for charging for slots. This would be similar to the situation at airports where aircraft need a landing slot at the airport of arrival before being allowed to take off. In response it was argued that, unlike an aeroplane, a ship will not always know its destination on leaving a port and even when it does, the journey time is much less certain. An example was given of the port of Newcastle in Australia that apparently needs to have 40 bulk carriers queuing outside the port in order to operate efficiently. And it was pointed out that shutting a refinery down due to lack of feedstock is so expensive that the refinery operators will guard against this by bearing the much lower cost of having ships queuing at a port with feedstock. On the other hand, some suggested that taking advantage of global positioning and new communication mechanisms enables ships to radio ahead to find out about the availability of docking space. Clearly, this may be more appropriate for some vessel or cargo types than others, but extending the operational procedures available to liners for some ships may be a fuel saving option. This type of approach would involve both the ports and ship owner/operator taking responsibility for improving the system to create fuel and CO_2 emissions savings.

(iv) Speed both in relation to UK waters and consumer expectations

Stakeholders identified that within the EU there is not enough berth planning, with permission problems, and bad weather throwing out schedules. However, adjusting transit times to reduce fuel burn (and therefore emissions), congestion and thereby extending delivery time from, say, eight weeks to nine would arguably require extra ships to maintain the same level of loading. It was indicated that bulk carriers are more likely to “hang around” after loading than liners and are sometimes used for temporary storage. Thus extra storage at ports may be helpful to avoid ships remaining close to ports (and using power as they do so) but available land is constrained in many nations. To alleviate these and related problems, stakeholders supported the idea of regulations across international ports, including the idea that premiums could be charged for goods slots.

(v) Carbon labelling

Participants noted that as 95% of all imported goods are transported by ship, a consumer label indicating that a good had been transported in this manner would therefore be on almost every imported item. Although this would allow consumers to make a choice between imported and domestically produced goods, it would not necessarily provide a clear indication on whether or not goods had a high or a low carbon footprint. For example, it was noted that issues around lifecycle emissions of food are complex, with some commentators arguing that it was less carbon intensive to import lamb from New Zealand to the UK than to rear it on the UK and others contesting this. Others suggested that carbon labelling would only work if there was an overarching personal carbon budgeting framework in place and that it could potentially create additional arguments in relation to how emissions are calculated and where boundaries are drawn. Picking out shipping for specific 'shipping' labels, therefore, was not considered a useful track to pursue, with widespread agreement for a level playing field such as a green tax for all modes of freight transport.

The strategic risk of brands not being seen to be 'green' by consumers was discussed, however, participants agreed that although consumer labels are, ostensibly, aimed at a retailer's customers, they are also aimed at its suppliers, incentivising them to reduce impacts along the supply chain.

(vi) Funding for RD&D

There was considerable support for making the UK a world leader in RD&D, although it was acknowledged that this would only have an impact on shipping emissions in the longer term.

6.3 Session 3: Apportioning shipping emissions

Presentation

In his presentation, Paul Gilbert (Tyndall Centre) defined *apportionment* as the sharing out between nations of past shipping emissions and contrasted this with the *allocation* of rights to future emissions that occurs under emissions trading schemes. He argued that if allocation of emissions rights to nations is to depend upon their current emissions (as under the *Contraction and Convergence* proposal), then allocation is dependent on apportionment of international shipping emissions, as apportionment is necessary in order to calculate nations' current emissions. An explanation was provided for three of 11 methods of apportionment identified in Table 5-2, which illustrated how a nation's shipping emissions can vary very substantially with the apportionment method used (see Table 6-3).

Table 6-3: Emission estimates for UK, Netherlands and Panama during 2006

	UK Mt CO_2	Netherlands	Panama
Bunker fuel sales	7.0 a	56.2 a	0.6 b
Flag of ship	10.3	4.7	186.7
Freight unloaded	41.3	40.6	
Freight loaded	24.7	13.4	

a using UNFCCC reported sales

b 1994 reported sales

Discussions

Participants expressed differing views with regard to i) the nature of apportionment and ii) the link between apportionment and allocation (see Sections 5.1 and 5.2). Discussion of apportionment led on to discussion concerning the baseline estimate for annual international shipping emissions. There was a difference of opinion between participants, with some favouring the IMO's activity-based method (see Chapter 3, IMO 2009) and others favouring the option of determining annual international shipping emissions through aggregating bunker fuel sales and arguing that the Bunker Delivery Receipt (BDR) provided by bunker suppliers could supply data for fuel consumption. However, to accurately determine CO_2 emissions would require additional data relating to vessel specific emission factors. Furthermore, it would require international cooperation since, as one stakeholder highlighted, not all nations currently report total bunker fuel sales. The use of ship GPS to calculate emissions data was also discussed but was subsequently dismissed by several stakeholders.

Some participants favoured apportionment as a means of emphasising the urgent need for the shipping sector to control its emissions and allowing the UK to monitor the emissions related to its international shipping activity. However, the majority of stakeholders opposed the idea of apportionment and instead argued that all international shipping emissions should be controlled through a sector-based emissions trading scheme, as recently proposed by the national shipowners associations of Australia, Belgium, Norway, Sweden and the United Kingdom (Australian Shipowners' Association et al. 2009). However, if nations wish to establish what their emissions are from international shipping, then a simple method such as apportioning by GDP or fuel sales would suffice.

The methodology of apportioning shipping emissions to the exporter (producer) and importer (consumer) of shipped goods was introduced and supported by some participants as a fair approach, as it concerns the nations ultimately responsible for the ship movement. However, the understanding among some of the stakeholders was that the ships were ultimately responsible for the emissions (more in line with the producer-based than consumer-based approach to emissions implemented by the UNFCCC) and therefore the release of emissions should be accounted for by the fuel user and then be linked back to where the fuel was sold.

The workshop closed with one participant citing that avoiding a high probability of experiencing dangerous climate change will require all sectors to engage in emissions reduction and that emissions are fairly apportioned between sectors.

7 Conclusions

Shipping requires a step-change in policy to begin the urgent process of decarbonisation. Given that the UK has influence over its imports and exports, waters and fuel sold, it has the potential to take a unilateral approach to tackling shipping emissions to complement globally implemented measures. However, policies tackling one part of the system must not induce rebound effects elsewhere. Assessing the potential for the UK taking unilateral action highlights the need for practical and fair apportionment regimes to determine the current level of emissions and provide a measure against which future mitigation policies can be benchmarked. In this analysis, those methods of apportionment based on imports and exports of shipped goods are deemed fairest in theory. In practice, however, these methods either incorporate a significant practical data burden or use proxies that can not capture future emission reductions made within the shipping system. The fairest approaches also tend towards the upper CO_2 estimates for UK shipping – up to six times higher than the currently reported figure. This project concludes that a hybrid of apportionment approaches may offer the most potential for use within UK unilateral policy, but the practical and economic implications require further research.

7.1 The scale of the challenge

The 2009 Copenhagen Accord recognises that "global temperatures should not rise by more than 2°C". To avoid this temperature rise, the cumulative emissions of greenhouse gases over the next century must be severely constrained. The sooner global emissions start to reduce, the more likely that the 2°C temperature rise can be avoided. However, global emissions are continuing to rise rapidly and therefore for any reasonable chance of avoiding 'dangerous climate change' associated with a 2°C rise, emissions across the aggregate of all sectors must be tackled.

Although it is likely that some sectors will mitigate their emissions more than others, this report illustrates that if international shipping emissions rise as projected, they will be at odds with the scale of emission reductions necessary. For a reasonable chance of avoiding temperatures rising above 2°C, the shipping sector must take measures to completely decarbonise within two to three decades. This level of decarbonisation is not currently being considered by the industry, and therefore a step-change in policies is required.

7.2 Shipping as a complex system

The complex nature of the global shipping sector, with its numerous players spread across the globe, makes shaping appropriate policy particularly difficult. A policy measure developed for one aspect of this system, may reap dividends in terms of overall emissions reduction throughout the system, or may induce rebound effects, further elevating greenhouse gas emissions. It is therefore important to consider what is to be incentivised/penalised (for example, low-carbon fuels, fuel efficiency, consumption), and where in the system this can best be achieved.

7.3 UK unilateral action

Shipping industry stakeholders involved with this project were broadly opposed to nations taking unilateral action to tackle shipping emissions prior to a global or EU agreement. However, given the slow pace of international negotiations and the urgency with which emissions on aggregate need to start to decline, innovative approaches to emission reduction will be necessary. In this vein, this project makes a preliminary assessment of the potential for unilateral UK shipping mitigation policies.

Unilateral UK policy is only viable if it can influence a particular aspect of the shipping system, and its impact is quantifiable. This analysis highlights that the UK can have influence over and can quantify the shipping emissions associated with:

- Port operations
- Quantity of imports/exports
- Amount by value of imports/exports
- Ultimate destination or origin of imports/exports
- Owner of the goods
- Type of fuel sold
- UK waters

It has limited unilateral influence over the shipping emissions associated with:

- The flag or registration of a vessel
- The construction or type of vessel
- The quantity of fuel sold
- Owner of goods if non-UK residents
- Scaled national emissions
- Scaled GDP emissions

Global policy measures are preferable for influencing some aspects of the shipping system, for example improving energy efficiency through ship design. However, if complementary unilateral mitigation policies were put in place, the most promising appear to be those that would tackle:

1) Goods imported/exported: policies could be implemented that could lower congestion, incentivise lower-carbon operational practices, drive innovation, incentivise shorter journeys, encourage more local consumption/production, lower overall consumption, but could also push freight onto land-base modes (assuming no accompanying regulation).

2) Location of emissions: could result in lower congestion at UK ports or incentivise more efficient routing, but may result in ships loading/unloading at close by ports and moving freight by land.

3) Fuel sales: could incentivise low-carbon fuels, but any higher fuel cost could result in ships simply purchasing fuel elsewhere.

Overall, UK unilateral action has the potential to drive the shipping system towards lower-carbon practices, whilst improving port infrastructure, driving UK shipping innovation and giving the UK an advantage as mitigation policies are eventually rolled out elsewhere on a larger spatial scale. However, unilateral action of this nature requires international shipping emissions to be apportioned for three reasons:

- To allow a nation to measure the level of emissions it considers itself responsible so that shipping emissions can sit alongside aviation emissions when the UK considers its carbon budgets
- To identify policies appropriate for incentivising/penalising appropriately
- To monitor the level of mitigation achieved

7.4 Appropriate use of apportionment

Quantifying CO_2 emissions from ships using the various apportionment methods available shows that for 2006, the range is from **7MtCO_2** (method 2, fuel sales) to **42MtCO_2** (method 9a – value of UK imports). As the method 2 figure is the one currently submitted to the UNFCCC, UK shipping emissions could in fact be six times higher than currently used estimates. If the UK were to consider these new estimates of shipping emissions in their carbon budgets, it would need to adjust upwards its target of an 80% emission reduction from other sectors by 2050 in order to compensate for a higher emissions total. Furthermore, if international shipping emissions are included in an EU scheme, the UK will also have to consider tighter emission cuts in its sectors.

Given the dependence of the UK CO_2 estimate on the chosen apportionment regime, each method of emission apportionment is assessed to highlight both practical and ethical barriers to its use. The methods considered within this analysis to be the most appropriate tend to incorporate as close a representation as possible of either goods imported (consumed) or goods exported (produced) by a nation. These assume that those nations either producing or consuming the goods are largely responsible for the associated emissions produced. However, accurate data to support the implementation of this type of method is costly and would require detailed information including distances moved by disaggregated modes of transport during the import and export of goods.

The trade-off between those methods requiring relatively raw, often top-down publicly-available data, and those requiring costly and privately-held data significantly influences the practicality of using a particular method. For instance, although top-down proxies for weight or value of goods could be used to estimate import/export-related emissions, they would not be able to reflect any change to the distance travelled or ship energy or carbon intensity. To this end, if one of the top-down proxies were to be used to apportion emissions to nations to reflect imports/exports, then this should be complemented with at least a coarse level assessment of trade routes. Other methods offering potential from a monitoring point of view include those that bear a close relationship to activity within local waters, such as method 5 (location of emissions). However, method 5's limited coverage of international shipping renders it appropriate only in combination with one or more of the other methods.

The current method used to apportion shipping emissions within the UNFCCC reporting procedures (fuel sales) is not considered to be an appropriate apportionment method. Although data is readily available, this method does not fairly represent national shipping activity as it disproportionally allocates responsibility for emissions to conveniently located coastal nations offering relatively cheap fuel.

Finally, those methods considered to be most ‘fair’ in this report, tend towards the upper estimates (all >30MtCO_2 or > 5% of UK CO_2).

7.5 Summary

Global policies for tackling shipping emissions are appropriate and necessary for mitigating the greenhouse gases associated with shipping. However, given the urgency with which emissions must start to reduce on aggregate, this report has explored complementary unilateral national mitigation policy aimed at the shipping system. Combining an assessment of data quality, cost and fairness of the various apportionment methods appropriate for monitoring unilateral policies measures, this project concludes that the fairest and most practically useful apportionment methods require a hybrid of approaches. Further research will explore these hybrid methods in terms of mitigation potential and determine if a unilateral approach could complement global mitigation measures to urgently tackle shipping emissions within the current economic environment.

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Appendix A

Criteria within the literature used for assessing apportionment methods

The UNFCCC (UNFCCC 1996b) considered the following criteria when assessing the suitability of the apportionment methods in Table 5-1:

- Would it be feasible for the nation to control the emissions apportioned to it?
- Could the required data be generated with sufficient precision?
- Is the method based on the "polluter pays" principle?
- Is the method equitable?
- Does the apportionment cover all the international emissions?
- Is the method suitable for all greenhouse gas emissions?
- Does the method supply a suitable basis for making projections?

And the following factors:

- Once emissions have been apportioned to nations, these nations would need to decide whether/how to control the emissions – should this be done nationally, or should the nation seek cooperation at regional/international level
- If shipping emissions are not apportioned, what measures should be introduced by the IMO to control emissions?
- Should the nations apportion based on historical emissions, using, for example 1990 as a reference year, or at a future date, which may affect whether a nation meets its national emission budget targets?

Entec UK Ltd (Entec UK Ltd 2005) evaluated the apportionment methods in Table 5-1 using a multi-criteria assessment and considered:

- Cost
- Simplicity and transparency
- Quality of data sources
- Potential accuracy and consistency
- Fairness and appropriateness

Wood et al (Wood et al. 2010) identified that if emissions from aviation are to be apportioned to aid the delivery of an emissions mitigation strategy, then they need to be coherent and transparent. It was additionally seen that the chosen method should help decision makers to understand the sensitivity of emission estimates to different intervention points and approaches. The criteria shaped by Wood et al (Wood et al. 2010) was developed from the SBSTA's international allocation proposals for the UNFCCC and was as follows:

- Could the required data be generated with sufficient precision and quality? Is this data publicly available and preferably free of charge?
- Is the method based on the "polluter pays" principle?
- Is the method consistent with the national inventory reported to the UNFCCC – could it be applied to all regions without overlap or omission?
- Is the apportionment method analogous to the treatment of other sources within the regional inventory?
- Is the method capable of monitoring emissions in the long term and reflect mitigative action taken by the inventory user(s)?

Wright (Wright 2008) at the LMIU defined the criteria to select an apportionment method as:

- Is the apportionment fair for each country?
- Is the data available?
- Is the methodology clear?
- Can the apportionment method be repeated annually?
- Is it compatible with calculations for other transport modes?

Appendix B

If responsibility is shared between the various players within the shipping system and their responsibility can be ranked, then in theory emissions could be apportioned using a top-down methodology based on the activities and rankings of the full set of actors (see Section 5.3). An example is given below, for a world consisting of four nations, A to D, and a shipping system consisting of the following five players:

1. producers of shipped goods
2. port operators
3. ship operators
4. bunker fuel sellers
5. consumers of shipped goods

Following this example, the ranking of responsibility for international shipping emissions would be as follows:

- consumers of shipped goods: 50%
- producers of shipped goods, 35%
- ship operators: 5%
- bunker fuel sellers: 5%
- port operators: 5%

In this case, as consumers of shipped goods are deemed to bear 50% of the responsibility for international shipping emissions, 50% of the annual international shipping emissions total would be apportioned between Countries A to D based on the proportion of shipped goods consumed by each nation. Thus, if Country A consumed half of all shipped goods, it would be apportioned half of this 50% of international shipping emissions (Table B.1). Similarly, as ship operators are deemed to bear 5% of the responsibility for international shipping emissions 5% of these emissions would be apportioned between Countries A to D based on the proportion of emissions released by their ship operators.

Table B.1

	Emissions per activity	**Nation's share of activity emissions (%)**			
Activity	**(%)**	*A*	*B*	*C*	*D*
Consumption of shipped goods	50	50	20	20	10
Production of shipped goods	35	30	40	20	10
Operation of ships	5	10	10	50	30

Sales of bunker fuels	5	10	10	70	10
Operation of ports	5	25	25	25	25
Final apportionment					
All activities		**38**	**26**	**24**	**12**
Highest ranked		**50**	**20**	**20**	**10**
Two highest ranked		**42**	**28**	**20**	**10**

Under the rankings in this example, Nation A would be apportioned the highest percentage of total international shipping emissions (38%) whilst Nation D would be apportioned the lowest (12%).

Section 5.3 goes on to suggest that an alternative would be to apportion on the basis of the activities of highest ranked (most responsible) player or players. Table B.1 shows the percentage of emissions apportioned to each nation if apportionment is based on either the highest ranked player or the two highest ranked actors.