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The Global Commission on the Economy and Climate

Working Paper

Raising Ambition to Reduce International Aviation and Maritime Emissions

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CONTENTS

Page

Overview

Global aviation and shipping together produce about 5% of global CO_2 emissions, and by 2050 this is expected to rise to 10–32%. Yet these sectors offer some of the most cost-effective emission reductions available today, particularly through improved fuel efficiency. There is a 27% difference in the fuel efficiency of the least and most fuel-efficient US airlines, and the most efficient crude oil tankers are about one-fifth as fuel-intensive as the least efficient. While domestic aviation and shipping are covered under national policies and emissions inventories, international aviation and shipping, which make up the majority of emissions, are not.

Two specialised UN agencies, the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO), govern international aviation and shipping activities, and are therefore best placed to drive further action. While ICAO has committed to introducing measures to cap net emissions at 2020 levels, and new IMO design efficiency standards for new ships are expected to lead to efficiency gains that will save an average of US$200 billion in annual fuel costs by 2030, progress in both sectors has been slow.

The Global Commission on the Economy and Climate recommends that emissions from the international aviation and maritime sectors be reduced in line with a 2°C pathway through action under ICAO and the IMO.

ICAO should take a decision in 2016 to start implementation of a market-based measure (MBM) from 2020, and should also introduce a stringent aircraft CO_2 standard. The IMO should adopt a global emission reduction target, and promote fuel saving through strong operational efficiency standards and a supporting data-sharing system.

These measures could help reduce annual GHG emissions by 0.6–0.9 Gt CO_2e by 2030.

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About this working paper

This New Climate Economy Working Paper was written as a supporting document for the 2015 report of the Global Commission on the Economy and Climate, *Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate*. It reflects the research conducted for Section 2.9 of the full report and is part of a series of 10 Working Papers. It reflects the recommendations made by the Global Commission.

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1. Introduction

The negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) cover the vast majority of global greenhouse gas (GHG) emissions, but two significant sources of rapidly growing emissions need to be addressed primarily outside the UNFCCC: international aviation and international shipping.[1] Due to their trans-boundary character, international cooperation is urgently needed to stem that growth and to seize opportunities for cost-effective emissions reduction.

Global aviation (domestic and international combined) produces around 2% of global CO_2 emissions, and global shipping about 3%.[2] But these proportions are growing quickly. By 2050, emissions from these sectors combined are projected to reach a level equivalent to between 10% and 32% of the total global emissions which would be consistent with a 2°C pathway.[3] The majority come from international activity – 65% and 84% for aviation and shipping, respectively.[4]

Without ambitious mitigation action in these areas, it will therefore be even more difficult to achieve the internationally agreed goal of keeping the average global temperature rise below 2°C. There are cost-effective options for reducing emissions from aviation and shipping available today, with significant scope to reduce fuel costs in particular, which represent around a third of operating costs in aviation and half in shipping.[5] In aviation, these measures include new aircraft technology and harmonised air traffic management systems. In shipping, it is estimated that taking full advantage of efficiency measures that are already available could save over US$30 billion in fuel costs each year for the industry and avoid 300 Mt CO_2 per year by 2030.[6]

International cooperation is crucial to unlocking this potential. In aviation and maritime transport, the vast majority of activity takes place across national borders. A single airline or shipping company can operate across six continents, which means that internationally harmonised policies are fundamental to effective governance. Specialised UN agencies govern international activity in these two sectors: the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO). Both are charged with overseeing their respective sectors, implementing international agreements and adopting industry-wide regulations to preserve a level playing field and ensure safety, security and good environmental performance.[7]

Both organisations have begun discussions on a process of tracking and reducing their members' emissions. The 191 ICAO Member States have set aspirational goals for international civil aviation: improving fuel efficiency by 2% annually and stabilising their net global CO_2 emissions at 2020 levels. As part of meeting these goals, ICAO member states are due to decide in 2016 on the implementation of a market-based measure to control emissions from 2020. The IMO has established the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). However, realising the cost-saving and climate protection potential of fuel efficiency improvements will require accelerated progress by these organisations and scaled-up ambition.

While the emissions reduction challenge is great, there are several recent developments in both aviation and shipping that can lay the groundwork for more ambitious climate action. Aircraft fuel efficiency continues to improve; several airlines have begun investing in sustainable fuels; and sophisticated technologies facilitate better air traffic coordination, allowing for more efficient routes and reductions in flight durations. In shipping, the private sector and NGOs have begun collaborating to understand and incentivise shipping efficiency; the EU has passed legislation to establish a transparent database on the efficiency of ships using its ports; and the Marshall Islands, the third-largest ship registry in the world, has pushed for international shipping to adopt an emissions target, though as yet without success.

Many of these initiatives are driven by collaboration among different industry stakeholders – and given the fierce global competition in these sectors, international cooperation will be essential for raising ambition. This paper examines the potential for further international cooperation in aviation and shipping to achieve both climate and economic benefits. We review the importance of the sector in the economy, the scale of emissions at stake, the options for reducing emissions, and the role of international cooperation. We conclude with recommended next steps for ICAO and the IMO, as well as for associated stakeholders in each sector.

2. International aviation

2.1 THE IMPORTANCE OF THE AVIATION SECTOR

Aviation is a major economic sector, central to trade and to growth for both developing and developed countries. Aircraft carry about 35% of world trade by value, although only 0.5% by volume.[8] Nearly US$6.5 trillion of cargo was handled by air in 2014.[9] Globally, the sector generates a total of 8.7 million direct jobs, and it is growing. The airline industry has doubled in the past decade, from revenue of US$379 billion in 2004 to US$733 billion in 2014.[10] Passenger bookings have increased by an average of 6% per year since 2010,[11] with growth of 6.7% projected for 2015; by 2032, bookings are forecast to double, to 6.5 billion per year.[12] The industry is also experiencing major regional shifts, with growth of air travel in developing markets, notably in Latin America and Asia. In 1993, more than 73% of all traffic was carried by airlines in Europe or North America. By 2033, that proportion is expected to shrink to 38%.[13] Other changes include low-cost business models becoming a viable option in emerging markets, offering consumers access to a wider range of destinations for business and leisure travel.

Aviation is also a major contributor to global GHG emissions. It contributes about 2% of globally produced CO_2 and accounts for 13% of fossil fuels consumed by transport.[14] Moreover, aviation's non-CO_2 emissions at high altitudes intensify the impact of aviation emissions on global warming, so they are much greater than that of CO_2 alone.[15] International aviation accounted for 65% of total fuel consumption in 2010, resulting in an estimated 448 Mt of CO_2 emissions, having grown from 185 Mt in 1990.[16] Given the growing role of aviation in the global economy, trade and business, ICAO expects international aviation emissions to rise to 682–755 Mt CO_2 by 2020. The global nature of the industry means that approaches to reducing international emissions – for example, through fuel-efficient technologies or new fuels – is likely also to lead to reduced domestic emissions.

2.2 CONTROLLING EMISSIONS FROM AVIATION

Controlling emissions growth will not be easy. But given the size of the sector's emissions, and the importance of ensuring that all sectors of the economy contribute to the global effort, it will be vital if the world is to get on a 2°C path.

There are several ways to reduce GHG emissions from aviation. On the demand side, there is a need to provide viable alternatives to flying. Good transport infrastructure, particularly high-speed inter-city and regional rail services, can make a difference.[17] But around 80% of all aviation emissions are from flights over 1,500 km, for which ground transport is not a viable alternative.[18] Advances in technology, such as video-conferencing, can also help to reduce travel needs in some circumstances, and can save time and money for businesses and individuals.

On the supply side, the focus needs to be on improving fuel efficiency and shifting to cleaner fuels. Both domestic policy and ICAO-led international policy have a role to play in incentivising such changes. At the domestic level, many countries including Brazil, India, the US and Japan have implemented jet fuel taxes for domestic flights, and Norway has enforced a carbon tax on domestic aviation since 1991.[19] Emissions from flights within the EU are covered in the EU Emissions Trading Scheme (ETS) but coverage of extra-EU flights, which account for most emissions, was dropped in late 2102 under strong international pressure.[20] Domestic aviation emissions are reported to the UNFCCC as part of national inventories and should be covered under countries' "intended nationally determined contributions" (INDCs).

At the international level, however, aviation fuel is not taxed – unlike almost all other fuels.[21] As a result, the incentives for reducing fuel use are lower than in other sectors. This is a clear policy failure but it is difficult to overcome by national policy alone. Long-standing legal bilateral air service agreements and their application, have effectively prohibited taxation of fuel for international aviation, and would require renegotiations to alter.[22]

However, even without being taxed, fuel remains a major cost for the industry, accounting for 30.1% of total costs in 2013, with the industry spending US$211 billion on fuel. (Fuel as a share of total costs in 2014 and 2015 is projected to be somewhat lower, about 28%, due to lower oil prices.)[23] Given this, fuel efficiency measures that will also reduce emissions are economically attractive. Since the early 1960s, aircraft design improvements have reduced CO_2 emissions per passenger by more than 70%. For every tonne of fuel saved, about 3.16 tonnes of CO_2 emissions are avoided.[24]

Efficiency improvements

There is clear room for wider efficiency improvements in the aviation industry: the difference between the fuel efficiency of the least and most efficient US airlines was 27% in 2013, and there was no improvement in fuel efficiency in US passenger airlines on domestic flights in 2012–2013.[25] Improving efficiency can both reduce emissions and reduce fuel costs for airlines. For instance, thanks to more than US$300 million invested in fuel-saving measures since 2005, American Airlines has saved approximately US$1.5 billion in fuel costs.[26]

Fuel efficiency can be improved in three ways:

Operational measures: These include introducing more efficient air traffic management procedures through crowded airspace, in-flight methods such as 'continuous descent' flight paths, using aircraft for trips within their optimal range, reducing the use of planes' auxiliary power units while they are parked at airports by connecting directly to electricity sources on ground, and measures such as reducing the weight of on-board equipment.

Aircraft design technologies: Airlines are continuously updating their fleets – more than 8,000 aircraft have been replaced since 2009 – and new units are more fuel-efficient. Manufacturers of aircraft and engines report that they spend US$15 billion a year on research to produce more efficient aircraft.[27] The pace of fuel efficiency improvement has been uneven over time, with periods of rapid gains (1960s and 1980s) followed by decades with relatively little progress (1970s and early 2000s).[28] Fuel efficiency standards would help provide a predictable, long-term incentive for technological progress. Airplanes are being built from lighter materials to reduce total weight, for example, and with more aerodynamic designs to reduce drag. "Winglets", for instance – up-tilted wingtip devices that reduce aircraft drag – can cost over US$1 million per aircraft to install, but improve fuel efficiency by 4% and pay for themselves in about two to three years (depending on fuel cost).[29] Some new types of engines can provide 15–20% efficiency improvements on the engines they replace.[30] All these developments have direct economic benefits for the airlines: the latest generation Airbus A320 is around 40% less expensive to operate than the aircraft it replaced.[31]

Improved infrastructure: This includes better-coordinated air traffic management and alternative routes that cut down travel time and distance. Over the past decade, there have been several changes in the airspace environment that create an opportunity to move towards a dynamic, more flexible routing structure. Advances in air traffic management systems and airport infrastructure have reduced delays and enabled more economic and GHG-reducing routings.[32] However, progress in this area heavily relies on the national directives and practices in place. Improvements to efficiency of routes, for example, can be limited by strict air traffic zone controls. Homogenising regional airspace, including moving towards a common airspace in the EU instead of 40 different zones, negotiating the use of military no-fly zones in many countries, and the implementation of the new satellite-based air traffic control systems, such as NextGen in the US,[33] can shorten routes and therefore fuel consumption considerably. An analysis of the EU's Single European Sky Air Traffic Management Research (SESAR) project found that it could save €35 billion in fuel costs by reducing flight time by 10%.[34]

More sustainable fuels

Aviation relies on a single type of petroleum-based fuel: jet fuel. But there are alternative fuels, made from non-fossil fuel sources such as biomass or waste, which offer a second potential approach to lowering emissions. These fuels are known as "drop-in", because they are completely interchangeable with conventional fuels, without having to make changes to aircraft structure. As well as reducing emissions, diversifying fuel supply in this way could be an important risk management strategy, reducing carriers' exposure to jet fuel price volatility in the long term.

However, as with the use of biofuels in other sectors, there are questions about life-cycle emissions and sustainability, as well as cost-effectiveness and availability to meet expected demand. It is not easy to evaluate the exact gains in emission reductions achieved by switching to more sustainable fuels. Measures designed to promote alternative fuel use in aviation need to consider the risk of direct and indirect land use change associated with some biofuels, the energy used in producing and transporting them, and other social and environmental issues, including the production of other pollutants such as nitrous oxide. Moreover, aviation-specific climate effects associated with high-altitude emissions of gases have to be taken into account.[35] Understanding the full life-cycle impact on emissions of switching to more sustainable fuels can thus be a very complex process, and while there are few other options for aviation, considerable questions remain about the sustainability benefits of biofuels.

Moreover, the technology has also not yet reached the scale needed to be economical, with current prices of these fuels around three times higher than conventional jet fuel.[36] Initiatives and research partnerships are nevertheless under way to scale up renewable jet fuel and reduce costs. Several airlines have signed long-term purchasing agreements with renewable fuel providers; for example, in 2013, Cathay Pacific negotiated an agreement with a US-based sustainable biofuel developer, Fulcrum, to supply over 10 years an equivalent of around 2% of its current annual fuel consumption.[37] Yet, even though 18 airlines have successfully deployed drop-in fuels at small scales, major obstacles remain to their wider deployment,[38] and projections for market share in 2020 have been consistently revised downwards.[39]

A group of airlines have formed the Sustainable Aviation Fuel Users Group (SAFUG)[40] to work with scientific agencies and environmental NGOs to accelerate the commercialisation of aviation biofuels, while ensuring sustainability and avoiding food security impacts. A study by the Australian Renewable Energy Agency (ARENA) examined what it would take to make a facility capable of producing 1.1 billion litres per year of renewable fuels viable. This amounts to almost a fifth of the standard jet fuel consumed in Australia in 2010.[41] It identified three key needs: 1) further investment and research and development in emerging feedstocks such as algae to increase their production; 2) building new infrastructure for biofuel production; and 3) supporting policies, such as extending biodiesel production grants to bio-jet fuel to make them more commercially viable.[42]

2.3 THE IMPORTANCE OF INTERNATIONAL COOPERATION

ICAO was originally expected to develop measures to control international aviation emissions following a recommendation in the Kyoto Protocol in 1997, and the slow progress in doing so thus far has been met with considerable criticism from the EU, environmental groups and others.[43] Over the last decade, however, the aviation industry has committed to targets for both carbon neutrality and fuel efficiency. In 2008, the Air Transport Action Group (ATAG), a coalition of companies and member organisations from the air transport industry, agreed to: further improve fleet fuel efficiency by 1.5% per year from 2008 until 2020; cap net emissions from the sector at 2020 levels; and reduce net emissions by half from 2005 levels by 2050.[44] Separately, at the 37th ICAO Assembly in 2010, governments agreed to set two aspirational goals: to improve fuel efficiency by 2% per year, and to make growth from 2020 onward "carbon neutral" in terms of net CO_2 emissions, to be achieved principally by "offsetting" them elsewhere in the economy. Both goals were reaffirmed by the 38th ICAO Assembly in 2013. However, these are not binding commitments, and even meeting the carbon-neutral growth target would be unlikely to achieve the reductions needed for a 2°C scenario.[45]

Governments, civil society and the industry have also committed to collaborating on the development by ICAO of a global CO_2 standard for new aircraft by 2016.[46] The coverage of this standard has not yet been finalised. If only "new types" of aircraft are included under the standard, then just 5% of the global fleet would be covered by 2030. If all "new in-production" aircraft are included, fleet coverage would rise to 55% in 2030.[47]

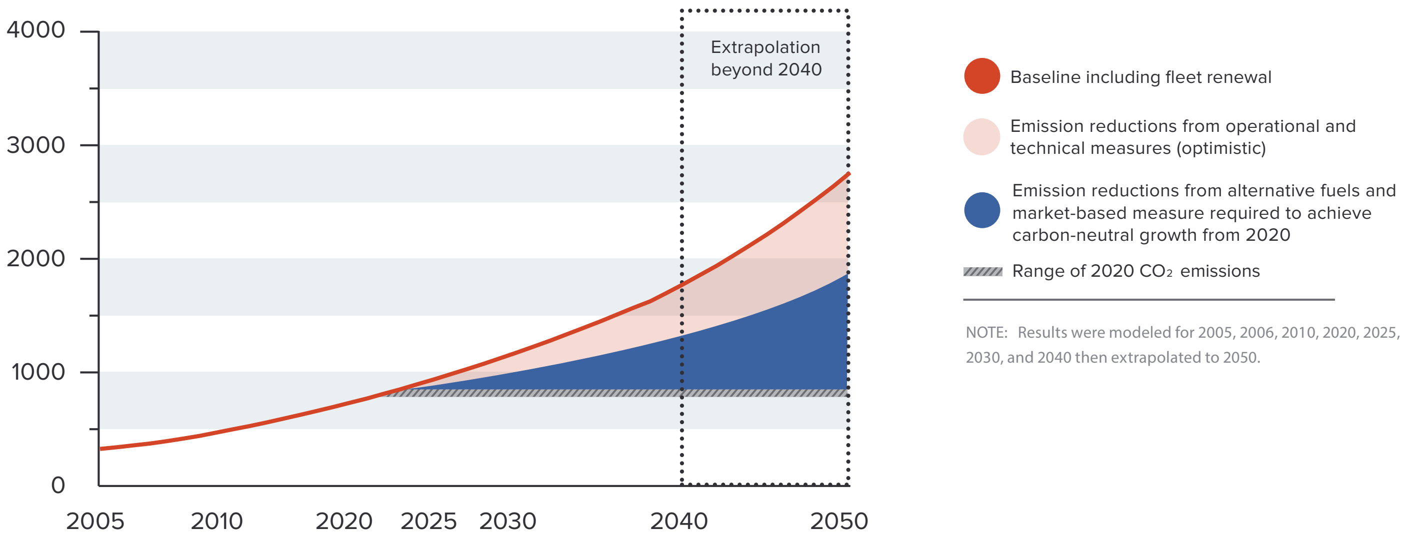
ICAO's Committee for Environmental Protection expects the standard to further reduce aviation emissions, but whether this is the case will depend on the coverage and stringency of the standard.[48]

Market-based measures

Yet these efforts are unlikely to be sufficient to meet the industry's targets. As already noted, taxation of jet fuel, implemented through an international agreement, would be an economically sensible way to incentivise further investment in efficiency improvements and alternative fuels, "internalising" the carbon pollution caused. Even though this option has made little headway within ICAO, it is possible for states to continue to remove this exemption from air service agreements on a bilateral basis. The chief instrument under discussion at ICAO to achieve the "carbon neutrality" target is a so-called "market-based measure" (MBM), mainly focused on offsetting emissions elsewhere in the economy. Figure 1 maps out the industry commitments, including the role of the MBM.

Figure 1

CO_2 emission trends from international aviation, 2005 to 2050



Source: ICAO, 2013. Environmental Report 2013.
Available at: http://cfapp.icao.int/Environmental-Report-2013/files/assets/basic-html/index.html#24

ICAO passed a resolution at its triennial General Assembly in 2010 to explore the guiding principles for the design and implementation of a global MBM. ICAO formally decided to develop an MBM at its 2013 General Assembly to "bridge the gap" between achievable in-sector reductions and the 2020 goal.[50] The action was in part a response to EU legislation adopted in 2008, and effective from 2012, to include emissions from all flights from, to and within the European Economic Area (EEA) within the EU Emissions Trading System (EU ETS). To allow time for negotiations on the MBM through ICAO, the EU ETS requirements were suspended in late 2012 for flights to and from non-European countries, and for 2013–2016, only emissions from flights within the EEA fall under the EU ETS.[51] The temporary EU ETS exemption puts additional pressure on ICAO and its members to establish an MBM in 2016, as the full EU ETS requirements will otherwise revert in 2017.

ICAO is due to make a decision on the measure in 2016, which would be fully implemented in 2020.[52] Three options are currently being considered:

An offset scheme would require participants to offset their CO_2 emissions above an agreed level by acquiring emissions permits from other sectors or companies. It is not yet clear what types of offsets would be approved. Options discussed within ICAO include project-based credits under the Clean Development Mechanism (CDM) or from voluntary programmes such as Verified Carbon Standard and Gold Standard; allowances or credits issued under national, sub-national or regional cap-and-trade schemes; and new types of credits that may become available, such as from REDD+ or for carbon capture and storage.[53] Ensuring that these offsets adhere to high quality standards is critical, as failing to do so would undermine the effectiveness of the offset scheme.

An **offset scheme with revenue** would function in the same way as the basic offset scheme, but would generate additional revenue by applying a fee to each tonne of CO_2 traded (e.g. a transaction fee). The revenue could be used for agreed purposes, such as to compensate and provide support to developing countries, including for efforts to reduce GHG emissions. This has been proposed as an innovative source for climate finance, which would not only correct a market distortion (the lack of taxation on aviation fuel), but also redistribute the benefits in an equitable way.[54] There is precedent for this type of finance-raising scheme: France, for instance, has a "solidarity tax" that finances health projects in developing countries via the Agence Française de Développement.[55]

The final option, an ICAO-run **global emissions trading scheme**, would cap total emissions from international aviation and create allowances for this amount (each equivalent to 1 tonne of CO_2). These allowances would then be distributed to participants using an agreed allocation method. Revenues could be generated by auctioning allowances rather than providing them to participants free of charge.[56]

Comparing the options and the administrative steps involved, some industry groups have recommended an offset scheme as the easiest to administer and quickest to implement.[57] Analysis for ICAO has raised concerns about uncertainty with regard to the long-term availability and cost of offsets if they were to be purchased externally; at the same time, creating a new trading scheme would require significant expertise and political agreement.[58] However, all three options officially remain on the table, and the potential to generate finance to compensate the impact on developing countries and for climate purposes makes the latter two particularly attractive.[59]

An ICAO study conducted in 2012 found that an MBM based on capping non-offset emissions at 2020 levels could require the offsetting of 464 Mt CO_2 of aviation emissions in 2036, roughly half the total emissions expected that year.[60]

Economic impacts of introducing an MBM

In 2012, ICAO conducted an analysis of the potential economic impact of introducing an MBM to help keep net carbon emissions from aviation at their 2020 level. The study found that under a scenario whereby carbon prices rise from US$30 in 2020 to US$45 in 2035, an MBM would only slow international aviation growth slightly, to 107% in 2020–2036, against a baseline of 110%.[61] The additional cost to airlines would be US$10/seat for a long-haul flight of 10,000–12,000 km, and US$1.50/seat for a short-haul flight of 900–1,900 km, with most models suggesting that the additional cost would be almost entirely passed on to consumers.[62] Global industry profits in the year 2036 would be US$33.3 billion, 1.2% lower than in a baseline scenario. As noted above, however, while operating costs would rise under an MBM, they are likely to be offset (to a degree) by action taken to make both planes and airline operations more efficient. Airlines with inefficient planes might lose market share if they raise prices more than their competitors, or lose profitability if they do not.[63] More recent analysis from ICAO has found that the total cost of the scheme could be as little as 0.2% of total air transport revenue.[64]

There are a number of design issues involved in setting up an MBM which will need to be resolved. A key issue for any scheme is its distributional impact – particularly how it will affect carriers based primarily in developing countries. ICAO operates on a principle of equal treatment of all carriers (Chicago Convention, Article 11)[65] but the UN climate regime follows the principle of "common but differentiated responsibilities", distinguishing among countries based on their resources and share of GHG emissions.[66] ICAO decided in 2013 that any MBM for international aviation should accommodate "the special circumstances and respective capabilities of developing countries".[67]

One way of addressing this issue of equity could be through financial support for affected low-income countries (if a revenue-generating scheme is employed), or by only purchasing offsets from developing countries. According to an IMF study, market-based instruments, implemented either through fuel taxes or emissions trading schemes, could provide an innovative source of climate finance. A globally implemented carbon charge of US$25 per tonne of CO_2 could raise around US$12 billion in revenue for developing countries.[68] Alternatively, some have suggested exempting particular routes or countries (i.e. all airlines flying from/to that country would be exempt). The latter would allow all airlines to be treated in the same way, in principle, but depending on the scope of the exemption, could limit the benefits of the MBM. If the EU ETS resumes coverage of aviation to and from the EEA, the plan is to exempt flights to and from countries with less than a 1% share in international aviation (measured in revenue tonne-kilometres).[69]A similar provision (perhaps with a lower percentage share to focus the exemptions on developing countries) could be adopted for a global MBM. Therefore adjusting the offset obligations for different routes need not have a large effect on the impact of an MBM and could enable the industry to meet its 2020 target while reflecting "common but differentiated responsibilities".

ICAO has assessed the distributional impacts of the three MBM options being explored. It has compared the impact on six different regions; on least developed countries (LDCs) vs. non-LDCs; and on countries classified by two different indicators of development – per capita income and international aviation activity. The studies showed that the differences between impacts were marginal. In all the six global regions examined, the MBM reduced traffic demand by around the global average of 1.2% – or about three months of typical growth[70] – and the change in operating profit varied from only 1.0% to 1.3% (the global average was 1.1%). The comparison of LDCs and non-LDCs showed a similar pattern to that of the six regions in terms of closeness to the global average results. However, impacts on traffic levels and profits were smaller in LDCs than developed economies. No differences between groups using development parameters were noted.[71]

A second key challenge in setting up an MBM is more technical: how best to design the monitoring, reporting and verification (MRV) systems and offsetting components. ICAO has been examining the existing global market-based processes, such as the Kyoto Protocol, to draw on best practice in terms of trading, rules, MRV mechanisms, etc. The MRV system of the aviation EU ETS also offers a model that could be easily adopted for a global scheme given that it is already applied to the sector. The potential offset mechanism would have to be well thought out and implemented, or else its integrity might be undermined. These issues need to be resolved swiftly if ICAO is to agree on an MBM framework in 2016 for implementation in 2020.

2.4 CONCLUSION AND RECOMMENDATIONS

The aviation industry has improved its energy efficiency in recent decades, and it has made laudable commitments to capping its net GHG emissions at 2020 levels, even while continuing to grow. However, aviation emissions are projected to more than double by 2050, so much greater efforts are needed to bring the sector in line with a 2°C trajectory. Offsetting as a means to meet these targets should only be seen as a partial, temporary measure, given the need to decarbonise the global economy over the long term to keep global warming within 2°C. However, with the available fuel options for the industry currently limited, other responses are also limited in the short term. The climate agreement at the Paris Climate Change Conference must encourage further action from ICAO. Efforts must be made to further reduce in-sector emissions by incentivising investments in energy efficiency and alternative fuels, and through ambitious industry standards. Still, the decision to implement a market-based mechanism is a welcome step, and it is therefore important for progress to be made rapidly on its design.

In order to ensure further progress, the Global Commission recommends that:

- **At its 2016 Assembly, ICAO agrees, as per its 2013 Assembly decision, to implement an MBM from 2020 which is in line with a global 2°C pathway and is ratcheted up over time. It should include the potential to raise revenue,** which could be used, for example, to provide support to developing countries and for their climate action. The agreement negotiated at the Paris Climate Change Conference should clearly articulate the need for the international aviation sector to set an ambitious emissions reduction target in line with keeping average global warming below 2°C.
- **ICAO strengthens efforts to implement a stringent aircraft CO_2 standard in 2016, including coverage of all newly delivered aircraft.** Further efforts should be made by airlines, governments and other stakeholders to increase research and development and investment into the design of aircraft that are more aerodynamic and lighter, engines that are more efficient, and airport and operation systems that reduce unnecessary fuel use both on the ground and en route.
- **The aviation sector expands the research, development and demonstration (RD&D) of sustainable biofuels.** Governments and airlines should work together to advance renewable jet fuel technology to reach a commercial scale, while ensuring the delivery of real emission reductions compared with alternatives and the use of stringent sustainability criteria including direct and indirect effects on land use.
- **Governments make strong efforts to provide alternatives where viable, such as high-speed rail, to reduce demand for air travel.**

3. International shipping

3.1 THE IMPORTANCE OF THE MARITIME SECTOR

International shipping plays an essential role in the global economy, carrying about 90% of world trade by volume.[72] The industry includes over 50,000 ships,[73] of which bulk carriers, oil tankers and container ships represent approximately 84% of total tonnage.[74] Ships have become much larger over time: the average ship built since 2010 is nearly seven times larger than the average ship over 20 years old.[75] Demand for maritime transport has risen significantly over the past several decades. Total cargo on international seaborne trade has risen from 2.6 billion tonnes in 1970 to 9.5 billion tonnes in 2013.

Shipping's contribution to greenhouse gas emissions has been rising as well. In 2012, CO_2 emissions from shipping totalled 949 Mt, close to 3% of global CO_2 emissions, up from 1.8% in 1996.[76] About 84% of the sector's emissions involved international shipping, equivalent to 796 Mt CO_2; the remaining 16% derived from domestic shipping and fishing.[77] Non-CO_2 emissions are also significant: shipping contributes 15% of global anthropogenic nitrogen oxide (NOx) emissions and 12% of sulphur oxide emissions.[78] Black carbon emissions from ships are also rising.[79] Emissions closely track broader economic factors; for example, emissions fell during the post-2008 recession and have risen again during the recovery. Accordingly, emissions are projected to increase rapidly, with the International Maritime Organization (IMO) projecting an increase of 50–250% by 2050.[80]

Because of the global nature of shipping, international collaboration is essential for effective regulatory action. A ship can be owned by a company based in one country, registered in another, and operated out of a third.[81] Because ships can be registered in any country of the owner's choice, if one country imposes stricter efficiency requirements on ships registered there, owners can simply move their registration. The competitive position of any country acting unilaterally could be affected, with few or no environmental benefits. Moreover, because shipping companies operate in so many different countries, the transaction costs of having different policies in different states can be very high. Thus far, however, global action under the IMO has been very slow.

3.2 CONTROLLING EMISSIONS FROM SHIPPING

Virtually all GHG emissions from shipping arise from the carbon content of fuels used in ship engines.[82] Shipping consumes 250–325 Mt of fuel per year,[83] about 85% of which is heavy fuel oil (HFO). The remainder is marine diesel oil (MDO), with minimal usage of liquefied natural gas (LNG).[84] However, restrictions on sulphur emissions may reduce HFO's prevalence.[85] In Emission Control Areas (ECAs) in North America and northern Europe, only fuel with a sulphur content of up to 1,000 parts per million (ppm) is permitted. Use of MDO, marine gas oil (MGO) and LNG is likely to rise in response to these restrictions.[86] Currently, most ships switch to low-sulphur fuels when travelling through an ECA, or they use scrubbers with HFO to reduce sulphur emissions. Unfortunately, these shifts are unlikely to have much effect on CO_2 emissions: aside from LNG, all of these shipping fuels have comparable carbon content, and using a scrubber does not eliminate CO_2 emissions.[87]

Based on emissions per unit of cargo transported, shipping is generally more efficient than any other form of transport.[88] However, ship efficiency varies widely, based on design (ship type, size and technology), fuel and power sources, and operations (ship speed, maintenance routines and routing).[89] The most efficient crude oil tanker is about one-fifth as fuel-intensive as the least efficient.[90]

Efficiency metrics are typically separated between technical design efficiency and operational efficiency, as even ships with similar design efficiencies can have vastly different operational efficiencies.[91] A fundamental driver of operational efficiency is speed: a 10% reduction in speed corresponds to a 27% drop in fuel use per unit of time.[92] "Slow steaming" practices, widely adopted from 2007–2012 in response to the global economic downturn, reduced daily fuel use by an average of 27% across the industry and by more than 70% in some ship size categories.[93] Utilisation rate also strongly influences efficiency, because fully loaded ships require fewer ship-kilometres to transport the same amount of cargo as relatively empty ships. Design efficiency, on the other hand, is affected by ship capacity, power and other technical features.[94] Unlike in other modes of transport, design efficiency of new ships has deteriorated by about 10% since 1990, in part because high freight rates encouraged more block-like, less hydrodynamic ship designs that maximise cargo capacity and are cheaper to build.[95] It is worth comparing this with the efficiency of aircraft design, which has improved on average around 7% over the same time period, and of cars, which has improved by around 20%.[96] Since 2008, however, design efficiency of new ships has begun to improve once again.[97]

Given that fuel represents 50% or more of a ship's operating cost, this lack of progress in shipping efficiency – particularly design efficiency – is surprising. In part, this reflects the lack of adequate incentives – as with aviation, international marine fuels, despite the pollution they generate, are not taxed.[98] Yet there is extensive evidence that there are several available design and operational efficiency measures that are cost-effective, saving more on fuel costs than is spent implementing the measures.[99]

For instance, according to the International Council on Clean Transportation (ICCT), more frequent propeller polishing can increase efficiency by 4% and costs just US$13 per tonne of fuel saved (fuel costs have ranged between US$300–800 per tonne).[100] Propeller polishing costs vary widely depending on ship type and size.[101] New hull coating technology that resists fouling also yields significant cost savings through efficiency gains. One company has found that a fouling-resistant hull coating applied to a bulk cargo vessel at a cost of US$360,000 saved about 5,400 tonnes of fuel over nine years, a 22% efficiency improvement.[102] At a fuel cost of US$300 per tonne, the technology would fully pay itself back in just over two years, and over US$1.2 million would be accrued in net savings over nine years.

Economics are not the determining factor preventing broader efficiency improvements, since these measures make clear business sense even without policy interventions. The next section will investigate why adoption of these efficient technologies has been so slow.

3.3 THE IMPORTANCE OF INTERNATIONAL COOPERATION

The lack of take-up of efficiency measures can be broadly attributed to two systemic market failures that prevent the industry from incentivising and rewarding energy efficiency.[103] First, there is little reliable information on ship efficiency and gains available from different technologies and operational measures. One recent test of 10 different technologies found that the level of savings realised was consistently lower than the marketing claimed.[104] There is also a lack of vessel-specific savings information, rather than generic ship type information.[105] As a result, ship owners are sceptical of manufacturers' efficiency claims and are reluctant to commit to retrofits for uncertain cost savings. The industry also suffers from lack of data regarding the operational efficiency of in-use ships. Because operational efficiency can be affected by weather, speed and other parameters, real-world data are a necessity for properly measuring ship efficiency. However, such data have largely been unavailable, and ship owners tend to be protective of such information for competitiveness reasons.[106]

The second market failure is an issue of split incentives between a ship owner and charterer that arises from the structure of ship charter contracts. Although individual contracts vary, charterers frequently bear some or all of the fuel costs, while the owner is responsible for the ship's technology and design. The ship owner, therefore, would bear the cost of upgrading to more efficient technology, but would not accrue the benefit of fuel savings. The charterer, on the other hand, has minimal control over the ship's technology but pays for the fuel. This situation is analogous to the familiar "landlord–tenant" problem, in which a landlord has no incentive to pay for building efficiency upgrades because the tenants would reap the cost savings. Ideally, charterers would pay a premium for a more efficient ship in anticipation of reduced fuel costs. Ship owners could thus recover the additional costs of upgrading their ships. However, such arrangements are rare. An examination of one market segment found that ship owners do achieve higher charter rates for more efficient ships, but that they only recoup 40% of the savings that their ships provide based on design efficiency.[107]

While problematic, these market failures are neither novel nor insurmountable. International, industry-wide efforts are needed to improve transparency and strengthen incentives for ship efficiency, and the IMO has the global scope necessary for leading such efforts.

Overcoming the lack of information

Trustworthy and consistent information on the efficiency of specific ships, technology, and operational measures enables ship owners, charterers and financiers to better incorporate efficiency into their decision-making.

Under the IMO, the two principal initiatives addressing this issue are the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). Adopted in 2011, the EEDI requires a certain level of design efficiency for new ships built from January 2013; the standard will rise over time.[108] It is the first mandatory GHG emissions reduction regime for an entire industry.[109] The IMO also requires that all ships use an operational efficiency management tool called the Ship Energy Efficiency Management Plan (SEEMP). A SEEMP must identify what energy-saving measures have already been undertaken and what further measures are possible. It also requires each ship to have procedures in place to monitor and evaluate efficiency. However, the SEEMP does not require implementation of any of the identified efficiency measures, nor does it require that an efficiency goal is set or met.[110]

Several independent initiatives have emerged to address the lack of transparency in the industry. For example, the organisations RightShip and Carbon War Room provide a rating system for over 70,000 vessels that grades each ship on design efficiency from A to G. These ratings are public, and ship owners can verify or update their fleet's information to ensure accuracy. Twenty-five charterers representing almost 2 billion tonnes of cargo (one-quarter of global non-containerised shipments) have begun factoring efficiency into their vetting process as they decide which ships to charter.[111] The Clean Shipping Index provides a similar service but rates carriers on all pollutants, including NO_x, SO_x, particulate matter, chemicals and on-board waste.[112] The Clean Cargo Working Group works with over 40 ocean freight carriers and cargo owners to analyse their shipping efficiency and compare them with their peers.[113] These initiatives help to foster an environment in which efficiency is monitored, prioritised and rewarded. However, these voluntary initiatives do not yet have full industry-wide influence, and they lack a single, standardised methodology for evaluating efficiency.

Financing efficiency upgrades

In the buildings sector, the landlord–tenant split incentive barrier has been tackled via Energy Service Companies (ESCOs), which provide financing for energy efficiency upgrades. Landlords pay them back over time with a portion of the energy savings resulting from the upgrade. Similar third-party financing schemes have emerged for shipping. These include the Sustainable Shipping Initiative's Save As You Sail (SAYS) and the Self-Financing Fuel-Saving Mechanism (SFFSM) driven by Carbon War Room and University College London.[114] In both models, a third-party financier pays for the upgrades, and the cost savings are shared between the third party, owner and charterer (depending on who is paying for the fuel). These emerging efforts are useful in addressing potential financing obstacles, but their impact is constrained by the lack of industry demand for these retrofits. The incentives for owners to upgrade their ships must be strengthened in order for these financing models to be deployed at larger scales.

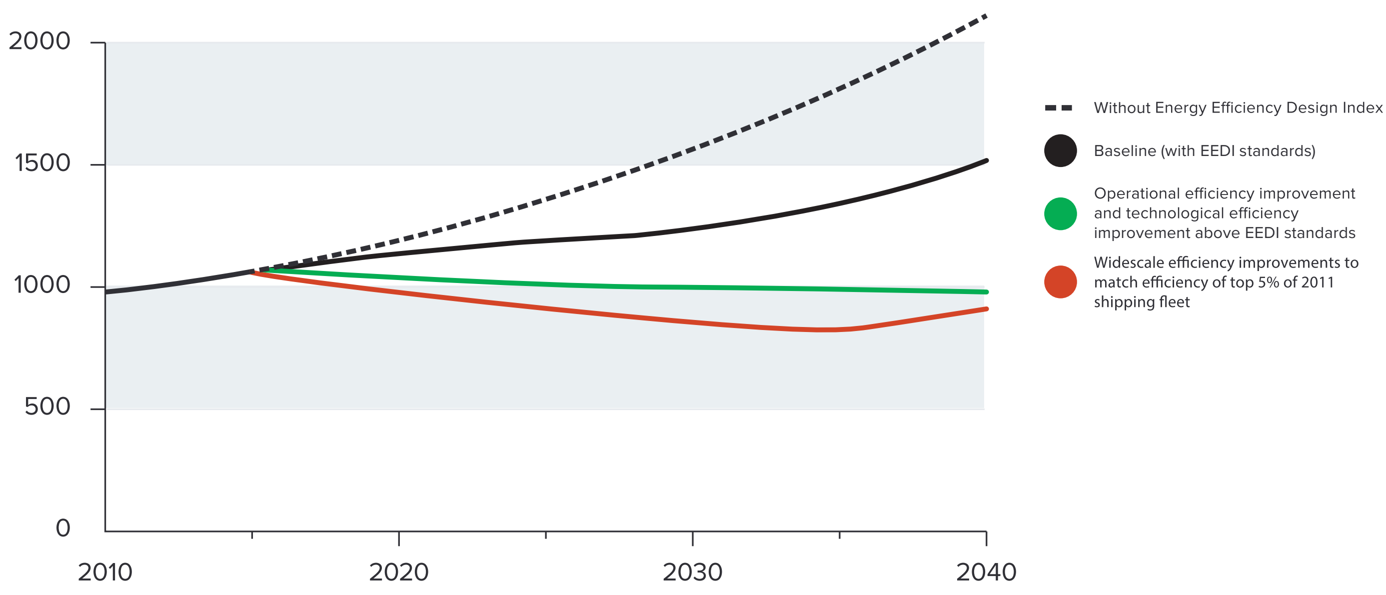
Incentivising greater efficiency

Ports and banks also have a role to play in incentivising efficiency. Port Metro Vancouver offers reduced harbour fees to more efficient vessels.[115] "Gold" rated vessels pay just over half the base rate. A vessel can earn a "gold" rating if it has an "A" rating through RightShip/Carbon War Room, a "green" rating through the Clean Shipping Index, or through use of alternative fuels. Two leading shipping banks, HSH Nordbank and KfW-IPEX Bank, have also reported using RightShip/Carbon War Room's rating scheme when evaluating the risk and return of a loan, favouring efficient ships because they are more likely to be chartered and to better maintain their second-hand value over time.[116] These systems further underscore the need for information on ship efficiency: the existence of RightShip and Clean Shipping Index's rating systems enabled Port Metro Vancouver to assess the efficiency of specific vessels.

These initiatives demonstrate what is possible. As shown in Figure 2, if the entire fleet achieved the efficiency of 2011's industry leaders by 2035, total emissions could be reduced even while shipping activity doubled. However, these initiatives need to be brought to a global scale (and in the case of efficiency indices, harmonised internationally) if they are to transform the industry into one that more comprehensively monitors, incentivises and increases fuel efficiency.

Figure 2
Shipping fleet CO_2 emissions with efficiency standards

Shipping fleet CO_2 emissions with efficiency standards, additional technologies, and full deployment of best available technology and best practices for in-use ship efficiency.



Source: International Council on Clean Transportation (ICCT), 2013. Long-term Potential for Increased Shipping Efficiency through the Adoption of Industry-Leading Practices. White paper. IICT, Washington, DC.

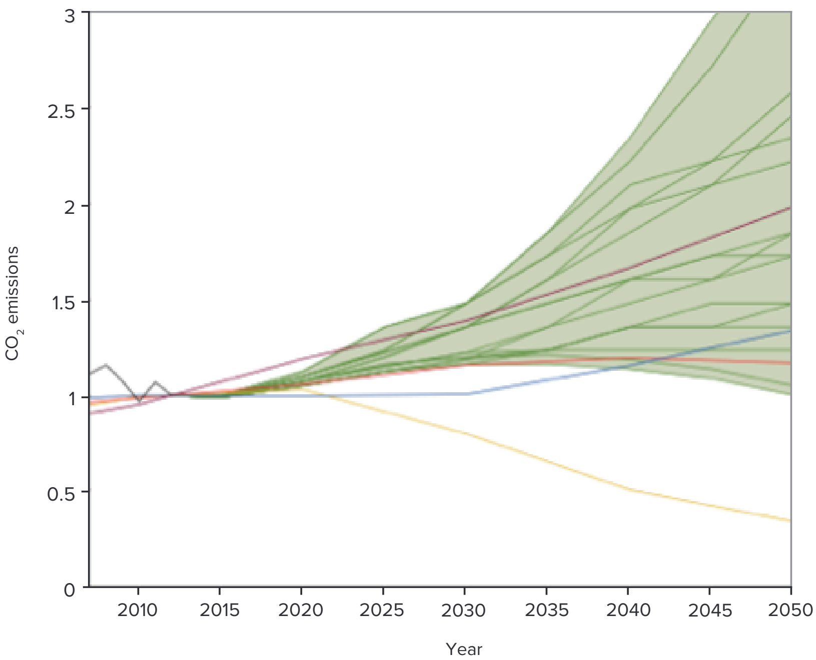
A global approach through the IMO

The IMO has acknowledged that the shipping industry must play its part in addressing climate change, and declared that shipping "will make its fair and proportionate contribution towards realizing the objectives that [the UNFCCC] and the global community pursue".[118] Reducing emissions from shipping to be in line with a 2°C pathway, would require a 50% reduction from 2012 levels by 2050, according to a study by University College London and the University of Manchester.[119] The EEDI and SEEMP are meant to help in achieving this goal; they are anticipated to save US$200 billion in fuel costs and 330 Mt CO_2 annually by 2030 at marginal cost in the near term.[120] The EEDI could be even more stringent: recent analysis shows that many of the ships that entered the fleet in 2013 and 2014 exceed the design efficiency standard required from 2015 to 2019, so it is technically feasible to strengthen the requirements.[121]

Nevertheless, despite the anticipated savings, shipping emissions are projected to double from 2012 to 2050 and more than triple over 1990 levels due to the increased transport demand.[122] Thus, in addition to the strong financial case for increasing fuel efficiency across the industry, there is an equally strong case from the climate perspective. As shown in Figure 3, without further action, shipping emissions will diverge farther and farther from the industry's estimated "fair and proportionate" contribution.

Recent developments demonstrate an appetite to make progress on the issue. On the policy front, EU legislation passed in April 2015 will mandate monitoring, reporting and verification of CO_2 emissions from large ships using EU ports, regardless of where ships are registered. The data will be publicly disclosed.[124] This measure will dramatically improve the quality of information within the industry, a fundamental first step that can enable further action.

Figure 3
Shipping emission projections



The green shaded region represents IMO projections, and the RCP 2.6 line represents the trajectory needed for shipping to reduce its emissions in line with a 2°C pathway. [123]

Source: Bows-Larkin et al, 2015.

In another important step forward, the Republic of the Marshall Islands recently submitted a proposal to the May 2015 meeting of IMO's Marine Environmental Protection Committee (MEPC) for the international shipping industry to adopt a global emissions reduction target.[125] This action was particularly significant because the Marshall Islands is the third-largest flag registry in the world, so it has the weight at the IMO to push for change.[126] However, the Committee decided to focus instead on finalising the emissions data collection system.

Several policy proposals were submitted to the IMO for consideration in 2010 during a discussion of market-based measures (MBMs) for emissions control. Since then, discussion of MBMs has been put on hold at the IMO, and there is as yet no indication of when it might return to the agenda. Possible policy measures include, among others, an emissions offset scheme, emissions trading, a fuel tax and mandated energy efficiency targets. In addition, the UNFCCC continues to discuss the possibility of a levy on international marine fuels that would raise climate finance to be channelled to developing countries, analogous to the one discussed in the aviation section. Similar to ICAO, the IMO operates under a principle of "no more favourable treatment", meaning that all ships are treated equally regardless of provenance. As under ICAO, this means that any emission reduction measures would have to balance this principle with the UNFCCC's "common but differentiated responsibilities".

In assessing potential policies, there are several important factors to consider. First, given the significant scope for cost-effective in-sector emission reductions, policy measures could usefully prioritise measures within the industry, rather than looking to offsets. Second, given that the industry is not responding to strong existing financial incentives for many technical and operational changes, due to the market failures described above, it is likely that simply increasing the financial incentive, for instance through a carbon tax, may not yield sufficient efficiency improvements. Finally, because speed and other operations are so influential in efficiency, any new policy should address operational efficiency, not just design efficiency.

Given these constraints, the best approach appears to be operational efficiency requirements that apply to all ships, complemented by a trading scheme that would permit highly efficient ships to sell their extra "efficiency credits" to less efficient ships. Similar to the EEDI, the operational efficiency standards would be differentiated based on ship type and size. The trading option provides flexibility and an additional incentive to maximise efficiency. The efficiency standards ensure that ships converge on industry-leading efficiency levels, while allowing ship owners the flexibility to choose whether to use design retrofits, operational measures or a combination to meet their efficiency target. The requirements could be ramped up over time to motivate continual improvement and adoption of cutting-edge technologies. The specifics of such a policy – which metrics to use, what the requirements should be and how they would change over time – should be carefully designed to minimise administrative costs and market distortions. Demonstrating the scope for improvement, one study by the International Council on Clean Transportation found that bringing all ships to industry-leading efficiency levels would avoid 300 Mt CO_2 per year by 2030.[127]

This combination of minimum standards and efficiency credit trading has been implemented in the UK, US and Italy to help companies or utilities meet mandates to improve energy efficiency by a certain amount each year.[128] For example, the Perform, Achieve and Trade programme under way in India sets efficiency improvement targets for factories. Companies that exceed their targets will get certificates that they can sell to companies that fall short.[129] In fact, a proposal along these lines was submitted by the US to the IMO in 2010, entitled Ship Efficiency and Credit Trading (SECT) programme (though it was based on design, not operational, efficiency requirements). It was analysed alongside nine other proposals, and the IMO found that its total mitigation potential was among the highest. It yielded by far the most in-sector reductions.[130]

This policy would need to be backed by a global system to track and report operational efficiency, making this information publicly available. Such standardised efficiency measurement would support charterers determining which ships to contract, ports offering differential harbour fees, and financiers evaluating retrofits. There is clear potential for the IMO to adopt a proposal such as this to drive industry-wide improvements in efficiency and unlock the associated economic and climate benefits.

3.4 CONCLUSION AND RECOMMENDATIONS

The maritime sector plays a fundamental role in supporting world trade. Increasing shipping efficiency would reduce fuel costs, with large economic benefits, while curbing the sector's fast-rising GHG emissions. However, progress in shipping efficiency has been slow to date, because of various market failures. Initiatives are under way to tackle these obstacles, but they are limited in scope. The IMO provides the global, industry-wide reach needed for effective action, but resistance from industry has stalled any serious international action. The IMO will have to step up its efforts to achieve the efficiency gains that are needed, so the sector can contribute to global efforts to tackle climate change. Therefore, the Global Commission recommends that:

- **The IMO implements a transparent, global system that provides reliable data on operational ship efficiency.** This would raise awareness within the industry and allow charterers to confidently discern between more efficient and less efficient ships during the vetting process, allowing them to realise reduced fuel costs.
- **The IMO adopts a global emissions reduction target for international shipping emissions.** The agreement at the Paris Climate Change Conference should clearly articulate the need for international shipping to set an ambitious emissions reduction target in line with keeping average global warming within 2°C.

- **The IMO accelerates the process to establish a policy measure that would promote operational efficiency,** such as a global efficiency standard with efficiency credit trading between ships. This would provide a universal incentive, allowing time for companies to adjust and to minimise the costs of premature scrapping of inefficient ships.
- **Ports and banks strengthen incentives for less polluting ships.** Ports should adopt different rates for harbour dues that incentivise more efficient ships. In evaluating the risk and return of a shipping loan, banks should factor in efficiency and the associated lower operating costs (and higher revenue) potential.
- **The IMO urgently open up again a review of the potential use of market-based measures (MBMs)** to complement other actions for emissions control.

ENDNOTES

1 Domestic aviation and maritime emissions (i.e., emissions from ships and planes travelling entirely within one country) are included under national emission inventories, and may also be included in a country's intended nationally determined contribution (INDC). On the other hand, international aviation and maritime emissions are not covered by any country's emissions inventories.

2 Aviation accounts for approximately 2% of global CO_2 emissions from fossil fuel use. See: *ICAO, 2013. ICAO Environmental Report 2013: Aviation and Climate Change*. International Civil Aviation Organization, Montreal. Available at: http://cfapp.icao.int/Environmental-Report-2013/.

Shipping accounts for approximately 3% of global CO_2 emissions from fossil fuel use. See: IMO, 2014. *Third IMO GHG Study 2014*. International Maritime Organization, London. Available at: http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Greenhouse-Gas-Studies-2014.aspx.

See also: *IEA, 2014. CO_2 Emissions From Fuel Combustion: Highlights 2014*. International Energy Agency, Paris. Available at: https://www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion-highlights-2014.html.

Sims, R., Schaeffer, R., Creutzig, F., Cruz-Núñez, X., D'Agosto, M. et al., 2014. Chapter 8: Transport. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner et al. (eds.). Cambridge University Press, Cambridge, UK, and New York. Available at: https://www.ipcc.ch/report/ar5/wg3/.

The IPCC (Sims et al., 2014) and IEA (2014) report somewhat different percentages. The IPCC includes forestry and land use in its total GHG emissions figure, while the IMO and ICAO do not. The IEA figures only account for international activity, not domestic, and thus are lower than total global emissions from these two sectors. The IMO analysis combines IEA data on fuel use with separate, bottom-up data to arrive at its figures, which are higher than the IEA's.

3 UNEP, 2011. Bridging the Emissions Gap: A UNEP Synthesis Report. United Nations Environment Programme, Nairobi, p42. Available at: http://www.unep.org/pdf/unep_bridging_gap.pdf. Under the projections cited by the UNEP report, total emissions for the aviation and shipping sectors combined are projected to increase to between 2.09 Gt CO_2e and 6.77 Gt CO_2e in 2050. The wide range of potential emissions in 2050 in different modelled projections reflects different possible levels of GDP growth, technology improvements and other factors. Under the scenarios reviewed by the IPCC, total global emissions would have to lie between 18-23 Gt by 2050 in order to stay within the 2°C pathway, with a median level of 21 Gt CO_2e. Therefore, without further reduction efforts, aviation and maritime emissions combined could represent between 10% and 32% of total "allowable" emissions by 2050.

4 ICAO, 2013. *ICAO Environmental Report 2013*. IMO, 2014. Third IMO GHG Study 2014.

5 Wang, H., 2014. The end of the era of heavy fuel oil in maritime shipping. The International Council on Clean Transportation. Blog, 9 July. Available at: http://www.theicct.org/blogs/staff/end-era-heavy-fuel-oil-maritime-shipping.

IATA, 2015. *Fact Sheet: Industry Statistics*. Updated June 2015. International Air Transport Association, Montreal. Available at: http://www.iata.org/pressroom/facts_figures/fact_sheets/Documents/fact-sheet-industry-facts.pdf.

6 ICCT, 2013. *Long-term Potential for Increased Shipping Efficiency through the Adoption of Industry-Leading Practices*. White paper. The International Council on Clean Transportation, Washington, DC. Available at: http://www.theicct.org/sites/default/files/publications/ICCT_ShipEfficiency_20130723.pdf.

7 For aviation and shipping, the Kyoto Protocol explicitly assigns responsibility to the IMO and ICAO. "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 fuel working through the International Civil Aviation Organization and the International Maritime Organization, respectively." (Source: http://www.unfccc.int/resource/docs/convkp/kpeng.pdf). ICAO was created in 1944 upon the signing of the Convention on International Civil Aviation (Chicago Convention). It works with the Convention's 191 Member States and global aviation organisations to develop international Standards and Recommended Practices (SARPs), which States reference when developing their legally enforceable national civil aviation regulations. IMO

was established through a convention adopted by the UN in 1948, which came into force in 1958. It has 171 members and is governed by its Assembly, which meets every two years, and its Council, which is elected by the Assembly.

8 ATAG, 2014. *Aviation Benefits Beyond Borders*. April 2014. Air Transport Action Group. Available at: http://aviationbenefits.org/media/26786/ATAG__AviationBenefits2014_FULL_LowRes.pdf.

9 IATA, 2015. *Economic Performance of the Airline Industry*. Mid-year report, June. International Air Transport Association, Montreal. Available at: https://www.iata.org/whatwedo/Documents/economics/IATA-Economic-Performance-of-the-Industry-mid-year-2015-report.pdf.

10 IATA, 2015. *Fact Sheet: Industry Statistics*.

11 Authors' calculation based on data in IATA, 2015. *Fact Sheet: Industry Statistics*.

12 ATAG, 2014. *Aviation Benefits Beyond Borders*.

13 Boeing, n.d. Long-Term Market, World Regions. Available at: http://www.boeing.com/commercial/market/long-term-market/world-regions/ [accessed 1 May 2015].

14 Kahn Ribeiro, S., Kobayashi, S., Beuthe, M., Gasca, J., Greene, D., Lee, D.S., Muromachi, Y., Newton, P.J., Plotkin, S., Sperling, D., Wit, R. and Zhou, P.J., 2007. Chapter 5: Transport and its infrastructure. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds), Cambridge University Press, Cambridge, UK and New York. Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter5.pdf.

Moreover, when its non-CO_2 impacts are factored in, it contributes 4.9% of the Earth's warming effect. Source: WWF and Vivid Economics, 2012. *Aviation Report: Market Based Mechanisms to Curb Greenhouse Gas Emissions from International Aviation*. Available at: http://awsassets.panda.org/downloads/aviation_main_report_web_simple.pdf.

15 IPCC, 1999. Aviation and the Global Atmosphere. J.E.Penner, D.H.Lister, D.J.Griggs, D.J.Dokken, M.McFarland (Eds.) Cambridge University Press. Available at: http://www.ipcc.ch/ipccreports/sres/aviation/.

16 ICAO, 2013. *ICAO Environmental Report 2013*.

17 IEA, 2009. *Transport Energy and CO_2: Aviation and Maritime, Expert Group Meeting on Transport for Sustainable Development*. 29 August 2009. International Energy Agency, Paris. Available at: http://www.un.org/esa/dsd/susdevtopics/sdt_pdfs/meetings/egm0809/cuenot_28_august.pdf.

18 ATAG, 2014. *Aviation Benefits Beyond Borders*.

19 European Commission, 2013. Evaluation of Directive 2009/12/EC on airport charges. Final Report. Available at: http://ec.europa.eu/transport/modes/air/studies/doc/airports/2013-09-evaluation-of-directive-2009-12-ec-on-airport-charges.pdf.

See also: IETA and EDF, 2013. *Norway, The World's Carbon Markets: A Case Study Guide to Emissions Trading*. Updated May 2013. International Emissions Trading Association and Environmental Defense Fund. Available at: http://www.ieta.org/assets/Reports/EmissionsTradingAroundTheWorld/edf_ieta_norway_case_study_may_2013.pdf.

20 European Union, 2009. Directive 2008/101/EC of the European Parliament and of the Council. *Official Journal of the European Union*. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0101&from=EN.

The EU's stated intention is to also cover flights *to and from* the EU, but in response to intense opposition from non-EU carriers and governments, the EU agreed to "stop the clock" on this provision through 2016, to allow time for action within ICAO (see discussion later in this paper). For a summary of the EU provisions and "stop the clock", see: http://ec.europa.eu/clima/policies/transport/aviation/.

21 Keen, M. and Strand, J., 2006. *Indirect Taxes on International Aviation*. IMF Working Paper. International Monetary Fund, Washington DC. Available at: https://www.imf.org/external/pubs/ft/wp/2006/wp06124.pdf.

22 The legal framework for not taxing international aviation fuel was established in the 1944 Convention on International Civil Aviation, the founding document of ICAO. It prevents countries from taxing fuel that arrives in a plane from another country. Bilateral air service agreements between countries typically establish tax exemptions for fuel purchased within each

country. See: Keen, M., Parry, I. and Strand, J., 2013. Planes, Ships, and Taxes: Charging for International Aviation and Maritime Emissions. *Economic Policy*, 28(76). 701–749. DOI:10.1111/1468-0327.12019.

23 IATA, 2015. *Fact Sheet: Industry Statistics*.

24 ICAO, 2013. *ICAO Environmental Report 2013*.

25 ICCT, 2014. *U.S. Domestic Airline Fuel Efficiency Ranking, 2013*. White paper. The International Council on Clean Transportation, Washington, DC. Available at: http://www.theicct.org/sites/default/files/publications/ICCT_USairline-ranking_2013.pdf.

26 American Airlines, n.d. Environment: Climate and Energy. Available at: http://www.aa.com/i18n/aboutUs/corporateResponsibility/environment/energy-efficiency.jsp [accessed 7 July 2015].

27 ATAG, 2015. Fact Sheet: Aviation's Climate Action Framework. Air Transport Action Group. February. Available at: http://www.atag.org/component/downloads/downloads/266.html.

28 ICCT, 2009. *Efficiency Trends for New Commercial Jet Aircraft*. The International Council on Clean Transportation, Washington, DC. Available at: http://www.theicct.org/sites/default/files/publications/ICCT_Aircraft_Efficiency_final.pdf.

29 Karp, G., 2014. Winglets go a long way to give airlines fuel savings. *Chicago Tribune*. 4 March. Available at: http://articles.chicagotribune.com/2014-03-04/business/ct-airline-winglets-0302-biz-20140304_1_fuel-savings-jet-fuel-southwest-airlines.

30 ATAG, 2010. *Beginner's Guide to Aviation Efficiency*. November. Air Transport Action Group. Available at: http://www.atag.org/component/downloads/downloads/59.html.

31 ATAG, 2010. *Beginner's Guide to Aviation Efficiency*.

32 IATA, n.d. IATA Flexible Routings (iFLEX). International Air Transport Association. Available at: http://www.iata.org/whatwedo/ops-infra/Pages/iflex.aspx [accessed 18 May 2015].

33 US Federal Aviation Administration, n.d. NextGen. Available at: https://www.faa.gov/nextgen/ [accessed 2 June 2015].

34 SESAR, 2011. *Assessing the macroeconomic impact of SESAR*. Final report. Single European Sky Air Traffic Management Research project. Available at: http://www.sesarju.eu/sites/default/files/documents/reports/SESAR-macrostudy-full.pdf.

35 Massachusetts Institute of Technology and RAND Corporation, 2009. *Near-Term Feasibility of Alternative Jet Fuels*, 2009. Available at: http://http://web.mit.edu/aeroastro/partner/reports/proj17/altfuelfeasrpt.pdf.

36 ATAG, 2014. *Aviation Benefits Beyond Borders*.

37 Aviation Benefits, 2014. Cathay Pacific invests in sustainable biojet fuel developer. 7 August. Available at: http://aviationbenefits.org/newswire/2014/08/cathay-pacific-invests-in-sustainable-biojet-fuel-developer/ [accessed 10 May 2015].

38 IATA, 2013. IATA 2013 *Report on Alternative Fuels*. International Air Transport Association, Montreal. Available at: http://www.iata.org/publications/documents/2013-report-alternative-fuels.pdf.

39 ICCT, 2013. *Measuring and Addressing Investment Risk in Second-Generation Biofuels Industry*. White paper. The International Council on Clean Transportation, Washington DC. Available at: http://www.theicct.org/sites/default/files/publications/ICCT_AdvancedBiofuelsInvestmentRisk_Dec2013.pdf.

40 See: http://www.safug.org.

41 Calculation based on: Index Mundi, n.d. Australia Jet Fuel Consumption by Year. Available at: http://www.indexmundi.com/energy.aspx?country=au&product=jet-fuel&graph=consumption [accessed 11 May 2015].

42 Aviation Benefits, 2013. Qantas and Shell release biofuel report. 3 December. Available at: http://aviationbenefits.org/newswire/2013/12/qantas-and-shell-release-biofuel-report/.

43 Transport and Environment, 2010. *Grounded: How ICAO failed to tackle aviation and climate change and what should happen now*. European Federation for Transport and Environment, Brussels. Available at: http://www.transportenvironment.org/sites/te/files/media/2010_09_icao_grounded.pdf.

According to the provisions of Article 2.2 of the Kyoto Protocol: "Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases...from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively." Unlike other sectors, responsibility for cutting international aviation emissions was not given to individual countries (parties). Instead reductions should be achieved by Annex 1 Parties working through international bodies that regulate these modes of transport – ICAO for aviation and IMO for maritime transport.

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ABOUT THE NEW CLIMATE ECONOMY

The Global Commission on the Economy and Climate, and its flagship project The New Climate Economy, were set up to help governments, businesses and society make better-informed decisions on how to achieve economic prosperity and development while also addressing climate change.

In September 2014, the Commission published *Better Growth, Better Climate: The New Climate Economy Report*. Since then, the project has released a series of country reports on the United States, China, India and Ethiopia, and sector reports on cities, land use, energy and finance. In July 2015, the Commission published *Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate*. It has disseminated its messages by engaging with heads of governments, finance ministers, business leaders and other key economic decision-makers in over 30 countries around the world.

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