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Methodological issues

Emissions from fuel used for international aviation and maritime transport

## Methodological issues relating to emissions from international aviation and maritime transport

Note by the secretariat

### *Summary*

The International Civil Aviation Organization and the International Maritime Organization organized two expert meetings to address methodological issues relating to the estimation and reporting of greenhouse gas (GHG) emissions from international aviation and maritime transport. Participants at both meetings considered the methodologies in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* and in the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. They concluded that it is possible to improve the accuracy and monitoring of GHG emissions from international aviation and maritime transport and identified areas for improvement that could be considered by the Intergovernmental Panel on Climate Change (IPCC) in its work on the development of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. This document discusses issues for further consideration that may assist national GHG inventory experts to improve their estimates of GHG emissions from these two international transport activities.

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## I. Introduction

### A. Mandate

1. The Subsidiary Body for Scientific and Technological Advice (SBSTA), at its eighteenth session, invited the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) to organize, in consultation with the secretariat, two expert meetings before the twentieth session of the SBSTA (FCCC/SBSTA/2003/10, para. 29 (c)). The objective of these meetings was to address options to improve the methodologies for estimating and reporting emissions from international aviation and maritime transport as an input to the work under way by the Intergovernmental Panel on Climate Change (IPCC) on the revision of the guidelines for preparing national greenhouse gas (GHG) inventories under the relevant provisions of the Convention and the Kyoto Protocol.

### B. Scope of the note

2. This document has been prepared to facilitate consideration by the SBSTA, at its twentieth session, of methodological issues relating to GHG emissions from international aviation and maritime transport. It draws on information from the two expert meetings mentioned in paragraph 1.

### C. Possible action by the Subsidiary Body for Scientific and Technological Advice

3. The SBSTA may wish to consider the information contained in this document, including the specific recommendations from the two expert meetings, and to forward this note to the IPCC as an input to the development of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (2006 IPCC Guidelines). It may also wish to consider the issues discussed in chapter V and invite the ICAO and the IMO to continue to cooperate with the secretariat on methodological issues relating to emissions from international aviation and maritime transport.

## II. Background

4. According to the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (1996 IPCC Guidelines) “emissions from the use of fuels for international marine and air transport are excluded from national emissions totals”.<sup>1</sup> This provision has been reflected in the “Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, part I: UNFCCC reporting guidelines on annual inventories” (UNFCCC reporting guidelines) that have been adopted under the Convention process (decision 18/CP.8).

5. The 1996 IPCC Guidelines and the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC good practice guidance) provide methodologies and advice to GHG inventory experts on how to estimate emissions from domestic and international aviation and maritime transport. The IPCC has already started work on the development of the 2006 IPCC Guidelines, which will incorporate the information contained in both the 1996 IPCC Guidelines and the IPCC good practice guidance.

6. The participants in the two meetings mentioned in paragraph 1 were experts involved in the preparation of GHG inventories, experts in the aviation and marine sectors and representatives of the IPCC. The ICAO meeting took place from 7 to 8 April 2004 in Montreal, Canada, and the IMO meeting took place on 21 April 2004 in London, United Kingdom. The purpose of the two meetings was:

- (a) To consider methodological issues relating to the estimation and reporting of GHG data from aviation and maritime transport, under the UNFCCC process;

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<sup>1</sup> *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, volume 2, page 1.3.

- (b) To provide advice/guidance to the IPCC on possible improvements or further elaboration of the methodologies for aviation and maritime transport that are included in the 1996 IPCC Guidelines.

### **III. Emissions from international aviation**

7. The expert meeting organized by ICAO focused on the following issues:
- (a) Comparison of modelled data with UNFCCC inventory data
  - (b) Distinction between domestic and international emissions
  - (c) Critical consideration of the IPCC estimation methodologies (1996 IPCC Guidelines and IPCC good practice guidance) to determine how these methodologies could be improved.

#### **A. Comparison of modelled data**

8. The developers of the AERO2K<sup>2</sup> and the SAGE<sup>3</sup> models presented the preliminary results of the comparisons of actual CO<sub>2</sub> and fuel consumption data, submitted by Parties included in Annex I of the Convention (Annex I Parties) in 2003, with data from the two models for selected Annex I Parties. For comparison purposes, modelled data from the AERO model (prepared for the ICAO expert meeting that took place in February 2003, (FCCC/SBSTA/2003/INF.3, para. 51)) were also presented. It was noted that the AERO2K and SAGE models were at different levels of development and validation, with SAGE being further developed and committed to produce global inventories annually. For the AERO2K, further checks and validation are required before results can be formally published.

9. For some of the selected Annex I Parties, there were differences between their submitted data and the modelled data. There were also differences between the results of the two models for the same Parties. These differences were partly due to the use of input data for different years by different models (for the AERO2K using data for 2002, for the SAGE using data for 2000 and 2001 and for the AERO using data for 1999) and partly due to differences in some of the assumptions and input parameters for the models.

10. The comparison proved to be a valuable exercise towards the further improvement of both models for the purposes of generating data for comparing with the UNFCCC data. Such improvements arise from:

- (a) Data comparison using a common year (e.g. 2002)
- (b) Common definition of international and domestic flights and flight legs
- (c) Common definition of national territories (airport code/country allocation)

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<sup>2</sup> The AERO2K project is supported through the European Commission Fifth Framework programme and is under development by a consortium led by QinetiQ (United Kingdom) with DLR (Germany), NLR (Netherlands), Eurocontrol, Airbus (France), Manchester Metropolitan University (United Kingdom) and the Department of Trade and Industry (United Kingdom). The objective of AERO2K is to develop a new four-dimensional (4-D: latitude, longitude, height and time) gridded database of global aircraft emissions of priority pollutants and to improve methodologies and analytical tools that facilitate novel and improved evaluations of the impact of aircraft emissions on the global atmosphere.

<sup>3</sup> The United States Federal Aviation Administration Office of Environment and Energy has developed the System for assessing Aviation's Global Emissions (SAGE), with support from the Volpe National Transportation Systems Center, the Massachusetts Institute of Technology and the Logistics Management Institute. The objective is for SAGE to be an internationally accepted computer model that is based on the best available data and methodologies, and used for estimating aircraft emissions (CO<sub>2</sub>, CO, hydrocarbons, NO<sub>x</sub>, H<sub>2</sub>O, and SO<sub>x</sub> modelled as SO<sub>2</sub>) over the whole flight regime including the landing and take-off cycle, and cruise.

- (d) Definition of commercial, general and military aviation
- (e) Comparison of detailed model assumptions (e.g. time-in-mode, winds)
- (f) Comparison of annual traffic data (e.g. sources, data cleaning, flight profiling)
- (g) Detailed individual flight fuel flow (and emissions) comparison for a variety of aircraft, ranges and altitudes.

11. It is planned that results from the AERO2K and SAGE models for an initial level of detailed comparison will become available during the second quarter of 2004.

### **B. Domestic and international emissions**

12. Participants noted that the IPCC good practice guidance (table 2.9) provides guidance for GHG inventory compilers on the distinction between domestic and international emissions. Although these definitions are different to the ICAO ones for domestic and international flights, it was noted that, in 2002, the steering group of the Committee on Aviation Environmental Protection (CAEP) concluded that it would be appropriate for the CAEP to take the IPCC definitions into account in its work on market-based measures to address emissions.

13. Some Annex I Parties indicated that there are problems with distinguishing between domestic and international fuel use (see also FCCC/SBSTA/2003/INF.3). The main issues that were identified during the meeting are summarized below:

- (a) In most countries, the identified problems arise primarily because the published national statistical information is not directly compatible with the data needed to compile a national GHG inventory;
- (b) The application of the IPCC definitions for domestic and international fuel use is closely related to the availability of the necessary statistical information (e.g. data on passenger or cargo drop-off and pick-up). For some countries this information may not be available or may be difficult to collect and use for the purpose of compiling national GHG inventories;
- (c) Tankering<sup>4</sup> (i.e. loading of fuel used for subsequent flight segments) or aircrafts carrying certain amounts of additional fuel, often mandated by national legislation for safety reasons, may lead to problems in reconciling total national fuel sale data and aggregated information from individual flights using, for example, a bottom-up approach. It was indicated, however, that this problem could be resolved by, for example, adjusting the cruise fuel consumption and emissions;
- (d) Some problems are also related to the availability of information about fuel use for military activities (e.g., confidentiality of data, delays in releasing the data, high aggregation that may not be appropriate for the GHG compilation process).

14. There was general agreement that there is scope for improving the definition of domestic and international flights. In particular, it was felt that it is difficult to obtain the information on passenger and freight drop-off and pick-up at stops in the same country that is required by the definition contained in the IPCC good practice guidance.

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<sup>4</sup> The main reasons for tankering of fuel include high fuel costs resulting from expensive distribution infrastructure and local taxes; low fuel availability at some remote airports; government-imposed fuel pricing monopoly distribution of fuel; concern over fuel quality at particular locations; and slot availability (see also chapter 8.3.1.3 of the IPCC Special Report entitled: *Aviation and the Global Atmosphere*).

## **C. Consideration of the Intergovernmental Panel on Climate Change methodologies**

### **1. Methodologies**

15. Participants recognized the importance of complete, reliable, consistent and accurate information on emissions from aviation and that the 1996 IPCC Guidelines and the IPCC good practice guidance provide useful methodologies for estimating emissions by all Parties. However, it was recognized that the IPCC methodologies are based on fuel usage and/or information on landing and take-off cycles (LTOs), whereas the models under consideration by ICAO adopt a more detailed approach using information on individual flights. It was further noted that methodologies based on LTO information are usually more suitable for estimating emissions associated with local air pollution problems.

16. Participants noted that some Annex I Parties are using a tier 1 or tier 2a method of the IPCC because of the unavailability of the information required for a higher tier approach. It was further noted that accuracy could be improved if steps were taken to enable Annex I Parties to use higher tiers. In this regard, it may be possible for these Parties to improve the accuracy of the emissions through the use of data from other sources, for example, from aviation authorities, airlines, airports, refineries and aviation inventory sources.

17. As an input for the development of the 2006 IPCC Guidelines the developers of the AERO2K, SAGE and FAST<sup>5</sup> models offered to examine the effects of the different IPCC tiers on emissions levels, using a small set of examples for which complete data are available.

18. The participants noted that it may be possible to develop a user-friendly computer software for national GHG inventory experts to estimate emissions using a detailed methodology. Consideration was given whether ICAO could play a coordinating role in such an initiative.

19. Participants also noted that national GHG emissions data disaggregated by commercial, general and military aviation traffic would be useful for improving the comparability with modelled data. They suggested that this information could be provided by Parties in their national inventory reports.

### **2. Emission factors**

20. Participants agreed that there is a need to revise the emission factors in the 1996 IPCC Guidelines and the IPCC good practice guidance taking into account the latest available information in the ICAO Exhaust Emissions Data Bank, information from the AERO2K and SAGE models, and any other available information in this area. The participants agreed that this work will be coordinated by ICAO through its CAEP before the meeting of the IPCC energy sector authors in September 2004.

### **3. Activity data**

21. Participants noted that some countries have difficulties in obtaining the movement data for individual flights that are necessary for using a more detailed methodology (e.g. tier 3 method). There was substantial discussion on the possibility of providing such data in order to assist Parties to improve the comparability of emissions data among Parties. It was noted that the ICAO secretariat has a database of commercial flights (scheduled services only, airport-to-airport, aircraft type and airline).

### **4. Recommendations**

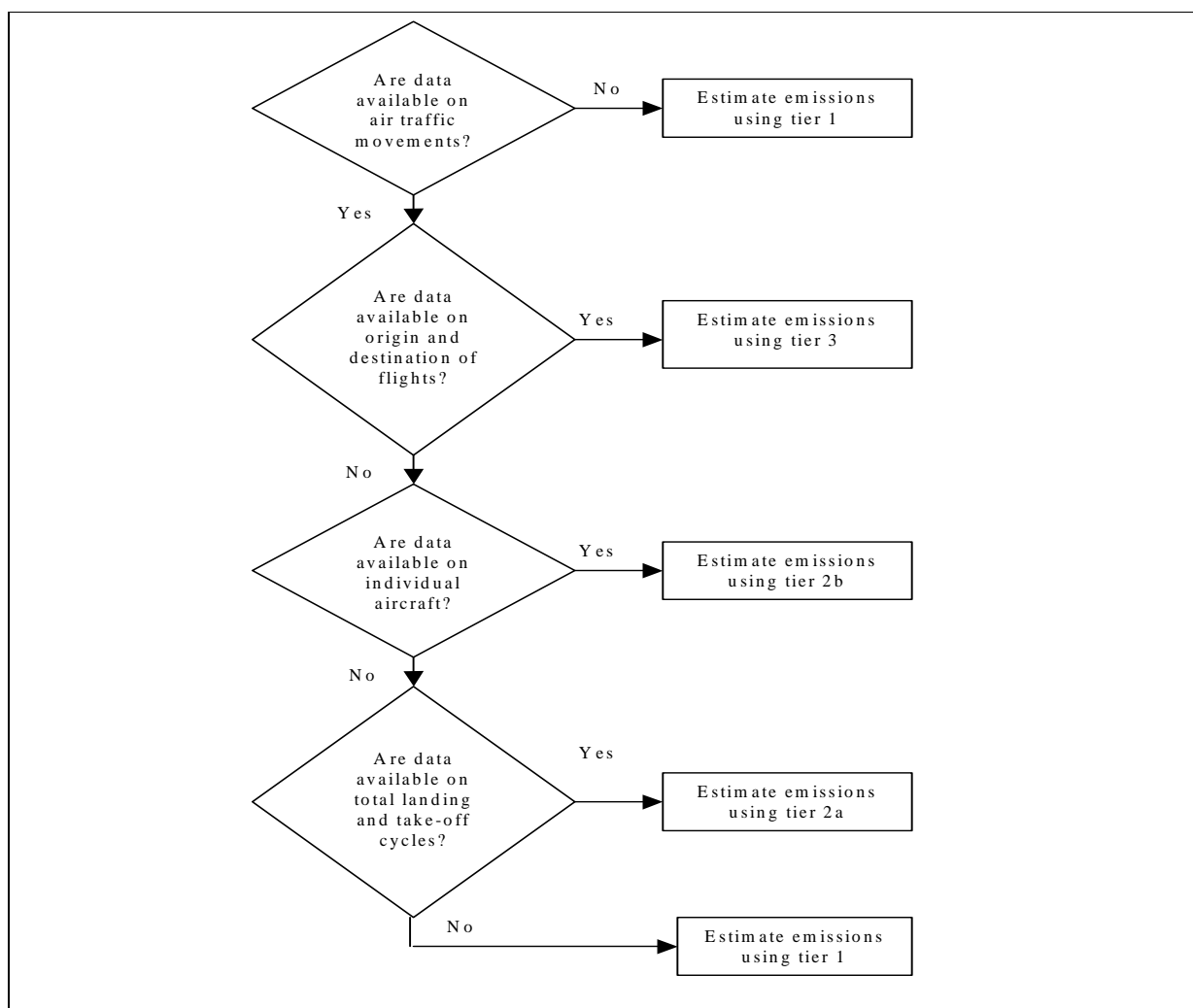
22. Participants agreed that there is scope for improving the methodologies contained in the 1996 IPCC Guidelines and the IPCC good practice guidance in the following respects:

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<sup>5</sup> FAST – Future Civil Aviation Scenario Software Tool. This model has been developed by the United Kingdom Department of Trade and Industry and Manchester University.

- (a) Adding new methodology or methodologies that would take into account more detailed data including, in addition to the fuel sales data, flight movement data. The IPCC could consider for example the EMEP/UNECE (United Nations Economic Commission for Europe) CORINAIR<sup>6</sup> Detailed Methodology;
- (b) Consideration of detailed methodologies based solely on flight movement data (origin and destination). ICAO is currently in the process of considering SAGE and AERO2K for endorsement;
- (c) A reconsideration of the decision tree of the IPCC good practice guidance – for illustrative purposes a hierarchical tree is presented in figure 1. (This is not a proposal for a new decision tree, but a visual representation of possible tiers in the new IPCC Guidelines);
- (d) Revision of emission factors taking into account the latest available information.

**Figure 1. Hierarchical tree for estimating emissions from aviation**



<sup>6</sup> EMEP – Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe. CORINAIR: a project to gather and organize information on emissions into the air relevant to acid deposition in the context of the work programme CORINE (CO-oRdination d'INformation Environnementale).

## **IV. Emissions from international maritime transport**

23. The expert meeting organized by IMO focused on the following issues:
- (a) Distinction between domestic and international emissions
  - (b) Critical consideration of the 1996 IPCC Guidelines and the IPCC good practice guidance to determine how the methodologies could be improved.

### **A. Domestic and international emissions**

#### 1. IPCC definitions

24. Participants noted that the current reporting on domestic and international emissions is based on the guidance provided by table 2.8 in the IPCC good practice guidance. It was noted that some Annex I Parties have problems disaggregating domestic and international fuel from the total fuel sales data. The main problems identified during the discussion are summarized below:

- (a) In most countries tax and custom dues are levied on bunkers for domestic consumption, and bunkers for international consumption are free of such dues. In many cases, this exception leads to the purchase of international bunkers, which are then used in domestic trade;
- (b) Where there is both a domestic and international segment to a journey (as defined by table 2.8 of the IPCC good practice guidance), differentiation between fuel consumed during the national and international segments is often problematic, and in some cases impossible;
- (c) Emissions from fishing vessels should, according to the IPCC Guidelines and the UNFCCC reporting guidelines, be reported under the category "Agriculture/Forestry/Fisheries" and there are no provisions for reporting disaggregated data from these vessels. This may add to the difficulty of distinguishing the amount of fuel used, and the corresponding emissions, from fishing activities. Because fishing vessels in general purchase their bunkers from the same bunker delivery companies as merchant ships, this could lead to reporting discrepancies. In addition it was noted that fishing vessels operate differently from merchant ships;
- (d) Reporting of emissions from bunkers used on board navy ships and non-commercial state-owned ships poses special problems (e.g. unavailability or confidential data).

#### 2. Recommendations

25. Participants agreed that:
- (a) There is scope for improving the IPCC definitions of domestic and international emissions. In particular, it was felt that it is generally difficult to obtain the information on passenger and freight drop-offs and pick-ups at stops in the same country that is required by the definitions contained in the IPCC good practice guidance;
  - (b) Additional guidance may need to be provided in the 2006 IPCC Guidelines regarding the fuel consumption data used for the inventory process and the estimation of emissions from fishing activities, naval operations and non-commercial ships.



## **B. Consideration of the Intergovernmental Panel on Climate Change methodologies**

### **1. Methodologies**

26. Participants recognized the importance of complete, reliable, consistent and accurate information on emissions from shipping and that the 1996 IPCC Guidelines and the IPCC good practice guidance provide useful methodologies for estimating emissions. They also recognized that reporting on ship-based GHG emissions should take account of all GHG emissions considered under the UNFCCC process.

27. It was noted that some of Annex I Parties use the tier 1 method of the IPCC because of the unavailability of the information required for a higher tier approach. The meeting made the following general observations:

- (a) On the basis that all marine fuels – gas oils to residual fuel oils – have only limited range of carbon contents (85.0–87.5 per cent), and in the absence of other significant exit routes than CO<sub>2</sub> (CO/hydrocarbons/particulate emissions very low in comparison), the ratio of fuel consumed to CO<sub>2</sub> emitted is fairly constant;
- (b) Estimating GHG emissions based on bunker oils delivered to ships would lead to a fairly accurate estimate of the emissions levels from shipping;
- (c) Although gases from cargo (liquefied natural gas (LNG) boil-off or volatile organic compound (VOC) recovery) may be used as fuels on ships, the amounts are usually not large in comparison to the total fuel consumed;
- (d) With regard to engine types on different types of ships, participants agreed that the emissions data provided by the engine manufacturers are more relevant to developing SO<sub>x</sub> and NO<sub>x</sub> emission factors;
- (e) Although it would be possible to develop an emission profile for each ship voyage, the research necessary to develop such profiles would be expensive and complicated, particularly because:
  - (i) The movement of international (and domestic shipping) is difficult to track: shipping has no equivalent of air traffic control systems;
  - (ii) The speed or power output of a ship is not constant over a voyage – it changes with the weather and with the time schedule of the ship;
  - (iii) The GHG emissions would have to be calculated for each segment of the voyage. As the world's ships make a vast number of voyages each year, the calculation of GHG emissions per voyage would be an almost impossible task.

### **2. Emission factors**

28. Participants noted that work on emission factors for GHG emissions is based on engine manufacturers data on rated output, whereas the quantity of GHG emissions is based on the relationship between a ship's speed and fuel consumption. In general the emission factors do not take into consideration auxiliary engines, i.e. boilers, what shipboard operations are carried out en route, refrigeration plant onboard reefer ships or the operation of refrigerated containers onboard a container ship. Because of the complexity of the operation of modern cargo ships it is complicated to develop emission factors, and even more complicated to apply them. Furthermore, there are still many steam-powered oil tankers in operation around the world, which may consume more fuel per day when discharging their cargo in port (to operate the cargo pumps) than they do in deep sea steaming. In many

cases, the emission factors based on the engine manufacturers' information do not reflect the consumption of fuel oils during the operation of ships. Special problems are also related to gas carriers using "cargo gas" boil off as fuel. Also the new development of crude oil carriers using cargo VOCs as fuel should be considered.

29. Participants noted that no specific N<sub>2</sub>O or CH<sub>4</sub> emission factors are available. Although CH<sub>4</sub> emissions may also result from cargo operations, these are reported as part of the national totals in accordance with the 1996 IPCC Guidelines and the UNFCCC reporting guidelines. Specifically, emissions from transport of petroleum products should be estimated and reported under the category "Fugitive emissions from oil and natural gas".

### 3. Activity data

30. Participants noted that additional fuel data will become available when Annex VI of MARPOL 73/78 enters into force (19 May 2005). According to regulation 18 of Annex VI:

- (a) A bunker receipt is required, which should include: ship IMO number; reference to ship size/type; date and place of bunker operation and quantity delivered
- (b) A bunker receipt registry for all delivered bunkers (diesel oil through to heavy fuel oils) and for local bunker suppliers is to be maintained by port (or other) authority
- (c) Bunker suppliers shall retain bunker receipts for three years from date of supply
- (d) Although specified for ships greater than 400 gross tonnage (GT), a bunker receipt of some type will also be supplied to ships of less than 400 GT
- (e) In MARPOL Convention countries fuel suppliers will also be required by their customers to ensure that such bunker receipts are supplied.

31. Consequently, after the entry into force of Annex VI, data will be available from 'all ports' for 'all bunker loading'. From these data a national collation could be made. The data will give: ship ID (hence type/GT/etc.), date and place of bunkering, and quantity of type of fuel oils loaded. Each delivery will only generate one bunker receipt, so double counting will be avoided. However, the following fuel supplies will not be covered:

- (a) Fuel delivered only for intra-national non-commercial usage
- (b) Fuel for recreational, national only usage
- (c) Fuel for military and non-commercial state-owned ships, because governments in most countries buy, store and deliver fuel for such usage. However, such data may be available from other national sources (i.e. Ministry of Defence or other national authorities).

32. From the above information it may be possible to improve the estimates on how much fuel is supplied to shipping – by year or as required. A national/international split could be indicated by the selection of ship gross tonnage (currently greater than 400 GT).

### 4. Recommendations

33. Participants agreed that:

- (a) The IPCC methodologies for calculating GHG emissions (particularly CO<sub>2</sub>) from shipping provide reasonable estimates, because they are based on the ratio of fuel consumed to CO<sub>2</sub> emitted that is considered fairly constant;

- (b) There is scope for improving the emission factors in the existing guidelines taking into account:
  - (i) The latest available information from manufacturers and any other relevant sources;
  - (ii) The use of “cargo gas” boil-off or recovered VOCs as fuel;
- (c) The IPCC could consider whether new information that will become available in the future (e.g. bunker receipts) could be used within the national GHG inventory preparation process.

## V. Issues for further consideration

34. Participants at both meetings confirmed the importance of continuing close cooperation and coordination of work under ICAO, IMO, UNFCCC and IPCC with the goal of further improving and harmonizing methodologies to estimate GHG emissions from aviation and maritime transport. Based on the discussions during the two expert meetings, the SBSTA could consider the following:

- (a) **Development of a software tool to estimate emissions from international aviation.** Parties could consider whether the availability of a user-friendly software tool for estimating emissions from international aviation based on a detailed methodology (making use of information on movement data for individual flights) would assist national GHG inventory experts to improve the accuracy of their GHG emission estimates. Should Parties wish to pursue this, they are invited to consider providing the necessary support for the development of such a software tool and may also wish to invite ICAO to facilitate its development and dissemination, in cooperation with the secretariat and the IPCC;
- (b) **Availability of data for individual flights.** Parties may wish to invite ICAO to consider how data on individual flights, which are needed in order to use a detailed methodology, could be made available to national GHG inventory experts for the purposes of preparing and reviewing GHG inventories;
- (c) **Development of new emission factors for GHGs and other gases for ships.** Parties may wish to consider whether they wish to invest in research to improve emission factors, which would take into account all on-board engines and/or operational conditions of ships, to assist improve the accuracy of emissions estimates from international maritime transport. Parties may wish to invite the IMO to facilitate this work;
- (d) **Availability of new information on fuel consumption from ships.** Parties could consider how to ensure that, once Annex VI of MARPOL 73/78 enters into force, information from bunker delivery notes (see paragraphs 30–32) could be made available for the compilation of national GHG inventories. Parties may also wish to consider whether changes are needed in their national data collection systems, taking into account any associated difficulties and cost implications.

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