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UNEP

2006 IPCC Guidelines for National Greenhouse Gas Inventories

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IPCC National Greenhouse Gas Inventories Programme

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Foreword

Recognizing the problem of potential global climate change, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) co-established in 1988 the Intergovernmental Panel on Climate Change (IPCC). One of the IPCC's activities is to support the UN Framework Convention on Climate Change (UNFCCC) through its work on methodologies for National Greenhouse Gas Inventories.

This report is the culmination of three years of work by the IPCC National Greenhouse Gas Inventories Programme, to update its own previous guidance on National Greenhouse Gas Emission Inventories. The task was started in response to an invitation made at the seventeenth session of the Subsidiary Body for Scientific and Technological Advice (SBSTA) of the UNFCCC, held in New Delhi in 2002. At the time, the IPCC was invited to revise the *1996 IPCC Guidelines*, taking into consideration the relevant work made under the Convention and the Kyoto Protocol[1], with the aim to complete this task by early 2006.

In response to this invitation by the UNFCCC, the IPCC initiated a process at its 20th session (Paris, February 2003) that led to an agreement at its 21st session (Vienna, November 2003) on the Terms of Reference, Table of Contents and a Workplan[2] for the *2006 IPCC Guidelines*. The Workplan aimed to complete the task in time for its acceptance and adoption at the 25th session of the IPCC, to be held in April 2006.

The 1996 guidelines comprised the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*[3], together with the *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*[4] and the *Good Practice Guidance for Land Use, Land-Use Change and Forestry*[5]. The *2006 Guidelines* have built upon this body of work in an evolutionary manner to ensure that the transition from the previous guidelines to these new ones will be as straightforward as possible. These new guidelines include new sources and gases as well as updates to the previously published methods whenever scientific and technical knowledge have improved since the previous guidelines were issued.

The development of these guidelines has depended on the expertise, knowledge and co-operation of the Coordinating Lead Authors, Lead Authors and Contributing Authors – the contribution over 250 experts worldwide. We wish to thank these authors for their commitment, time and efforts in preparing this report throughout all the drafting and reviewing stages of the IPCC process. As indicated, this report has built upon the work of the previous IPCC inventory reports as well as on reports of the inventory experts' experiences in using the IPCC inventory guidelines without which the task would have been much more demanding and we are pleased to acknowledge our debt with all those who contributed to these reports.

The steering group, consisting of IPCC TFI Co-Chairs Taka Hiraishi (Japan) and Thelma Krug (Brazil) together with Michael Gytarsky (Russian Federation), William Irving (USA) and Jim Penman (UK) has guided the development of these guidelines, ensuring consistency across all the volumes and continuity with the earlier IPCC inventory reports. We would therefore wish to thank them for their considerable efforts in leading and guiding the report preparation.

Authors and experts meetings were held in Oslo (Norway); Le Morne (Mauritius); Washington (USA); Arusha (Tanzania); Ottawa (Canada); Manila (The Philippines); Moscow (Russian Federation); and Sydney (Australia). We would therefore like to thank the host countries and agencies for organizing these meetings. We would also

[1] Including, inter alia, work by the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation, and by the Consultative Group of Experts on National Communications from Parties not included in Annex I to the Convention, and the technical review of greenhouse gas inventories of Annex I Parties.

[2] The Terms of Reference, Table of Contents and Work plan can be found at http://www.ipcc-nggip.iges.or.jp/ .

[3] Intergovernmental Panel on Climate Change (IPCC) (1997). Houghton J.T., Meira Filho L.G., Lim B., Tréanton K., Mamaty I., Bonduki Y., Griggs D.J. and Callander B.A. (Eds). *Revised 1996 IPCC Guidelines for National Greenhouse Inventories*. IPCC/OECD/IEA, Paris, France.

[4] Intergovernmental Panel on Climate Change (IPCC) (2000). Penman J., Kruger D., Galbally I., Hiraishi T., Nyenzi B., Emmanuel S., Buendia L., Hoppaus R., Martinsen T., Meijer J., Miwa K., and Tanabe K. (Eds). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. IPCC/OECD/IEA/IGES, Hayama, Japan.

[5] Intergovernmental Panel on Climate Change (IPCC) (2003), Penman J., Gytarsky M., Hiraishi T., Krug, T., Kruger D., Pipatti R., Buendia L., Miwa K., Ngara T., Tanabe K., Wagner F., *Good Practice Guidance for Land Use, land-Use Change and Forestry* IPCC/IGES, Hayama, Japan

like to thank all governments that supported authors and reviewers, for without their contributions, the production of this report might not have been possible.

Two reviews of these guidelines were made in 2005. The first, an expert review, produced over 6000 comments, while the second, a combined governmental and expert review, resulted in an additional 8600 comments. The efforts of the reviewers and their comments have contributed greatly to the quality of the final report and we wish to thank them accordingly. Furthermore, the review editors have ensured the appropriate consideration of all the comments received, so we would also like to thank them for their work.

In addition, the NGGIP Technical Support Unit (TSU Head: Simon Eggleston; Programme officers: Leandro Buendia, Kyoko Miwa, Todd Ngara and Kiyoto Tanabe; Administrative Assistant: Ayako Hongo; Project Secretary: Masako Abe; and IT Officer: Toru Matsumoto) has provided guidance and assistance as well as technical and organisational support for the project. They worked extensively with the authors especially in the editing of the various drafts and preparation of the final version, and we wish to congratulate them for their exemplary work. We would also like to express our gratitude to the Government of Japan, for its generous support for the TSU, without which this report might not have been completed.

We would also like to thank the IPCC Secretariat (Jian Liu, Rudie Bourgeois, Annie Courtin, and Joelle Fernandez) for their assistance and support in enabling this project to meet its tight deadlines.

Finally we would like to thank IPCC Chair Rajendra Pachauri, IPCC Secretary Renate Christ and the Task Force Bureau: the TFI Co-Chairs and Soobaraj Nayroo Sok Appadu (Mauritius), Dari N. Al-Ajmi (Kuwait), Ian Carruthers (Australia), Sergio Gonzalez-Martineaux (Chile), Art Jaques (Canada), Jamidu H.Y. Katima (Tanzania), Sadeddin Kherfan (Syria), Dina Kruger (USA), Kirit Parikh (India), Jim Penman (UK, since 2006), Helen Plume (New Zealand), Audun Rosland (Norway until 2005) and Freddy Tejada (Bolivia) for their support.

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Secretary-General
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Preface

These *2006 IPCC Guidelines for National Greenhouse Gas Inventories* build on the previous Revised 1996 IPCC Guidelines and the subsequent Good Practice reports in an evolutionary manner to ensure that moving from the previous guidelines to these new guidelines is as straightforward as possible. These new guidelines cover new sources and gases as well as updates to previously published methods where technical and scientific knowledge have improved.

This guidance assists countries in compiling complete, national inventories of greenhouse gases. The guidance has been structured so that any country, regardless of experience or resources, should be able to produce reliable estimates of their emissions and removals of these gases. In particular, default values of the various parameters and emission factors required are supplied for all sectors, so that, at its simplest, a country needs only supply national activity data. The approach also allows countries with more information and resources to use more detailed country-specific methodologies while retaining compatibility, comparability and consistency between countries. The guidance also integrates and improves earlier guidance on good practice in inventory compilation so that the final estimates are neither over- nor under-estimates as far as can be judged and uncertainties are reduced as far as possible.

Guidance is also provided to identify areas of the inventory whose improvement would most benefit the inventory overall. Hence limited resources can be focused on those areas most in need of improvement to produce the best practical inventory.

The IPCC also manages the *IPCC Emission Factor Database* (EFDB). The EFDB was launched in 2002, and is regularly updated as a resource for inventory compilers to use to assist them by providing a repository of emission factors and other relevant parameters that may be suitable for use in more country-specific methodologies.

The 2006 Guidelines are the latest step in the IPCC development of inventory guidelines for national estimates of greenhouse gases. In the opinion of the authors, they provide the best, widely applicable default methodologies and, as such, are suitable for global use in compiling national greenhouse gas inventories. They may also be of use in more narrowly-defined project based estimates, although here they should be used with caution to ensure they correctly include just the emissions and removals from within the system boundaries.

We would also like to thank all the authors (over 250) as well as reviewers, review editors, the steering group and the TFB for their contributions and experience. We would also like to thank all the governments who contributed by hosting meetings (Oslo, Norway; Le Morne, Mauritius; Washington, USA; Arusha, Tanzania; Ottawa, Canada; Manila, The Philippines; Moscow, Russian Federation; and Sydney, Australia) as well as those who supported authors and other contributors. Finally we would like to express our gratitude to the NGGIP TSU and the IPCC Secretariat for their invaluable support throughout the entire process of drafting and producing these guidelines.

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CHAPTER 3

MOBILE COMBUSTION

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Overview

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3.2.4 Reporting and Documentation

It *is good practice* to document and archive all information required to produce the national emissions inventory estimates.

It is not practical to include all documentation in the national inventory report. However, the inventory should include summaries of methods used and references to source data such that the reported emissions estimates are transparent and steps in their calculation may be retraced. This applies particularly to national models used to estimate emissions from road transport, and to work done to improve knowledge of technology-specific emission factors for nitrous oxide and methane, where the uncertainties are particularly great. This type of information, provided the documentation is clear, should be submitted for inclusion in the EFDB.

Confidentiality is not likely to be a major issue with regard to road emissions, although it is noted that in some countries the military use of fuel may be kept confidential. The composition of some additives is confidential, but this is only important if it influences greenhouse gas emissions.

Where a model such as the USEPA MOVES or MOBILE models or the EEA COPERT model is used (EPA 2005a, EPA 2005b, EEA 2005, respectively), a complete record of all input data should be kept. Also any specific assumptions that were made and modifications to the model should be documented.

3.2.5 Reporting tables and worksheets

See the four pages of the worksheets (Annex 1) for the Tier I Sectoral Approach which are to be filled in for each of the source categories. The reporting tables are available in Volume 1, Chapter 8.

3.3 OFF-ROAD TRANSPORTATION

The off-road category (1 A 3 e ii) in Table 3.1.1 includes vehicles and mobile machinery used within the agriculture, forestry, industry (including construction and maintenance), residential, and sectors, such as airport ground support equipment, agricultural tractors, chain saws, forklifts, snowmobiles. For a brief description of common types of off-road vehicles and equipment, and the typical engine type and power output of each, please refer to EEA 2005. Sectoral desegregations are also available at USEPA, 2005b[12.]

Engine types typically used in these off-road equipment include compression-ignition (diesel) engines, spark-ignition (motor gasoline), 2-stroke engines, and motor gasoline 4-stroke engines.

3.3.1 Methodological issues

Emissions from off-road vehicles are estimated using the same methodologies used for mobile sources, as presented in Section 3.2. These have not changed since the publication of the *1996 IPCC Guidelines and the GPG2000*, except that, as discussed in Section 3.2.1.2, the emission factors now assume full oxidation of the fuel. This is for consistency with the Stationary Combustion Chapter. Also these guidelines contain a method for estimating CO_2 emissions from catalytic converters using urea, a source of emissions that was not addressed previously.

3.3.1.1 CHOICE OF METHOD

There are three methodological options for estimating CO_2, CH_4, and N_2O emissions from combustion in off-road mobile sources: Tier 1, Tier 2, and Tier 3. Figure 3.3.1: Decision tree for estimating emissions from off-road vehicles provides the criteria for choosing the appropriate method. The preferred method of determining CO_2 emissions is to use fuel consumption for each fuel type on a country-specific basis. However, there may be difficulties with activity data because of the number and diversity of equipment types, locations, and usage

[12] Appendix B of this reference provides Source Classification Codes (SCC) and definitions for: (a) Recreational vehicles; (b) Construction equipment; (c) Industrial equipment; (d) Lawn and garden equipment; (e) Agricultural equipment; (f) Commercial equipment; (g) Logging; (h) GSE/underground mining/oil field equipment; (i) Recreational marine and; (j) Railway maintenance are provided in Appendix B.

patterns associated with off-road vehicles and machinery. Furthermore, statistical data on fuel consumption by off-road vehicles are not often collected and published. In this case higher tier methods will be needed for CO_2 and they are necessary for non-CO_2 gases because these are much more dependent on technology and operating conditions.

A single method is provided for estimating CO_2 emissions from catalytic converters using urea. Many types of off-road vehicles will not have catalytic converters installed, but emission controls will probably increasingly be used for some categories of off-road vehicles, especially those operated in urban areas (e.g., airport or harbour ground support equipment) in developed countries. If catalytic converters using urea are used in off-road vehicles, the associated CO_2 emissions should be estimated.

The general method for estimating greenhouse gas emissions from energy sources can be described as:

EQUATION 3.3.1
TIER 1 EMISSIONS ESTIMATE

$$Emissions = \sum_j \left(Fuel_j \bullet EF_j \right)$$

Where:

Emissions = Emissions (kg)

$Fuel_j$ = fuel consumed (as represented by fuel sold) (TJ)

EF_j = emission factor (kg/TJ)

j = fuel type

For Tier 1, emissions are estimated using fuel-specific default emission factors as listed in Table 3.3.1, assuming that for each fuel type, the total fuel is consumed by a single off-road source category.

For Tier 2, emissions are estimated using country-specific and fuel-specific emission factors which, if available, are specific to broad type of vehicle or machinery. There is little or no advantage in going beyond Tier 2 for CO_2 emissions estimates, provided reliable fuel consumption data are available.

EQUATION 3.3.2
TIER 2 EMISSIONS ESTIMATE

$$Emissions = \sum \left(Fuel_{ij} \bullet EF_{ij} \right)$$

Where:

Emissions =emissions (kg)

$Fuel_{i,j}$ = fuel consumed (as represented by fuel sold) (TJ)

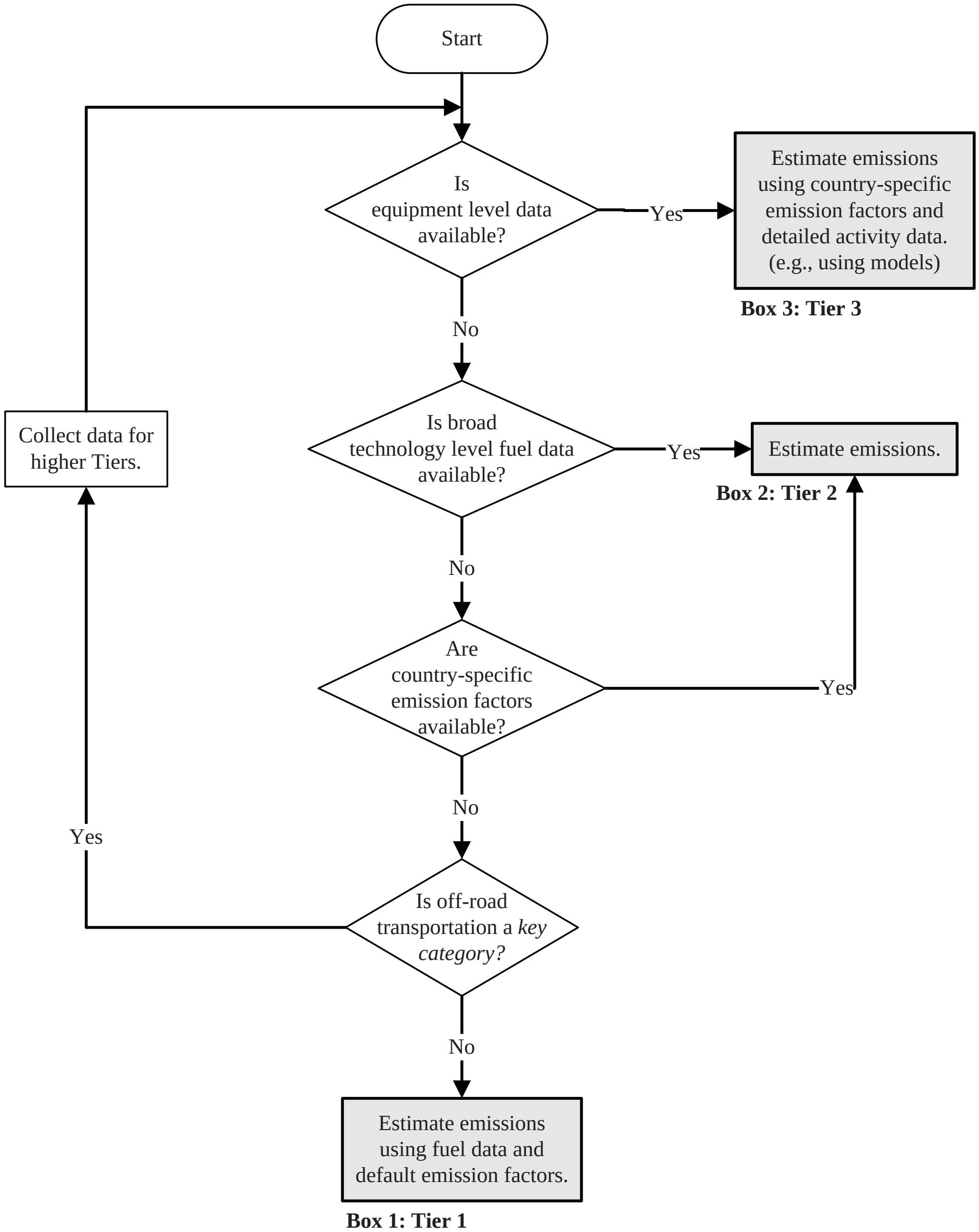
$EF_{i,j}$ = emission factor (kg/TJ)

i = vehicle/equipment type

j = fuel type

For Tier 3, if data are available, the emissions can be estimated from annual hours of use and equipment-specific parameters, such as rated power, load factor, and emission factors based on power usage. For off-road vehicles, these data may not be systematically collected, published, or available in sufficient detail, and may have to be estimated using a combination of data and assumptions.

Figure 3.3.1 Decision tree for estimating emissions from off-road vehicles



Note: See Volume 1 Chapter 4, "Methodological Choice and Key Categories" (noting section 4.1.2 on limited resources) for discussion of *key categories* and use of decision trees.

Equation 3.3.3 represents the Tier 3 methodology, where the following basic equation is applied to calculate emissions (in Gg):

EQUATION 3.3.3
TIER 3 EMISSIONS ESTIMATE

$$Emission = \sum_{ij} \left(N_{ij} \bullet H_{ij} \bullet P_{ij} \bullet LF_{ij} \bullet EF_{ij} \right)$$

Where:

Emission = emission in kg.

N_{ij} = source population

H_{ij} = annual hours of use of vehicle i (h)

P_{ij} = average rated power of vehicle i (kW)

LF_{ij} = typical load factor of vehicle i (fraction between 0 and 1)

EF_{ij} = average emission factor for use of fuel j in vehicle i (kg/kWh)

i = off-road vehicle type

j = fuel type

Equation 3.3.3 may be stratified by factors such as age, technological vintage or usage pattern, and this will increase the accuracy of the estimates provided self-consistent sets of parameters H, P, LF and EF are available to support the stratification, (EEA 2005). Other detailed modelling tools are available for estimating off-road emissions using Tier 3 methodology (e.g., NONROAD (USEPA 2005a) and COPERT (Ntziachristos 2000)).

For estimating CO_2 emissions from use of urea-based additives in catalytic converters (non-combustive emissions), Equation 3.3.4 is used:

EQUATION 3.3.4
EMISSIONS FROM UREA-BASED CATALYTIC CONVERTERS

$$Emissions = Activity \bullet \left(\frac{12}{60}\right) \bullet Purity\ Factor \bullet \left(\frac{44}{12}\right)$$

Where:

Emission = Emission of CO_2 (kg)

Activity = Mass (kg) of urea-based additive consumed for use in catalytic converters

Purity factor = Fraction of urea in the urea-based additive (if percent, divide by 100)

The factor (12/60) captures the stochiometric conversion from urea ($(CO(NH_2)_2)$) to carbon, while factor (44/12) converts carbon to CO_2.

3.3.1.2 CHOICE OF EMISSION FACTORS

Default CO_2 emission factors assume that 100% of the fuel carbon is oxidised to CO_2. This is irrespective of whether the carbon is emitted initially as CO_2, CO, NMVOC or as particulate matter.

Country-specific NCV and CEF data should be used for Tiers 2 and 3. Inventory compilers may wish to consult CORINAIR 2004 or the EFDB for emission factors, noting that responsibility remains with the inventory compilers to ensure that emission factors taken from the EFDB are applicable to national circumstances.

For a Tier 3 approach example, please see Box 3.3.1 where more information on tailoring the NONROAD emissions model using country-specific data as well as the model to enhance national emission factors are given.

The default emission factors for CO_2 and their uncertainty ranges, and the default emission factors for CH_4 and N_2O for Tier 1 are provided in Table 3.3.1. To estimate CO_2 emissions, inventory compilers also have the option of using emission factors based on country-specific fuel consumption by off-road vehicles.

TABLE 3.3.1 DEFAULT EMISSION FACTORS FOR OFF-ROAD MOBILE SOURCES AND MACHINERY [(a)]									
	CO_2			CH_4[(b)]			N_2O [(c)]		
Off-Road Source	Default (kg/TJ)	Lower	Upper	Default (kg/TJ)	Lower	Upper	Default (kg/TJ)	Lower	Upper
Diesel									
Agriculture	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Forestry	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Industry	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Household	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Motor Gasoline 4-stroke									
Agriculture	69 300	67 500	73 000	80	32	200	2	1	6
Forestry	69 300	67 500	73 000						
Industry	69 300	67 500	73 000	50	20	125	2	1	6
Household	69 300	67 500	73 000	120	48	300	2	1	6
Motor Gasoline 2-Stroke									
Agriculture	69 300	67 500	73 000	140	56	350	0.4	0.2	1.2
Forestry	69 300	67 500	73 000	170	68	425	0.4	0.2	1.2
Industry	69 300	67 500	73 000	130	52	325	0.4	0.2	1.2
Household	69 300	67 500	73 000	180	72	450	0.4	0.2	1.2

Source: EEA 2005.

Note: CO_2 emission factor values represent full carbon content.

[a] Data provided in Table 3.3.1 are based on European off-road mobile sources and machinery. For gasoline, in case fuel consumption by sector is not discriminated, default values may be obtained according to national circumstances, e.g. prevalence of a given sector or weighting by activity

[b] Including diurnal, soak and running losses.

[c] In general, off-road vehicles do not have emission control catalysts installed (there may be exceptions among off-road vehicles in urban areas, such as ground support equipment used in urban airports and harbours). Properly operating catalysts convert nitrogen oxides to N_2O and CH_4 to CO_2. However, exposure of catalysts to high-sulphur or leaded fuels, even once, causes permanent deterioration (Walsh, 2003). This effect, if applicable, should be considered when adjusting emission factors.

3.3.1.3 CHOICE OF ACTIVITY DATA

Comprehensive top-down activity data on off-road vehicles are often unavailable, and where this is the case statistical surveys will be necessary to estimate the share of transport fuel used by off-road vehicles. Survey design is discussed in Chapter 2 of Vol.1 (Approaches to Data Collection). The surveys should be at the level of disaggregation indicated in Table 3.3.1 to make use of the default emission factor data, and be more detailed for the higher tiers. For the Tier 3 approach, modelling tools are available to estimate the amount of fuel consumed by each subcategory of equipment. Box 3.3.1 provides further information on using the NONROAD emissions model. This model may also be developed to incorporate country-specific modifications (see Box 3.3.2 for the Canadian experience).

BOX 3.3.1
NONROAD EMISSION MODEL (USEPA)

NONROAD 2005 is a mathematical model developed by the USEPA and may be used to estimate and forecast emissions from the non-road (off-road) transportation sectors. The model itself and all available supporting documentation are accessible on the EPA's website (http://www.epa.gov/otaq/nonrdmdl.htm). This model estimates emissions for six exhaust gases: hydrocarbons (HC), NO_X, carbon monoxide (CO), carbon dioxide (CO_2), sulphur oxides (SO_X), and particulate matter (PM). The user selects among five different types for reporting HC — as total hydrocarbons (THC), total organic gases (TOG), non-methane organic gases (NMOG), non-methane hydrocarbons (NMHC), and volatile organic compounds (VOC).

Generally, this model can perform a bottom-up estimation of emissions from the defined sources using equipment specific parameters such as: (i) engine populations; (ii) annual hours of use; (iii) power rating (horsepower); (iv) load factor (percent load or duty cycle), and (v) brake-specific fuel consumption (fuel consumed per horsepower-hour). The function will calculate the amount of fuel consumed by each subcategory of equipment. Subsequently, sub-sector (technology/fuel)-specific emission factors may then be applied to develop the emission estimate. The model is sensitive to the chosen parameters but may be used to apportion emissions estimates developed using a top-down approach.

It is not uncommon for the bottom-up approach using this model to deviate from a similar top-down result by a factor of 2 (100%) and therefore users are cautioned to review documentation for areas where this gap may be reduced through careful adjustment of their own inputs. Consequently, users must have some understanding of the population and fuel/technology make-up of the region being evaluated. However, reasonable adjustments can be established based upon: national manufacturing levels; importation/export records; estimated lifespan and scrappage functions. Scrappage functions attempt to define the attrition rate of equipment and may help illustrate present populations based upon historic equipment inventories (see Box 3.2.3 of Section 3.2 of this volume).

3.3.1.4 COMPLETENESS

Duplication of off-road and road transport activity data should be avoided. Validation of fuel consumption should follow the principles outlined in Section 3.2.1.3. Lubricants should be accounted for based on their use in off-road vehicles. Lubricants that are mixed with motor gasoline and combusted should be included with fuel consumption data. Other uses of lubricants are covered in the Volume 3: IPPU Chapter 5).

Amounts of carbon from biomass, eg. biodiesel, oxygenates and some other blending agents should be estimated separately, and reported as an information item to avoid double counting as these emissions are already treated in the AFOLU sector.

3.3.1.5 DEVELOPING A CONSISTENT TIME SERIES

It is *good practice* to determine activity data (e.g., fuel use) using the same method for all years. If this is not possible, data collection should overlap sufficiently in order to check for consistency in the methods employed. If it is not possible to collect activity data for the base year (e.g. 1990), it may be appropriate to extrapolate data backwards using trends in other activity data records.

Emissions of CH_4 and N_2O will depend on engine type and technology. Unless technology-specific emission factors have been developed, it is *good practice* to use the same fuel-specific set of emission factors for all years.

Mitigation activities resulting in changes in overall fuel consumption will be readily reflected in emission estimates if actual fuel activity data are collected. Mitigation options that affect emission factors, however, can only be captured by using engine-specific emission factors, or by developing control technology assumptions. Changes in emission factors over time should be well documented.

For more information on determining base year emissions and ensuring consistency in the time series, see Volume 1, Chapter 5 (Time Series Consistency).

BOX 3.3.2
CANADIAN EXPERIENCE WITH NONROAD MODEL

Using the model to enhance national emission factors:

NONROAD is initially populated with data native to the United States but may be customised for a given region or Party by simply adjusting the assumed input parameters to accommodate local situations. Parties may wish to designate their region as similar to one of those present in the USA to better emulate the seasonal climate. However, a designated temperature regime may also be input elsewhere. The NONROAD model is, thus, pre-loaded with local USA defaults thereby allowing their constituents to query it immediately.

Canada has begun to adjust this model by commencing national studies to better evaluate country-specific engine populations, available technologies, load factors and brake-specific fuel consumption values (BSFC) unique to the Canadian region. This new information will facilitate creation of Canada-specific input files and therefore not alter the core EPA programme algorithm but allow complete exploitation of the programmes strengths by providing more representative population and operating definitions. Through the introduction of lower uncertainty input data, the model may be used in conjunction with national fuel consumption statistics to arrive at a reasonable, disaggregated emission estimate. When operated with a similarly constructed On-Road model, for which operating parameters are better understood, a complete bottom-up, "apparent" fuel consumption estimate may be scaled to total national fuel sales. The country has used this modelling concept to help improve country-specific emission factors for the off-road consumption of fuel. The total fuel consumed is estimated by fuel type for each of the highly aggregated equipment sectors: (i) 2 cycle *versus* 4 cycle engines; (ii) Agriculture, Forestry, Industrial, Household and Recreational sub-sectors; (iii) gasoline versus diesel (spark vs. compression ignition). Once the model reports the total amount of fuels consumed according to this matrix, a composite emission factor is built based on the weighted averages of the contributing sub-sectors and their unique emission factors. The 2 cycle versus 4 cycle proportions will contribute to an average Off-Road gasoline EF while the Diesel EF is directly determined. Emission factors representing most GWP gases are not well researched and documented currently in North America and therefore, Canada has historically utilized applicable CORINAIR emission factors for these aggregated equipment sectors. The similarities between earlier technologies present in Europe and North America allow this utilization without introducing unreasonable uncertainty.

3.3.2 Uncertainty assessment

Greenhouse gas emissions from off-road sources are typically much smaller than those from road transportation, but activities in this category are diverse and are thus typically associated with higher uncertainties because of the additional uncertainty in activity data.

The types of equipment and their operating conditions are typically more diverse than that for road transportation, and this may give rise to a larger variation in emission factors and thus to larger uncertainties. However, the uncertainty estimate is likely to be dominated by the activity data, and so it is reasonable to assume as a default that the values in section 3.2.1.2 apply. Also, emission controls, if installed, are likely to be inoperable due to catalyst failure (e.g., from exposure to high-sulphur fuel). Thus, N_2O and CH_4 emissions are more closely related to combustion-related factors such as fuel and engine technology than to emission control systems.

3.3.2.1 ACTIVITY DATA UNCERTAINTY

Uncertainty in activity data is determined by the accuracy of the surveys or bottom-up models on which the estimates of fuel usage by off-road source and fuel type (see Table 3.3.1 for default classification) are based. This will be very case-specific, but factor of 2 uncertainties are certainly possible, unless if there is evidence to the contrary from the survey design.

3.3.3 Inventory Quality Assurance/Quality Control (QA/QC)

It is *good practice* to conduct quality control checks as outlined in Chapter 6 of Volume 1, and expert review of the emission estimates, plus additional checks if higher tier methods are used.

In addition to the guidance above, specific procedures of relevance to this source category are outlined below.

Review of emission factors

The inventory compiler should ensure that the original data source for national factors is applicable to each category and that accuracy checks on data acquisition and calculations have been performed. For default factors, the inventory compiler should ensure that the factors are applicable and relevant to the category. If possible, the default factors should be compared to national factors to provide further indication that the factors are applicable and reasonable.

Check of activity data

The source of the activity data should be reviewed to ensure applicability and relevance to the category. Where possible, the data should be compared to historical activity data or model outputs to look for anomalies. Where surveys data have been used, the sum of on-road and off-road fuel usage should be consistent with total fuel used in the country. In addition, a completeness assessment should be conducted, as described in Section 3.3.1.4.

External review

The inventory compiler should carry out an independent, objective review of calculations, assumptions or documentation or both of the emissions inventory to assess the effectiveness of the QC programme. The peer review should be performed by expert(s) who are familiar with the source category and who understand national greenhouse gas inventory requirements.

3.3.4 Reporting and Documentation

It is *good practice* to document and archive all information required to produce the national emissions inventory estimates as outlined in Chapter 8 of Volume 1.

It is not practical to include all documentation in the national inventory report. However, the inventory should include summaries of methods used and references to source data such that the reported emissions estimates are transparent and steps in their calculation may be retraced.

Some examples of specific documentation and reporting issues relevant to this source category are provided below.

In addition to reporting emissions, it is *good practice* to provide:

- Source of fuel and other data;
- Emission factors used and their associated references;
- Analysis of uncertainty or sensitivity of results or both to changes in input data and assumptions.
- Basis for survey design, where used to determine activity data
- References to models used in making the estimates

3.3.5 Reporting tables and worksheets

See the four pages of the worksheets (Annex 1) for the Tier I Sectoral Approach which are to be filled in for each of the source categories. The reporting tables are available in Volume 1, Chapter 8.

3.4 RAILWAYS

Railway locomotives generally are one of three types: diesel, electric, or steam. Diesel locomotives generally use diesel engines in combination with an alternator or generator to produce the electricity required to power their traction motors.

Diesel locomotives are in three broad categories – shunting or yard locomotives, railcars, and line haul locomotives. Shunting locomotives are equipped with diesel engines having a power output of about 200 to 2000 kW. Railcars are mainly used for short distance rail traction, e.g., urban/suburban traffic. They are equipped with a diesel engine having a power output of about 150 to 1000 kW. Line haul locomotives are used for long distance rail traction – both for freight and passenger. They are equipped with a diesel engine having a power output of about 400 to 4000 kW (EEA, 2005).