

# GUIDELINES FOR ESTIMATING GREENHOUSE GAS EMISSIONS OF ASIAN DEVELOPMENT BANK PROJECTS

ADDITIONAL GUIDANCE FOR TRANSPORT PROJECTS

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# Contents

List of Tables	iv
Abbreviations	v
I. Background, Purpose, and Scope	1
II. Principles	3
III. Guidance for Main Subsectors	8
A. Road Transport (Nonurban)	8
B. Rail Transport (Nonurban)	10
C. Urban Transport (Urban Roads and Traffic Management, Urban Public Transport)	11
D. Water Transport (Ports and Inland Waterways)	13
E. Air Transport (Airports)	15
F. Multimodal Projects and/or Transport Policy	16
Annex 1: Mobile Combustion Emission Factors	17
Annex 2: Applied Example for a Railway Project	18
Annex 3: Representative Carbon Emission Factors of Construction and Rolling Stock Material	20

# List of Tables

1. Mobile Combustion Emission Factors
2. Estimation of GHG Emissions during Construction Phase
3. Estimation of GHG Emissions at Operation Phase
4. Representative Carbon Emission Factors of Construction and Rolling Stock Material

# Abbreviations

- ADB – Asian Development Bank
- BRT – bus rapid transit
- CO<sub>2</sub> – carbon dioxide
- CDM – Clean Development Mechanism
- GHG – greenhouse gas
- MRT – mass rapid transit
- TEEMP – Transport Emissions Evaluation Model for Projects
- TSG – Transport Sector Group



# I. Background, Purpose, and Scope

## A. Background

Transport contributes almost a quarter of global energy-related carbon dioxide (CO<sub>2</sub>) emissions. Today, the majority of CO<sub>2</sub> emissions from the sector are from road transport in developed countries. However, vehicle emissions in developing countries are growing due to rapid motorization.<sup>1</sup> The International Energy Agency's *World Energy Outlook 2013* projects that transport fuel demand globally will grow nearly 40% by 2035.

Environmental sustainability is a pillar of Strategy 2020, the corporate strategy of the Asian Development Bank (ADB).<sup>2</sup> In the transport sector, ADB's Sustainable Transport Initiative Operational Plan, approved in 2010, makes addressing climate change a priority.

Recognizing the importance that the operational plan attaches to incorporating impacts of climate change, ADB staff need to be able to quantify the implications of transport projects for greenhouse gas (GHG) emissions,<sup>3</sup> so that these can be taken into account in the project design and approval process.<sup>4</sup>

## B. Purpose

In view of this background, these guidelines describe the principles to follow in measuring climate change impacts of transport projects. They also provide a practical set of methods that can be applied to measure GHG emissions. The guidelines are intended for use by ADB transport sector staff and consultants and may be shared outside of ADB upon request from any third party.

ADB projects increasingly require estimation of GHG impact. These guidelines will help toward establishing reliable and consistent approaches to GHG estimation for transport projects, including with respect to the following:

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<sup>1</sup> International Energy Agency. 2013. *CO<sub>2</sub> Emissions from Fuel Combustion: Highlights*. Paris.

<sup>2</sup> ADB. 2008. *Strategy 2020: The Long-Term Strategic Framework of the Asian Development Bank, 2008–2020*. Manila. <https://www.adb.org/documents/strategy-2020-working-asia-and-pacific-free-poverty>

<sup>3</sup> GHGs are carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF<sub>6</sub>) as defined by the Kyoto Protocol.

<sup>4</sup> For climate adaptation measures, refer to case examples in ADB. 2014. *Climate Proofing ADB Investment in the Transport Sector: Initial Experience*. Manila. <https://www.adb.org/publications/climate-proofing-adb-investment-transport-sector-initial-experience>



- **ADB's Safeguard Policy Statement**, which asks that all projects be screened in terms of their gross GHG emissions and that more detailed analysis be conducted if a certain threshold is exceeded.<sup>5</sup>
- **ADB's Revised Project Classification System**, whereby projects identified as addressing climate change mitigation need to be reported in terms of their net GHG emissions and contribution to climate finance.<sup>6</sup>
- **International Financial Institution Framework for a Harmonised Approach to Greenhouse Gas Accounting**, under which sector-specific documents are currently being deliberated and/or formulated.<sup>7</sup>

## C. Scope

The guidelines apply to investment projects in the transport sector, based on ADB's Project Classification System under which ADB defines the following subsectors as belonging to the transport sector:

- road transport (nonurban),
- rail transport (nonurban),
- urban roads and traffic management,
- urban public transport,
- water transport (nonurban),
- air transport,
- multimodal logistics, and
- transport policies and institutional development.

The guidelines focus on GHG emissions as part of climate change mitigation. They are consistent with and support the related work of the International Financial Institution Working Group on GHG Accounting as well as the Multilateral Development Banks' Working Group on Climate Finance Tracking and Working Group on Sustainable Transport. The guidelines do not consider the issues of adaptation and climate proofing.<sup>8</sup>

This document is organized in the following manner: Section II sets out key principles for calculating GHG emissions of transport projects and Section III provides suggested methodologies in calculating GHG emissions in the different transport subsectors. As best practice on such methodologies continues to evolve, this guidance is intended to be a living document that will be updated and enhanced over time.

<sup>5</sup> ADB. 2006. *Operations Manual*. Section F1: Environmental Considerations in ADB Operations. Manila.

<sup>6</sup> ADB. 2014. *Project Classification System: Final Report*. Manila. <https://www.adb.org/documents/project-classification-system-final-report>

<sup>7</sup> International Financial Institutions. 2012. *International Financial Institution Framework for a Harmonised Approach to Greenhouse Gas Accounting*. [http://www.worldbank.org/content/dam/Worldbank/document/IFI\\_Framework\\_for\\_Harmonized\\_Approach%20to\\_Greenhouse\\_Gas\\_Accounting.pdf](http://www.worldbank.org/content/dam/Worldbank/document/IFI_Framework_for_Harmonized_Approach%20to_Greenhouse_Gas_Accounting.pdf) (updated 2015).

<sup>8</sup> Guidance on adaptation and climate proofing projects is available in ADB. 2014. *Climate Risk Management in ADB Projects*. Manila. <http://www.adb.org/publications/climate-risk-management-adb-projects>

## II. Principles

Regardless of the mode of transport, the accounting for greenhouse gas (GHG) emissions of transport projects should generally follow the following principles.

### A. Scope of Calculations

The framework of the Greenhouse Gas Protocol classifies emissions as *direct GHG emissions* and *indirect GHG emissions* (Box 1).<sup>9</sup> Under this definition, the majority of GHG emissions for the transport sector are considered to be scope 3 indirect GHG emissions, since they primarily arise from the use of energy by vehicles whose movements occur on or due to the infrastructure. This generally comes in the form of consumption of gasoline, diesel, and other forms of fossil fuels. Therefore, scope 3 emissions are the primary consideration for transport projects. Emissions that relate to the construction of the transport infrastructure are considered direct GHG emissions, and may be included in the analysis for certain types of transport sector projects where such emissions are known to constitute a large part of total emissions (see Annex 3 for representative emission factors for construction material).

Carbon dioxide (CO<sub>2</sub>) comprises the majority of transport GHG emissions. Unless there are reasons to believe that other GHGs are significantly affected by the project (for example, when biomethane is used as the transport fuel), it is suggested to focus the GHG assessment on CO<sub>2</sub> emissions.

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<sup>9</sup> Greenhouse Gas Protocol. About the GHG Protocol. <http://www.ghgprotocol.org/about-ghgp>

### Box 1: Definitions of Scope of Emissions

**Direct greenhouse gas (GHG) emissions:** emissions from sources that are owned or controlled by the reporting entity

**Indirect GHG emissions:** emissions that are a consequence of the activities of the reporting entity, but occur at sources owned or controlled by another entity

**Scope 1:** all direct GHG emissions

**Scope 2:** indirect GHG emissions from consumption of purchased electricity, heat, or steam

**Scope 3:** other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g., transmission and distribution losses) not covered in scope 2, outsourced activities, waste disposal, etc.

Source: Greenhouse Gas Protocol. About the GHG Protocol. <http://www.ghgprotocol.org/about-ghgp>

## B. Basic Construct of Transport Emissions

Transport GHG emissions are calculated as a product of level of activity, modal structure, intensity of fuel use, and fuel carbon content (ASIF):

$$\text{Total Transport Emissions} = \text{Activity (vkm, pkm, tkm)} \times \text{Modal Structure} \times \text{Intensity (l/pkm, kJ/pkm)} \times \text{Fuel carbon content (g/l, g/kJ)}$$

whereby

- (i) Activity reflects travel demand. This is usually expressed in trips and is driven by external factors, including geographical characteristics, land-use patterns, and economic growth. This can be estimated as vehicle-kilometer (vkm) for road users, train-kilometer (train-km) for rail users, and ton-kilometer (tkm) for freight carried by a mode of transport. Passenger-kilometer (pkm) is also commonly used and can be converted to vkm using known vehicle occupancy rates.
- (ii) Structure reflects mode share. This is the proportion of trips on the different transport modes, including road users, rail users, and bus passengers.
- (iii) Intensity is the fuel efficiency of the considered mode, as measured in liters per passenger-kilometer, or kilojoules per passenger kilometer. Intensity depends notably on load factors.
- (iv) Fuel carbon content is the GHG emissions per unit of fuel used or electricity consumed, usually expressed in grams per liter (g/l) or grams per kilojoule (g/kJ). This is also determined by vehicle composition and fuel efficiency.

## C. Forecasting Activity (Travel Demand) and Modal Structure

The same information on transport activity and modal structure used in the traffic forecast for economic analysis should be used for estimating GHG emissions. The following are best practices for such a demand analysis or forecast:

- A transport model is usually developed to undertake cross-modal transport demand analysis to assess the impact of proposed transport interventions (projects and/or policies) on transport demand to assess “activity” and “mode share.” This analysis should take account of geographical characteristics, sociodemography of the project area in the base year and future years, income distribution, travel cost, and travel time.
- The transport model is usually used to generate “without project” and “with project” scenarios to derive model outputs to assess “activity” in the different scenarios.
- Proportionate efforts should be applied to model changes in “activity,” “mode share,” and “intensity.” Therefore, in cases where mode shifting is expected to be negligible (for example, rural roads), a full transport model may not be required. However, it is worth highlighting that the quality and robustness of traffic forecasts are key elements of the validity of the GHG assessment. Therefore, one should take care that traffic modeling used to inform GHG assessment is defensible and robust.
- Should there be any uncertainties regarding key parameters, project teams are recommended to use conservative values.

If induced or diverted traffic is captured in the economic analysis, this should also be included in the GHG emissions assessment. The same applies for any rebound effects of congestion relief measures (i.e., if project measures to relieve congestion would lead to attracting additional traffic).

## D. Estimating Intensity and Fuel Carbon Content

These should be matched to the relevant local context of the project and may take into account

- (i) vehicle characteristics,
- (ii) speed (potentially affected by congestion and safety considerations),
- (iii) vehicle loading,
- (iv) driving cycles, and
- (v) driver behavior.

For electric vehicles or other electric modes including buses and trains, the total electricity consumed could be calculated as a function of the unit rate of electricity consumption as per the specification information from the vehicle manufacturer.

Priority should be given to using project-specific data on intensity and fuel carbon content where possible. If these are not available, project teams should rely on authoritative sources, for example, the Intergovernmental Panel on Climate Change (IPCC).

## E. Choice of Tools and Methodologies

As long as the tool and/or methodology adheres to the basic principles laid out in these guidelines, the choice of specific assessment tool and/or methodology is left to the discretion of each project team.

In most or many cases, little additional effort is needed to estimate GHG emissions from transport projects, since the calculations rely on information that can be readily extracted from the transport model already developed for traffic forecasting and economic and financial analysis of the project. Project teams then only need to augment information relating to intensity of fuel use for different vehicle types (which can be derived from literature or local estimates) and fuel carbon content (provided in Annex 1).

There are many readily available tools and methods to support the estimation of GHG emissions from transport projects. Useful tools include the following:

- Highway Development and Maintenance Management System Tool (HDM-4): mainly for use on road projects
- Urban transport models: for urban transport projects
- Transport Emissions Evaluation Model for Projects (TEEMP): for “rapid” evaluation of GHG emissions when limited data and time are available to conduct a fuller analysis
- Clean Development Mechanism (CDM) methodologies: when a project is seeking climate financing from the CDM

The required level of effort and accuracy depends on the purpose of the GHG estimation. Compliance with ADB’s Safeguard Policy Statement and Project Classification System or the International Financial Institution (IFI) Framework for a Harmonised Approach to GHG Accounting would require minimal additional effort and data beyond what is undertaken as part of project preparation. A more detailed approach may be needed if climate-related financing is being sought.<sup>10</sup>

## E. Assessment Period

The assessment period for GHG emissions should generally be consistent with the appraisal period considered in the economic analysis of the project. Wherever possible, GHG emissions should be estimated for the construction phase, opening year, and annually over the project life. A representative value for annual GHG emissions will be derived from an average of emissions over the assessment period. For estimating GHG emissions in

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<sup>10</sup> The degree of accuracy of the GHG estimate depends on the requirement of the funding source.

future years, interpolation between modeled forecast years can be applied (this approach is commonly used in studying economic costs and benefits).

## F. Gross versus Net Emissions

Depending on specific requirements, each project can be reported against either or both of the following:

- **Absolute or gross GHG emissions:** total GHGs generated by the project in absolute terms
- **Relative or net GHG emissions:** change in GHGs generated by the project as compared to “business as usual” or “without project.” Net GHG emissions is simply the difference between gross GHG emissions in the “with project” and “without project” scenarios. When reporting emissions on a net basis, it is recommended to clearly document the underlying assumptions for these two scenarios.

## G. Best Practice on Reporting

For transparency, the following information should be documented and disclosed, wherever feasible, along with the forecasts:

- source of the emissions (scopes 1, 2, and/or 3), disaggregated effect of induced traffic if significant, baseline (static/dynamic), and project boundaries
- absolute/gross or relative/net assessment of GHG emissions
- assessment period
- GHG emissions in the construction phase and operation phase (e.g., opening year and average annual emissions in forecast years)
- nature of the “representative year” of operation (e.g., average or first full operating year)
- key assumptions determining the forecasts
- sources of input data, if not project specific

## III. Guidance for Main Subsectors

Transport interventions can often have wide-ranging impacts, particularly across different modes. Subsections A–E set out the suggested approaches to estimating GHG emissions within the different transport subsectors (modes). General approaches for projects with multimodal features are suggested in section F. An applied example for a railway project with multimodal impact is also presented at the end of these guidelines (Annex 2). While the guidance provided here on the approaches for different subsectors is not exhaustive, it illustrates the main concepts and approaches for estimation of GHG emissions of transport projects.

### A. Road Transport (Nonurban)

#### 1. General Approach

Road transport projects (rehabilitation, reconstruction, and greenfield) typically are subject to economic appraisal using standard techniques and tools such as HDM-4. These tools calculate the economic benefits of a transport project based on information on forecast traffic in the project period, projected improvement in road surface quality (international roughness index), and projected changes in traffic speeds. The “with project” and “without project” scenarios are compared to arrive at the additional economic benefits provided by the project, both in the form of vehicle operating cost savings and time cost savings.

Vehicle operating cost savings include those from changes in transport fuel consumption, which take into account typical speeds and fleet characteristics. These savings (expressed in liters of gasoline or diesel) can then be multiplied by the GHG emission factor for these fuels (see Annex 1) to arrive at the GHG savings of the project.

In a typical case, the improvements in road quality brought about by the project would reduce fuel consumption (and thereby GHG) per vehicle-kilometer. However, these savings would be partially or wholly offset by the increase in total vehicle-kilometers due to traffic generation.

#### 2. Further Considerations

The aforementioned general approach should be expanded in the following cases:

- (i) If the project is expected to generate a significant amount of GHG during construction (mostly greenfield projects and major reconstruction): further detailed modeling of construction emissions is recommended, based on information from the environmental assessment of the project (Annex 3).

- (ii) If the project is expected to induce large changes in land use along the road (e.g., deforestation): the GHG analysis should consider such impacts further, following the process laid out in the Safeguard Policy Statement of the Asian Development Bank (ADB).<sup>11</sup>
- (iii) If the project is expected to divert large portions of traffic from alternative modes of transport (e.g., rail): the changes in GHG emissions from such alternative modes of transport should be calculated and recorded.

The following is a list of available tools and additional references:

#### a. Road Transport: Available Tools

- **Highway Development and Maintenance Management Model (HDM-4):** HDM-4 is a software package and associated documentation which is an industry-standard tool for the analysis, planning, management, and appraisal of road maintenance, improvements, and investment decisions in developing countries. ADB, among other partners, was one of the contributors to the development of HDM-4. Licenses are available to ADB teams through the Transport Sector Group (TSG) Secretariat. Available at <http://www.hdmglobal.com/>
- **Motor Vehicle Emission Simulator (MOVES):** The United States Environmental Protection Agency (US EPA) has developed the MOVES. This emission modeling system estimates emissions for mobile sources covering a broad range of pollutants and allows multiple scale analysis. Available at <http://www.epa.gov/oms/climate/measuring.htm>
- **Transport Emissions Evaluation Model for Projects (TEEMP):** The TEEMP Road Model allows the evaluation of emissions (carbon dioxide [CO<sub>2</sub>], particulate matter [PM], and oxides of nitrogen [NO<sub>x</sub>]) impacts of three types of roads—expressways, rural roads, and urban roads. Available at <http://cleanairasia.org/portal/TEEMPTool> (consult the TSG Secretariat for the most recent version)

#### b. Road Transport: Additional References

- **Methodology for Estimating Carbon Footprint of Road Projects: India Case Study:** This is a pilot study to derive a carbon footprint methodology for road projects in India. Available at <https://www.adb.org/publications/methodology-estimating-carbon-footprint-road-projects-case-study-india>
- **Estimation of Greenhouse Gas Emissions from Land-Use Changes due to Road Construction in the Republic of Korea:** This 2013 study quantified GHG emissions and sequestration from land-use changes due to road construction. Following the guidelines of IPCC, this study developed a framework to estimate GHG emissions for land-use changes. Eighteen cases involving a typical highway construction project in the Republic of Korea were selected for this study. Available at [http://ascelibrary.org/doi/abs/10.1061/\(ASCE\)CO.1943-7862.0000620](http://ascelibrary.org/doi/abs/10.1061/(ASCE)CO.1943-7862.0000620)
- **Greenhouse Gas Emissions Mitigation in Road Construction and Rehabilitation:** This is a study carried out by the World Bank to look at different construction and labor practices and their respective GHG emissions. Available at <http://siteresources.worldbank.org/INTEAPASTAE/Resources/GHG-ExecSummary.pdf>

<sup>11</sup> For more details, refer to P. Smith et al. 2014. Agriculture, Forestry and Other Land Use (AFOLU). In O. Edenhofer et al, eds. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK, and New York, NY: Cambridge University Press. pp. 811–922.



## B. Rail Transport (Nonurban)

### 1. General Approach

Railways are generally an environment-friendly mode of transport capable of moving large volumes of freight and passengers over long distances. The modal shift to rail from road-based transport is one of the key drivers to reduce GHG emissions in the transport sector.

The approach to estimating GHG emissions of railway transport projects depends on the nature of the project in question. Projects may include rehabilitation or upgrading, double-tracking, network expansion, electrification, or a combination of these. The project team should assess to what extent the changes due to the project may generate new net traffic, induce a modal shift away from road, and/or improve the carbon efficiency of existing rail operations.

Major rehabilitation and upgrading of railway tracks would induce considerable GHG emissions during construction. For such projects, teams should consider calculating GHG emissions not only for project operations but also for construction. An applied example of GHG emission estimation for a railway project with considerable construction emissions and multimodal impact is in Annex 2.

Railway freight traffic is typically measured in tons and ton-kilometers and passenger traffic in passengers and passenger-kilometers. Load factors significantly influence energy and fuel consumption. CO<sub>2</sub> emissions are based on fuel consumption estimates multiplied by the emission factor of the specific fuel used by locomotives (Annex 1). Emissions associated with power generation for electrification of rail are estimated based on the amount of electricity consumed multiplied by the grid emission factor.<sup>12</sup>

### 2. Further Considerations

The impacts of railway projects often extend over many decades. As such, the economic life and GHG assessment of railway projects may need to consider an extended assessment period.

The following is a list of available tools and additional references:

#### a. Rail Transport: Available Tools

- **Railway Handbook:** The International Union of Railways (UIC), in partnership with the International Energy Agency, publishes handbooks containing information on rail energy use and emissions statistics that can be used as references when estimating railway CO<sub>2</sub> emissions. Available at [http://www.uic.org/IMG/pdf/iea-uic\\_railway\\_handbook\\_2016.pdf](http://www.uic.org/IMG/pdf/iea-uic_railway_handbook_2016.pdf)
- **Emission Factors for Locomotives:** The US EPA has established emission standards for NO<sub>x</sub>, hydrocarbons (HC), carbon monoxide (CO), PM, and smoke for

<sup>12</sup> Use national grid emission factors, if available; else, refer to IPCC. Emission Factor Database. <http://www.ipcc-nggip.iges.or.jp/EFDB/main.php>

newly manufactured and remanufactured locomotives. Available at <https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-emissions-locomotives>

- **Rail Carrier Partner 2.0.15 Tool:** This is US EPA's SmartWay 2.0.15 Rail Tool with technical documentation of methods to calculate emissions, fuel consumption, and comparison metrics based on data provided by railway companies to the Department of Transportation's Federal Railroad Administration. Available at <https://www.epa.gov/smartway/smartway-rail-carrier-tools-and-resources>

#### b. Rail Transport: Additional Reference

##### **Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit:**

This provides guidance to transit agencies for quantifying their GHG emissions, including both emissions generated by transit and the potential reduction of emissions through efficiency and displacement. Available at <http://www.apta.com/resources/hottopics/sustainability/Documents/Quantifying-Greenhouse-Gas-Emissions-APTA-Recommended-Practices.pdf>

## C. Urban Transport (Urban Roads and Traffic Management, Urban Public Transport)

### 1. General Approach

A variety of transport options are available for urban areas. Urban transport projects differ greatly from nonurban transport projects mainly due to the complex and multimodal network effects that arise from them. This being said, the principles underlying GHG estimation for urban transport projects are the same as for other transport projects.

Most urban transport projects estimate traffic, speeds, and benefits using multimodal transport models specific to the project location. This is particularly true of large cities, where it is common to develop a transport model of the city. Such models allow for modeling changes brought about by a specific project, notably with respect to trip attraction and generation, trip distribution, mode choice,<sup>13</sup> and route choice. These changes can then be multiplied by the emission factors relating to the intensity and fuel of each mode of transport to derive (changes in) GHG emissions.

Recent developments in the capability of various commercial transport modeling software packages enable the models to provide an integrated approach to estimating GHG emissions of multiple urban transport projects. Project teams may consider incorporating GHG estimation when using such models.

<sup>13</sup> A modal shift to urban transport projects such as bus rapid transit (BRT) leads to "displaced emissions" as travel by private vehicle is reduced. The equivalent GHG emissions from the modal shift are estimated based on the reduced fuel consumption compared with the previous mode options multiplied by the corresponding fuel emission factor.

## 2. Further Considerations

In case there are limited data and resources available, sketch tools can be used to derive approximations of GHG emissions of the project. For example, the following is a list of several tools for estimating GHG emissions from bus rapid transit (BRT) projects:

### Urban Transport: Available Tools

- **Proprietary macrosimulator tools and software:** These are available from several vendors, for example, EMME2, PTV Visum, CUBE, and TransCAD. These models are often used by transport agencies and financiers to conduct appraisal of urban transport projects. They often include a module that allows for the estimation of GHG emissions or fuel consumption. Available at:
  - » <http://vision-traffic.ptvgroup.com/en-us/products/ptv-visum/>
  - » <http://www.caliper.com/tcovu.htm>
  - » <http://www.inrosoft.com/en/products/emme/new-in-emme-4-2/>
- **Clean Development Mechanism (CDM) AM0031: Bus rapid transit projects – version 5.0.0:** This is the registered methodology for BRT projects which are eligible for crediting under the CDM. The methodology is applicable to project activities that reduce emissions through the construction and operation of a new BRT system or lane(s) for urban road-based transport. It is also applicable to the construction and operation of the extension of bus lanes of existing BRT systems. The methodology requires that passengers be able to realize their entire trip on the project system and is best used for BRT systems with feeder-trunk routes. It is very data intensive due to the requirement for verification of progress during the lifetime of the project. Up-front costs for data collection are high so it is not suitable for smaller-scale BRT projects. Available at <https://cdm.unfccc.int/methodologies/DB/GBFY1EP0Q2XUZQY9HJLL5BP9DOM0QW>
- **CDM ACM0016: Mass rapid transit projects – version 3.0.0:** This is the registered consolidated methodology for mass rapid transit (MRT) projects which are eligible for crediting under the CDM. It covers rail-based systems such as subways and metros, light rail transit (LRT) systems including trams, or suburban heavy duty rail systems or road-based bus systems. For the purpose of this methodology, road-based MRT systems are bus systems using bus lanes, which can also be called BRT systems. It is very data intensive due to the requirement for verification of progress during the lifetime of the project. Up-front costs for data collection are high so it is not suitable for small-scale projects. Available at <https://cdm.unfccc.int/methodologies/DB/8PBZENI1PK0QIJW8RJ5LEDXV6WX600>
- **CDM Tool 18: Baseline emissions for modal shift measures in urban passenger transport – version 1.0:** This tool provides methodological guidance to estimate baseline emissions for transport projects implementing modal shift measures in urban passenger transport. It is applicable to project activities in urban passenger transport that implement a measure or a group of measures aimed at a modal shift to urban public transit such as metro, BRT, light rail, and trams. Available at <https://cdm.unfccc.int/methodologies/PAMethodologies/tools/am-tool-18-v1.pdf>
- **CDM Tool 17: Baseline emissions for modal shift measures in inter-urban cargo transport – version 1.0:** This tool provides methodological guidance to determine baseline emissions for transport projects implementing modal shift measures in interurban cargo transport. It is applicable to project activities in interurban cargo transport that implement a measure or a group of measures aimed at a modal shift

from road to waterborne (using barges or domestic ships) or rail transport. Available at <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-17-v1.pdf>

- **TEEMP BRT Model:** This model can be used in estimating the emissions impact of a BRT project. It takes into account the emissions generated through the operations of BRT buses, as well as the emissions associated with the construction of the BRT facilities. The tool utilizes a hypothetical business-as-usual scenario which the user can define. Business-as-usual emissions are estimated based on the vehicles that would have been used by the BRT riders in the absence of the project. Available at <http://cleanairasia.org/portal/TEEMPTool> (consult the TSG Secretariat for the most recent version).
- **TEEMP MRT Model:** This model is similar in approach to the aforementioned TEEMP BRT model. It enables users to consider the energy characteristics of electricity generation used to power electrified trains. Available at <http://cleanairasia.org/portal/TEEMPTool> (consult the TSG Secretariat for the most recent version)

## D. Water Transport (Ports and Inland Waterways)

### 1. General Approach

Water transport is generally a low-carbon transport mode for freight on a per ton-kilometer basis, when compared to road transport. Water transport projects may include inland waterways, short sea shipping, ports, or a combination of these.

Similar to railway projects, water transport projects may be assessed in terms of their GHG impact with regard to how they may generate new net traffic, induce a modal shift away from road, and/or improve the carbon efficiency of existing water transport operations. Available tools and references are provided.

For port projects, the first consideration is the emissions arising directly from the construction and operation of the port infrastructure (direct emissions).<sup>14</sup> Such projects are often formulated to support the development of trade including generating new traffic to and from a country or region (predominantly freight, sometimes passengers). It is best practice to also estimate the increase in ship traffic that will be generated from the enhanced or new port infrastructure (indirect emissions). Direct emissions are estimated from fuel consumption of construction and operation equipment and vehicles, multiplied by corresponding emission factors depending on the type of fuel used. Similarly, indirect emissions are estimated based on additional fuel consumption from generated ship traffic.

Most inland waterway transport and short sea shipping projects offer a direct substitute for road transport. The GHG emission reduction due to the modal shift is the difference between the estimated fuel consumption used by conventional road transport compared to the amount of fuel used by ships to transport the equivalent load (either freight or passengers).

<sup>14</sup> These include GHG emissions due to cargo handling equipment, fuel-fired heating units, portable or emergency generators, electricity-consuming equipment and buildings, and refrigeration or cooling equipment.

It is important to consider when there are any changes in vessel technology (upgrading of vessels, switching of fuels, etc.). Different technological interventions will have different impacts on GHG emissions. Quantification of the impacts should be based on the resulting amount of fuel consumed and the emission factor of the specific fuel used.

## 2. Further Considerations

Although water transport projects are generally carbon efficient in their operation stage, a major source of emissions (and other environmental impacts) may arise if they involve either damming and/or dredging. Project teams should determine whether such impacts are part of the project and, if so, take these into account when conducting the GHG analysis.

For port projects, project teams may also take into account generation of traffic to and/or from the port using road and rail. The treatment of emissions from such generated traffic should be documented in the reporting.

The following is a list of tools and references for water transport projects:

### a. Water Transport: Available Tool

**Carbon Footprinting for Ports:** This guidance document prepared by the Carbon Footprint Working Group of the World Ports Climate Initiative serves as a resource guide for ports wanting to develop or improve their GHG emission inventories. Available at [http://wpci.iaphworldports.org/data/docs/carbon-footprinting/PV\\_DRAFT\\_WPCI\\_Carbon\\_Footprinting\\_Guidance\\_Doc-June-30-2010\\_scg.pdf](http://wpci.iaphworldports.org/data/docs/carbon-footprinting/PV_DRAFT_WPCI_Carbon_Footprinting_Guidance_Doc-June-30-2010_scg.pdf)

### b. Water Transport: Additional References

- **Third International Maritime Organization GHG Study 2014:** This study provides updated GHG emission estimates for ships. Available at <http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Greenhouse-Gas-Studies-2014.aspx>
- **Shipping Emissions in Ports:** This International Transport Forum paper provides useful data on shipping emissions in ports across the world. Available at <http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP201420.pdf>
- **Inland Waterway Transport Toolkit (draft):** This paper provides basic information to assist the formulation of inland waterway projects. Available from the Transport Sector Group Secretariat.
- **Contribution to Impact Assessment of Measures for Reducing Emissions of Inland Navigation:** This research project by the European Commission outlines key issues affecting emissions from inland waterway transport and measures to reduce them. Available at <http://ec.europa.eu/transport/modes/inland/studies/doc/2013-06-03-contribution-to-impact-assessment-of-measures-for-reducing-emissions-of-inland-navigation.pdf>
- **Emissions by the Transport Sector – Rail and Inland Waterways:** This is the ongoing research by Eurostat on identifying and evaluating suitable data and methods for assessing the impact of railway and inland waterways transport on GHG emissions. Available at <http://emisias.com/content/emissions-transport-sector-%E2%80%93-rail-and-inland-waterways>

## E. Air Transport (Airports)

### 1. General Approach

Airport projects generally would have similar GHG emission considerations to port projects. In the first instance, the focus should be on the emissions which arise from the construction and operation of the airport.

Best practice would also account for the emissions arising from the increase in air traffic due to the airport improvements. Depending on data availability, possible methods of estimating GHG emissions include (i) using fuel sales data for the airport to calculate total emissions for all departure flights, (ii) using fuel sales data in combination with methods or models to separately calculate landing and take-off cycle emissions, and (iii) relying on models capable of calculating fuel consumption and emissions associated with all modes of flight including cruise.<sup>15</sup> Standard methodologies for such GHG estimation are available from specialized agencies (see lists that follow).

### 2. Further Considerations

Project teams are also recommended to account for non-CO<sub>2</sub> emissions that have significant global warming impacts, which in the case of air traffic, constitute a sizable amount of GHG emissions (unlike other subsectors). These include NO<sub>x</sub> emissions, contrails, and cirrus clouds, which, when combined (with CO<sub>2</sub>), produce 2–5 times greater global warming potential than CO<sub>2</sub> alone.<sup>16</sup>

The following is a list of tools and references for air transport projects:

#### a. Air Transport: Available Tools

- **International Civil Aviation Organization (ICAO) Carbon Emissions Calculator:** The ICAO has developed a methodology to calculate the CO<sub>2</sub> emissions from air travel which applies the best publicly available industry data to account for various factors such as aircraft types, route specific data, passenger load factors, and cargo carried. Available at <http://www.icao.int/environmental-protection/Pages/Tools.aspx>
- **Guidebook on Preparing Airport Greenhouse Gas Emissions Inventories:** This report for the United States Federal Aviation Administration provides detailed methodologies for accounting for airport emissions. Available at [http://onlinepubs.trb.org/onlinepubs/acrp/acrp\\_rpt\\_011.pdf](http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_011.pdf)

#### b. Air Transport: Additional Reference

**Airport Carbon Accreditation:** This is an institutionally endorsed carbon management certification standard used by major airports across the world. Available at <http://www.airportcarbonaccreditation.org/>

<sup>15</sup> Cruise is defined as all activities that take place at altitudes above 3,000 feet (1,000 meters). In the GHG inventory methodology, it includes climb to cruise altitude, cruise, and descent from cruise altitudes.

<sup>16</sup> R. Sausen et al. 2005. Aviation Radiative Forcing in 2000: An Update on IPCC (1999). *Meteorologische Zeitschrift*. 14 (4). pp. 555–561.

## F. Multimodal Projects and/or Transport Policy

### 1. General Approach

Projects which are multimodal in nature, and/or have policy components that affect GHG emissions from the transport sector in general, require a different approach to GHG accounting. The latter may include but may not be limited to (i) setting of vehicle emission standards for a country, (ii) taxation of fuels and/or phasing out of fossil fuel subsidies, (iii) road user charges, (iv) guidelines and/or regulations on land use, (v) car ownership quotas, (vi) and national and/or regional programs in support of low-carbon transport which combine various components of the above.

For such projects, it is recommended to utilize policy-based tools (as compared to project-based tools) which are able to model changes to aggregate transport activity caused by policy changes. Some examples and additional references are given in the following lists:

#### a. Multimodal Projects/Transport Policy: Available Tool

**For Future Inland Transport Systems (ForFITS) Model:** This is primarily focused on CO<sub>2</sub> emissions from inland transport, including road, rail, and inland waterways, and predicts future emissions based on current patterns. CO<sub>2</sub> emissions from aviation and maritime transport are also covered by ForFITS, but in a simplified manner in comparison to the other transport modes. The model is suitable for the analysis of transport systems having a regional, national, and/or local dimension, with a primary focus on national systems. Available at <http://www.unece.org/?id=19273>

#### b. Multimodal Projects/Transport Policy: Additional References

- **Strategies to Reduce GHG Emissions from Road Transport: Analytical Methods:** This publication aims to (i) clarify what steps are being taken by road transport in the way of policies or measures to reduce or stabilize transport GHG emissions, (ii) scope out existing evaluation frameworks, and (iii) consider future trends in GHG emissions from transport. Available at <http://www.itf-oecd.org/sites/default/files/docs/02greenhousee.pdf>
- **Assessment of GHG Analysis Techniques for Transportation Projects:** This study for the American Association of State Highway and Transportation Officials (AASHTO) provides (in the US context) a useful analysis of methodologies available at the state and/or national level for the conduct of GHG estimation. Available at [http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/25-25\(17\)\\_FR.pdf](http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/25-25(17)_FR.pdf)

# Annex 1: Mobile Combustion Emission Factors

**Table 1: Mobile Combustion Emission Factors**

Fuel Type	Emission Factor (kg CO <sub>2</sub> per unit)	Unit
Aviation gasoline	2.20	liter
Biodiesel (100%)	2.50	liter
Compressed natural gas	0.0545	standard cubic foot
Diesel Fuel	2.70	liter
Ethane	1.07	liter
Ethanol (100%)	1.52	liter
Jet fuel (kerosene type)	2.58	liter
Liquefied natural gas	1.18	liter
Liquefied petroleum gas	1.50	liter
Methanol	1.08	liter
Motor gasoline	2.32	liter
Propane	1.51	liter
Residual fuel oil	2.98	liter

CO<sub>2</sub> = carbon dioxide, kg = kilogram.

Liquefied natural gas data sourced from Table B-5 in United States Environmental Protection Agency. 2008. *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance - Direct Emissions from Mobile Combustion Sources*. Washington, DC.

Methanol data sourced from Table 13.1, US Default CO<sub>2</sub> Emission Factors for Transport Fuels in The Climate Registry. 2013. *General Reporting Protocol for the Voluntary Reporting Program Version 2.0*. Default Emission Factors. Los Angeles, CA.

Sources: Tables C-1 and C-2 in Federal Register. 2009. *Environmental Protection Agency - 40 CFR Parts 86,87,89 et al. Mandatory Reporting of Greenhouse Gases; Final Rule*. Released on 30 October. <https://www.gpo.gov/fdsys/pkg/FR-2009-10-30/pdf/E9-23315.pdf>; amended under R. Schmeltz to Docket EPA-HQ-OAR-2012-0934, memorandum, 24 September 2013, Table of Final 2013 Revisions to the Greenhouse Gas Reporting Rule. <https://www.epa.gov/sites/production/files/2015-01/documents/memo-2013-technical-revisions.pdf>



## Annex 2: Applied Example for a Railway Project

The following is an example of the application of the key principles stated in these guidelines. The example case is a rail project (section III.B), which could have extensive greenhouse gas (GHG) impact not only in the construction phase but also in the operations phase, affecting several modes of transport.

This example has been adapted from an assessment of carbon emissions conducted for Phase One and Two of the High Speed Rail project in the United Kingdom.<sup>1</sup> The example illustrates the concept and approach of estimating GHG emissions in a project with multimodal impact or in a multimodal context. Carbon conversion factors used to convert a unit of material (i.e., kilogram of steel) into associated carbon emissions (kilogram of carbon dioxide equivalent, [kgCO<sub>2</sub>e]) of some construction and rolling stock materials are in Annex 3.<sup>2</sup>

**Table 2: Estimation of GHG Emissions during Construction Phase**

Emissions Source	Approach	Variable
Emissions from the carriage of construction plant equipment to site	For each plant type: carbon emissions = distance traveled by plant type x relevant emissions factor (kg CO <sub>2</sub> /km)	Number and type of plant equipment, distance traveled (km)
Emissions from the carriage of bulk construction materials to site	For each bulk material: carbon emissions = total volume of material (tons) x % carried by road, rail x distance from point of manufacture to site (km) x relevant emissions factor (kg CO <sub>2</sub> /km)	Volume of each bulk material (tons), % carried by mode of transport (road, rail), distance from point of manufacture to site (km)
Emissions from the carriage of excavated material from site	Carbon emissions = total volume of excavated material (tons) x % carried by road, rail x distance traveled to landfill site(s) (km) x relevant emissions factor (kg CO <sub>2</sub> /km)	Volume of excavated material (tons), distance to landfill site(s) (km), % carried by mode of transport (road, rail)

*continued on next page*

<sup>1</sup> See Temple-ERM. 2013. *Sustainability Statement: Appendix F – HS2 and Carbon*. [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/400836/hs2ml-carbon\\_assessment\\_and\\_narrative-\\_25thoct13\\_wed\\_tagged\\_version\\_-\\_updated\\_0.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/400836/hs2ml-carbon_assessment_and_narrative-_25thoct13_wed_tagged_version_-_updated_0.pdf)

<sup>2</sup> See Department for Transport. 2013. *London–West Midlands Environmental Statement: Volume 5 – Technical Appendices*. [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/259613/Volume5\\_Climat\\_Summary\\_carbon\\_calculation\\_outputs\\_CL-002-000.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/259613/Volume5_Climat_Summary_carbon_calculation_outputs_CL-002-000.pdf)

Table continued

Emissions Source	Approach	Variable
Emissions from construction personnel travel to and from the site	Mode of transport characteristics (i.e., private transport or public transport)	Mode of transport specification and/or efficiency
Emissions from the manufacture (cradle to gate) of bulk construction materials (embedded carbon) for each type of track feature (i.e., rail, rail driveway, viaducts, tunnels, stations); bulk construction materials include concrete, steel, aluminum, copper, and aggregate	Carbon emissions = tons of steel x relevant emissions factor (kg CO <sub>2</sub> /ton)	Tons of steel
	Carbon emissions = tons of concrete x relevant emissions factor (kg CO <sub>2</sub> /ton)	Quantity (tons) and grade (% of cement) of concrete used
	Carbon emissions = tons of ballast (aggregate) x relevant emissions factor (kg CO <sub>2</sub> /ton)	Quantity (tons) of aggregate required

CO<sub>2</sub> = carbon dioxide, kg = kilogram, kgCO<sub>2</sub>e = kilogram of carbon dioxide equivalent, km = kilometer.

**Table 3: Estimation of GHG Emissions at Operation Phase**

Emissions Source	Approach	Variable
Rail – electric <i>Electricity consumption from electric train operations</i>	Carbon emissions = annual mean electricity demand (kWh) x relevant emissions factors (kg CO <sub>2</sub> /kWh)	Annualized electricity demand, projected carbon emission factors
Rail – diesel <i>Fuel consumption from existing diesel train operations, based upon stock types</i>	Carbon emissions = train distance traveled (train-km) x relevant emissions factor (kg CO <sub>2</sub> /train-km)	Annualized diesel usage, projected carbon emission factors
Road <i>Fuel consumption in road transport emissions</i>	For each vehicle type: carbon emissions = change in total vehicle kilometers travelled in each year x emission factor (year, petrol/diesel/electric split/vehicle speed)	Total vehicle kilometers travelled, year, proportion of petrol, diesel and electric vehicles, vehicle speed, projected carbon emission factors
Air <i>Fuel consumption in air passenger travel</i>	Carbon emissions = total daily aviation passengers x average per passenger emission factor	Total aviation passengers, projected carbon emission factors

CO<sub>2</sub> = carbon dioxide, kg = kilogram, km = kilometer, kWh = kilowatt-hour.

# Annex 3: Representative Carbon Emission Factors of Construction and Rolling Stock Material

**Table 4: Representative Carbon Emission Factors of Construction and Rolling Stock Material**

Material	Unit	Emission Factor (kg CO <sub>2</sub> per unit)	Detail	Source
Concrete	kg	0.110	Concrete, normal, at plant/CH U (262.7251 kgCO <sub>2</sub> e/m <sup>3</sup> , density 2380 kg/m <sup>3</sup> )	SimaPro 7.3.3 software
Steel	kg	1.460	Reinforcing steel, at plant/RER U	SimaPro 7.3.3 software
Concrete with reinforcement	kg	0.107	Concrete (reinforced)	SimaPro 7.3.3 software
Aggregates	kg	0.004	Gravel, crushed, at mine/CH U	SimaPro 7.3.3 software
Cement	kg	0.762	Cement, unspecified, at plant/CH U	SimaPro 7.3.3 software
Cement mortar (grout)	kg	0.190	Cement mortar, at plant/CH U	SimaPro 7.3.3 software
Asphalt	kg	0.066	Hot rolled asphalt, asphalt, 4% bitumen binder content (by mass) data – 1.68MJ/kg feedstock energy (included)	University of Bath 2011
Sand	kg	0.002	Sand, at mine/CH U	University of Bath 2011
Aluminum	kg	9.160	General aluminum – typical (assumed a UK ratio of 25.6% extrusions, 55% rolled, 18.7% castings, and a worldwide recycled content of 33%)	University of Bath 2011
Steel (rolling stock)	kg	1.950	General steel – world typical, worldwide 39% recycled content	University of Bath 2011
Copper	kg	2.170	Tube and sheet – typical, EU production data, estimated from Kupfer Institut LCI data, 37% recycled content (the 3-year world average)	University of Bath 2011
Iron	kg	2.030	(Virgin) Iron, statistical average	University of Bath 2011

CO<sub>2</sub> = carbon dioxide, CH = Switzerland, EU = European Union, J = joules, kg = kilogram, LCI = life-cycle inventory, m<sup>3</sup> = cubic meter, RER = Europe, U = unit, UK = United Kingdom.

## **Guidelines for Estimating Greenhouse Gas Emissions of Asian Development Bank Projects**

### *Additional Guidance for Transport Projects*

Transport contributes almost a quarter of global energy-related carbon dioxide emissions, mostly coming from developed countries. However, vehicle emissions in developing countries are also growing due to rapid motorization. This publication provides Asian Development Bank transport sector staff, consultants, and other interested readers with an understanding of key concepts and principles in measuring climate change impacts of transport projects. Guidelines herein focus on greenhouse gas emissions as part of climate change mitigation and include a practical set of methods in measuring emissions of different transport subsectors.

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