Guidelines for Developing Emission Inventory in East Asia

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Study Committee for
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Emission Inventory in East Asia

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Introduction

In East Asian region, the rapid economic growth is causing emission increase of substances responsible for acid rain such as sulfur dioxide (SO_2) and nitrogen oxide (NOx), and volatile organic compounds (VOC), leading to concerns of its environmental impact. Also tropospheric ozone has attracted attention as long range trans-boundary air pollutant, and there has been reports on its density increase, effects on plants, and its reaction with VOC in the air which react to form photochemical oxidants.

This serious condition of air pollution following economic growth will interfere with the continuous development of East Asian countries. This condition will effect to increase the background level of long range trans-boundary air pollution on Japan as well as on a global scale. In addition, the large scale emission source is also a cause of large amount of greenhouse gases.

However, in East Asian region, the organization of basic information necessary to manage atmospheric environment, is insufficient. In relation to this, it is difficult to formulate effective anti-pollutant measure based on scientific knowledge, including knowledge of reduction of anti-pollutant measure to its goal, reduction potential and methods of countermeasures.

The theory used to create emission inventory of air pollutant, has been established in Europe and USA under the framework of Convention on Long-Range Transboundary Air Pollution (CLRTAP). This method is used in south Asian, south African and other developing countries, and discussion is undergoing for air pollutant transportation across half the globe using this inventory and atmospheric transport models.

On the other hand, in east Asian region, a few emission inventory survey have been conducted. However, it is still difficult to establish a system to formulate transparent and comparable emission inventory which the governments in each east Asian country are agreeable.

Therefore, in the Ministry of the Environment in Japan, a review has been considered on making an Emission Inventory Policy-making Guidebook for East Asia, through emission inventory policy-making assistance in Vietnam from 2009.

This Guidebook is expected to be used for preparation of detailed and reliable emission inventory in East Asia, and is expected to be used to establish strategy for anti-pollution measures in specific location, country or in East Asia.

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1 Introduction

1.1 Emission inventory

Emission Inventory is the record that shows the amount of air pollutant discharged within a specific period of time and location of the emission source. It is an indispensable tool widely used when making policy in anti-pollution measures.

The objective of emission inventory use is as follows[1]

1) Knowing the actual emission volume

The quantitative emission estimates provided by an inventory promote a better understanding of the actual emissions and help to raise awareness of both policy makers and the general public. Through this process, the major emission sources can be identified, and the priorities for emission reduction and any data gaps requiring additional work are revealed.

2) Input to simulation model and its application

Emission data allocated spatially and temporally can be used as input data for atmospheric transport and deposition models. The simulation model is build by comparing and verifying the calculated results and ground monitoring data. By comparing the model's calculated result for future years and current environment standard, it is possible to evaluate effective air pollution policy required to achieve environment standard, and also the effect to human, animal, agricultural product, and natural ecosystem.

3) Forecasting and anti-pollution measure policy

The inventory data is estimated from the active data and emission factor of socio-economic statistics. The future emission is estimated based on forecast of socio-economic indices (for example population growth, economic growth, changes in energy use per activity data) lower emission factors fuel switching and so forth. The estimated future emissions provide important information for setting air pollution prevention plan.

4) Consideration of possible reduction measures

An emission inventory enables easy comparison of emission before and after introduction of control measures as a result of introduction of various prevention technologies. Furthermore by evaluating and comparing the cost of various prevention technologies and the result of emission reduction, prevention technology with higher cost effectiveness can be selected.

1.2 Background and Objectives of "Guidelines for Developing Emission Inventory in East Asia"

1.2.1 Background

East Asia region, whose economy has been rapidly growing, has seen the increase in emissions of air pollutants such as SO2 and NOx, which are also acidifying species, Volatile Organic Compound (VOC), and particulate matters, leading to rising concerns of their environmental impacts as shown in Figure 1.2-1. Also, tropospheric ozone, partly generated through the chemical reaction process involving NOx and VOC, has attracted attention as regional air pollution, and there have been reports on the increase in its concentrations, and effects on plants. Fine particulate matter is another pollutant of concerns in many countries.

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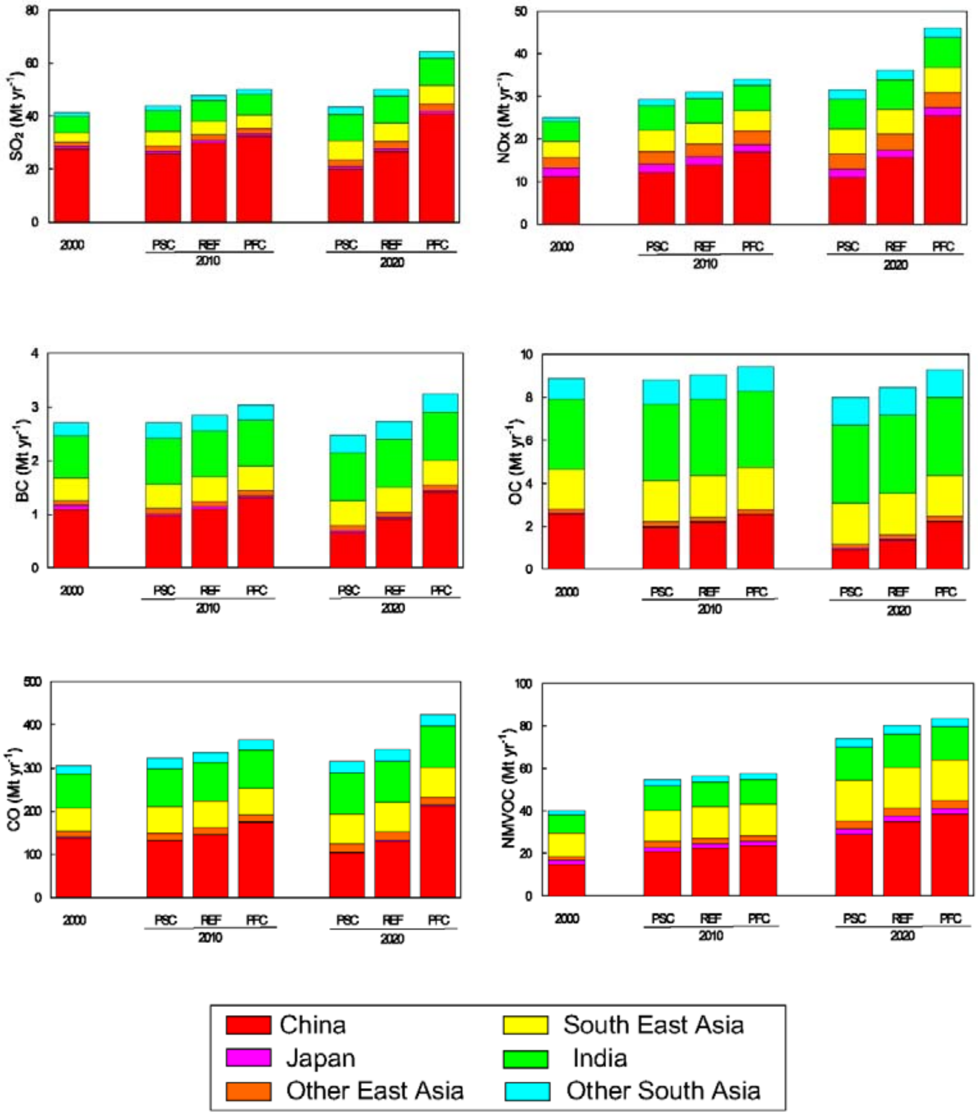
[1] What is emission inventory?, Asia Air Pollution Research Center, http://www.acap.asia/acapjp/doc/emissionjp.pdf

This serious condition of air pollution not only impedes the sustainable development in each country in the East Asia region, but may also affect the air quality of neighboring countries or the background level on a global scale. Large point sources of air pollutants are also large point sources of greenhouse gas.

In order to take science-based effective policy measures against these air pollutants, basic information necessary to assess reduction potentials and control measures and to establish reduction targets should be organized as a starting point. So far, a few sets of emission inventory, including global-scale one, which is one form of such basic information, have been developed in East Asia by respective governments and researchers. However, there were no agreed methodologies of developing emission inventory, which would improve the transparency and comparability of inventory. This guidelines (hereinafter "the Guidelines") are developed with the aim to establish the common methodologies of developing emission inventory.



PSC (Policy Success Case), REF (Reference Case), PFC (Policy Failure Case)

Figure 1.2-1 Emission volume in Asia in year 2000, 2010 and 2020[2]

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[2] T. Ohara, H. Akimoto, J. Kurokawa, N. Horii, K. Yamaji, X. Yan, and T. Hayasaka, An Asian emission inventory of anthropogenic emission sources for the period 1980–2020, Atmos. Chem. Phys., 7, 4419–4444, 2007

1.2.2 Objectives

Effective management of atmospheric environment at regional level is becoming more urgent in East Asia, as shown, among other things, by the increase in tropospheric ozone concentrations. To handle long range transports of air pollutants, analyses based on emission inventory and simulation models are especially critical. Such analyses will be much more simplified and useful, once the methodologies can be standardized across the region. Also through cooperation in preparing emission inventory, national capacity could be developed for the measurement of emission and emission factor as well as application of inventory and models. These can result in contribution to both environmental protection in each country and reduced long range transports of air pollutants.

For better understandings of air pollution in East Asia, and strengthening the capacity of atmospheric environment control in each country, the inventory experts in Japan gathered to make Guidelines for continuous improvement.

Through this East Asian Inventory Guidelines, estimation method of inventory applicable to East Asia will be established. Also based on Guidelines, making high quality emission inventory will contribute to the improvement of higher accuracy of emission inventory.

These guidelines assume to be used by participating countries of East Asia Acid Rain Network (EANET), whom have a goal to prepare emission inventory. The participants of EANET are Cambodia, China, Indonesia, Japan, Laos, Malaysia, Mongolia, Myanmar, Philippines, Korea, Russia, Thailand and Vietnam.

1.3 Position of guidelines

Emission inventory guidelines are compiled based on Global Atmospheric Pollution Forum Air Pollutant Emissions Inventory Manual Version 1.5 (”GAP Forum Manual”). This GAP Forum Manual has its target at developing countries with rapid economic growth, and developing of easy-to-use inventory estimation method.

However, in GAP Forum Manual has barely any explanation on temporal change and spatial distribution, which makes the users difficult to estimate emission by using this manual. Also, sufficient information and conditions of active data and emission factor, suitable for East Asia, are not available, so in current condition, GAP Forum Manual is not useful for East Asia. Therefore, in these guidelines, the items suitable for East Asia are provided. That is, in addition to the contents in GAP Forum Manual, the useful emission estimation method and emission factors are covered for East Asian inventory. For instance, the emission factors in these guidelines are based on GAP Forum Manual, nonetheless, for emission factors and estimation method of pollutants and its sectors not stated nor described in GAP Forum Manual, they are set by using EMEP/EEA Emission Inventory Guidebook 2009 (“EMEP/EEA Guidebook”), AP-42, Compilation of Air Pollutant Emission Factors (“AP-42”), COPERT and other references of emission factors.

GAP Forum Manual is emission inventory manual compiled by Global Air Pollution Forum setup by Stockholm Environmental Institute (SEI), located at York University. EMEP/EEA Guidebook is an emission estimation guideline with its target at human sources and natural sources in Europe. AP-42 is emission factor data of EPA of USA. COPERT is European automobile emission factor estimation model developed based on EMEP/EEA Guidebook.

The target year in these guidelines is current year. However, the estimations of inventory of future years are useful for setting air pollution prevention policy using the future prediction of socio-economic statistics and emission factors. Therefore, for the future analysis, the possible estimation methods of the target sectors are summarized and explained clearly.

2 Basic policy in estimating emission inventory of air pollutants

2.1 Emission estimation method

In general, emissions of air pollutants are estimated by the following basic formula for each source category, when it is difficult to measure them directly. Details of emission estimation method are explained in each sector.

Emission = Emission Factor × Active Data

Example

- SOx emission per the amount of fuel burnt, calculated based on sulfur content of fuel, the sufur retained in the ash and the reduction achieved by emission control technology (fuel combustion)
- NOx emission per distance (exhaust gas emission from vehicles)
- SOx emission per the amount of copper smelted (copper smelting)

- The amount of fuel burnt (fuel combustion)
- The distance of vehicle travelled (exhsut gas emissions from vehicles)
- The rates of the production of the commodity (industrial process without combustion)

2.1.1 Emission factor

Emission factors are the average rate of emission of a pollutant per unit of activity data for a given category. When there is no emission factor reflecting the actual local situation, default values in manuals can be used.

However, if the default factor is considered to be inappropriate, it is preferable to obtain an emission factor that reflects the real situation by direct measurement etc.

The reduction level and the deployment rate of technical measures have to be reflected in the emission factor or the formula, as introduction of countermeasures reduces the emission.

In these Guidelines, the values from “GAP Forum Manual”, “EMEP/EEA Guidebook”, “USEPA AP-42”, “COPPERT” and so on, are cited for emission factors, such as the default values or the values specified by control technology, etc.

2.1.2 Activity data

Activity data indicates the extent of activity causing emissions. Required data can be basically collected from statistics and surveys. Within these Guidelines, the statistics data of a targeted country have given first priority. If no data exists in the country, then use international statistical data in principle.

2.1.3 Sectors and categories

The Guidelines are described corresponding to each sector shown below. Each sector (e.g. Industrial Process) comprises individual categories (e.g. Mineral Products) and sub-categories (e.g. Cement Industry). Final product of inventory would be built up from the sub-categories, because accurate estimates can only be made at this level and because this detail information makes inventory more useful to policymakers.

2.2 Emission estimation method according to intended use of inventory

2.2.1 Emission estimation method

Emission estimation method can be simple or detailed. The basic policy of estimation method is as follows.

2.2.1.1 Simple method

Simple method is a method that estimated emission by multiplying the Active Data (amount of fuel used) of sub-category for the country and the representable average Emission Factor. Simple method is a top-down method, and used to find the rough estimation of emission. Spatial distribution is the smallest unit of Active Data obtained as statistic data at national or provincial level. Temporal Change is the emission distributed over a period of time, using data which indicates the active data over a period of time of the emission source to be estimated. The details of index on spatial distribution and temporal change are described in each chapter.

2.2.1.2 Detailed method

Detailed method is emission estimation method other than simple method. It has bottom-up method which estimates by accumulating information of each source; and also has top-down method which estimates with more detailed spatial distribution and accuracy improvement of Emission and Temporal Change. The details in estimation method are described in each chapter.

2.2.2 Selection of inventory estimation method according to its intended use

Emission Inventory can be classified into inventory by country or by region, simulation inventory, and technology-based inventory. Depending on inventory, the accuracy, spatial distribution, temporal change may vary. Therefore, to enable the user of this guideline to measure the emission according to the purpose of use of the emission inventory, the application method of the simple method (inventory by country and by region) or the detailed method (technology-based inventory, simulation inventory) is described below.

2.2.2.1 Inventory by country/region

The objective of inventory by country/region is to find out annual total air pollutant emission by country/region as the basic data for air pollution prevention policy. Therefore, it estimates emission, using simple method. The Temporal change is not set essentially, as its aim is to estimates total annual emission. In case of estimating emission by region in spatial distribution, the emission will be by sections of statistic data.

2.2.2.2 Technology-based inventory

The objective of technology-based emission inventory is to compare the technological effect on emission before and after measures. Therefore, emission inventory that reflects emission or abatement efficiency before and after the measure had been taken is estimated, when considering to change certain non-measured facilities to technically measured facilities; or when considering to use a different production process..

2.2.2.3 Simulation inventory

In emission inventory that becomes the input data for simulation model, spatial distribution or temporal change corresponding to calculation area and resolution, is important, to enable the model estimated air pollution concentration to represent actual value of atmospheric environment, Therefore, when conducting simulation, there is detailed method in the sector to calculate, and the statistical data required in detailed method is available; or when survey/measurements are applicable, it is preferable to estimate emission using detailed method as reference. Nonetheless, in case of the following conditions, emission can be estimated by using simple method as reference.

- Sub-category with the only available method is simple method
- Sub-category with detailed method data not available
- Sub-total of the sector emission is relatively small, compared to the total emission of the entire estimated inventory. Judgement of “small” depends on the inventory compiled person, but in this guideline, it is “small” when compared rate is less than 5%.
- When highly accurate emission inventory is not required as input data for model.

In sectors where temporal change setting is possible, the actual emission condition of source should be identified as much as possible to set the temporal change. In spatial distribution, set detailed spatial distribution with target on the large emission source, such as stationary sources, mobile sources, and industrial processes, as point/line source data.

2.2.3 Selection of inventory estimation method

Emission estimation method for the objective of inventory is shown in Table 2.2-1.

Table 2.2-1 Selection of emission estimation method that suits the objectives of inventory use

Source type	Country/region	Technology-based	Simulation
Stationary source (Chapter 3.2)	Simple method (3.2.1)	Detailed method (policy, 3.2.2)	Basically Detailed method is used (3.3.2.1-2, 3.3.3.2, 3.3.4.2, 3.3.5.2, 4.2.2, 4.3.2, 5.2.2, 5.3.2, 5.4.2, 5.5.2, 6.3, 7.2.2, 7.3.2, 7.4.2, 7.5.2, 8.2, 9.2.2, 9.3.2, 9.4.2, 9.5.2, 9.6.2) However, depending on sector, simple method may also be used as reference in estimating emission.
Mobile source (Chapter 3.3)	Simple method (3.3.2.1-1, 3.3.2.2, 3.3.3.1, 3.3.4.1, 3.3.5.1)	Detailed method (policy, 3.3.2.1-2, 3.3.3.2, 3.3.4.2, 3.3.5.2)	
Fossil fuel leakage (Chapter 4)	Simple method (4.2.1, 4.3.1)		
Industrial process (Chapter 5)	Simple method (5.2.1, 5.3.1, 5.4.1, 5.5.1)	Detailed method (policy, 5.2.2, 5.3.2, 5.4.2, 5.5.2)	
Solvent and other product usage (Chapter 6)	Simple method (6.2)		
Agricultural activities (Chapter 7)	Simple method (7.2.1, 7.3.1, 7.4.1, 7.5.1)		
Forest fire (Chapter 8)	Simple method (8.1)		
Waste treatment (Chapter 9)	Simple method (9.2.1, 9.3.1, 9.4.1, 9.5.1, 9.6.1)		
Natural source (Chapter 10)	Simple method (10.1, 10.2, 10.3)		

2.3 Pollutants

Pollutants targeted are SOx, NOx, CO, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC (Black Carbon), OC (Organic Carbon), and green house gas ("GHG"): CO_2, CH_4, and N_2O.

In GHG emission estimation, from the point of view of co-benefit evaluation, the emission is calculated by using the same method as SOx, NOx, CO, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, and OC of air pollutant. It is possible to evaluate quantitatively, by using the same method, the effect on the level of GHG reduction due to anti-pollution measures.

For the sub-category, emission is estimated for SOx, NOx, CO, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, and OC, and for the sub-category of GHG emission only, estimation is not a target for estimation.

2.3.1 SOx

As a result of fossil fuel burning, sulfur content in the fuel is oxidized, and the majority becomes SO_2, and partly SO_3. The combination of SO_2 and SO_3 is called Sulfur Oxide (SOx). However, SOx contains little SO_3, so instead, it will be expressed as SO_2 molecular weight, and often called SO_2 in convenience. SOx is also the precursor for aerosol.

The main human-causing source of SOx is sulfur content in coal and crude oil combustion. In industrial process, such as metal refining, crude oil refining, and sulfuric acid production, large amount of SOx is emitted. On a global scale, coal combustion at power plant is largest human-causing source of SOx, and activity of volcano is the largest natural source.[3]。

2.3.2 NOx

For air pollution prevention, NOx is an important air pollutant. Nitrogen monoxide (NO) and nitrogen dioxide (NO_2) are referred to as NOx. NOx is formed by NO emitted in high-temperature combustion process, and the emitted NO reacting with oxygen to become NO_2. This reaction does not occur immediately, so NO and NO_2 co-exist in the air. The main sources are extensive, such as cars, boilers, industrial plants, households and others. NOx reacts with hydrocarbon due to ultraviolet rays to react photochemically and produces ozone and other photochemical oxidants.

SOx and NOx are the main air pollutants causing acid rain. SOx and NOx emitted from cars, power plants, boilers and other sources, which react to form sulfuric acid and nitric acid in the air, and they are transported or deposited through wet and dry process which causes trans-boundary problems.

2.3.3 CO

Carbon monoxide (CO) is the most widespread, and exists generally as one of air pollutants. CO is an air pollutant which is formed from incomplete combustion of carbon contained matters, and the largest source is cars. Some CO is also emitted from industrial process of aluminum and steel production. The natural sources of CO are volcanic eruption, photochemical reactions of VOC, chlorophyll degradation, forest fire, marine microbiological effect, and so forth.

Health effects of CO is also concerning. The CO inhaled is absorbed in the lungs and combine with hemoglobin (Hb) in the blood to become carboxyhemoglobin (COHb). The main toxics of CO cause oxygen-deficiency in animals.

Environment impact of carbon monoxide emitted from cars and motorbikes in cities are in concern. CO concentration in air is from several ppm to 50 to 60ppb, depending on weather and traffic condition. CO mainly contributes to the localized air pollution, but it also involved in the formation of tropospheric ozone, so it is now a major research theme.

2.3.4 NMVOC

Volatile Organic Compound (VOC) refers to organic air pollutants which is volatile in the atmosphere. VOC includes toluene, xylene, ethyl acetate, benzene, formaldehyde and so forth that comprises hundreds of type. Methane (CH_4), one of the matters of VOC, is suspended in the air for a long time, and is one of the major matters to contribute to green house gas (GHG), and has relatively small in reaction compared to other VOCs. Therefore $CH_4$is excluded from GHG matters, and treated as NMVOC.

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[3] Kentaro Murano: Trans-boundary pollution comparative test from Asia mainland to Japan - tracing technology for environmental circulation diagnostics - University of Tsukuba Terrestrial Environment Research Center, Electronic Monograph No.2 http://www.suiri.tsukuba.ac.jp/pdf_papers/terc_em02/terc_em02_10.pdf

NMVOC, together with NOx and CO, are the main air pollutants that generate photo-chemical oxidant. NMVOC travels over a long distance, so photo-chemical oxidant became one of the big concerned also in East Asia[4].

The main sources of NMVOC are paints, inks, organic solvents used in adhesives, biomass burning of crude oil, chemical industries, cars, households, and so forth. Natural source is mainly NMVOC emission of plants.

2.3.5 NH_3

Ammonia (NH_3) contributes largely to aerosol production and soil oxidization, so it is important to estimate emission of ammonia. Compared to SO_2 and NOx, the research in NH_3 in the air is not progressing. In Europe, it was found that about 70% of acid deposition is neutralized by NH_3. NH_3 is alkaline component which neutralizes the acid in rain, but if ammonium ion accumulates in ecological system, it may become nitrate in nitrogen circulation and oxidize. Oxidization may also occur when nitrate ion is penetrated from soil. Therefore, even if acid buffer is provided in the neighborhood of ammonia emission, NH_3 deposition has oxidation power, so ammonia, together with nitrate and sulfuric acid, has been a component of acidic deposition. NH_3 is also a precursor to aerosol.

The main sources of NH_3 are derived from agriculture activities such as management system of livestock manures and fertilization. The effect of catalysts used in cars are also in concern; and there is also an information on large emission of NH_3 from soil and biomass combustion.

2.3.6 PM (TSP, PM_{10}, $PM_{2.5}$, BC, OC)

Particulate Matter (PM) is a collection of fine solid and liquid particles. Particles vary in sizes, chemical composition and property, according to their sources. Besides natural sources such as pollen, sea salt particles, soil dust, volcanic activities, particles are emitted from human activities such as fine particles from smoke, fly-ash and ferric oxides.

“Primary particles” refer to particles emitted to the air directly from sources such as fuel combustion and burning other materials, physical destruction of goods and flying particles. “Secondary particles” refer to gaseous matter such as SO_2, NH_3 involved in chemical and physical reactions. The main sources of primary particles are smokes from factories/facilities, dusts, dust from small scale source like households, and diesel particles from cars, vessels and so on, sea salt particles, soil particles and so forth. For secondary particles, it may be formed gases emitted from human or natural source. This guideline concerns only on primary particles.

PM is divided, according to the sizes of particles as follows.

- TSP is the total suspended particles in the air (about 45µm and less).
- PM_{10} is atmospheric TSP with particle size of 10µm C50%.
- $PM_{2.5}$ is atmospheric TSP with particle size of 2.5µm V 50%.

Coarse particle with diameter more than 10µm tends to fall in the neighborhood of the source, which tend to cause local concerns. PM_{10} has particles with smaller diameter, and its suspension time in the air is longer than the larger particles, and can travel quite far. PM_{10} can penetrate deep into the lungs, causing serious health effect. $PM_{2.5}$ causes even more adverse effect than PM_{10}. In this guideline, both PM_{10} and $PM_{2.5}$ are estimated.

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[4] T. Ohara: East Asia wide area trans-boundary air pollution and its effect to Japan - The 33rd Environmental Pollution Research Joint Presentations

Black Carbon (BC) is formed directly from biomass and fossil fuel combustion, and is the element that absorbs solar radiation exceptionally, among the aerosols in the air. Therefore, it is the material that has GHG effect.

Organic Carbon (OC) contains primary and secondary particles. Particle (primary) is formed from direct emission of sources as a result of biomass and fossil fuel combustion. Particles (secondary particles) is formed from VOC like organic solvent becoming particles in the air, however the source is almost unknown.

TSP (suspended particles) is not included in GAP Forum Manual. In East Asia, the environment is unlike Europe, there are many countries that depend on fuel and coal, and it is common to have air pollution concerns like fly-ash and bottom-ash. Also, TSP is important in terms of air pollution control in East Asia, so it is included in this guideline.

The chemical composition of PM is different according to particles. $PM_{0.1}$ has sulfur acid particles and carbon particles (especially OC) as main contents; whereas $PM_{2.5}$ contains OC, Elemental Carbon (EC), sulfate (SO_4^{2-}), nitrate (NO_3^-), ammonium salt (NH_4^+), chloride (Cl^-) and other inorganic chloride, Cadmium (Cd), Arsenic (As) and traces of metal compounds. For larger particles like $PM_{2.5}$ and PM_{10}, in addition to sea salt particles represented by sodium chloride, there are many soil particles, and aluminum (Al), Silica (Si), Calcium (Ca), Titanium (Ti), steel (Fe) and other metal components are the main elements[5].

2.3.7 CO_2, CH_4, N_2O

Carbon dioxide (CO_2) is the main material that causes of global warming, and mainly emitted from burning of fossil fuels. Sources other than fossil fuel are industrial process such as cement manufacturing, waste incineration, and leakage from fuel.

Methane (CH_4) is formed from incomplete burning of fuel or waste, leakage from fossil fuel during mining and agricultural or waste burial, sewage treatment and other organic separation.

Nitrogen monoxide (N_2O) is formed from chemical industry that uses fuel burning or nitric acid or adipic acid, and agriculture, or waste incineration.

2.4 Sectors

The sectors involved are fuel consumption (stationary source, and mobile source), leakage from fossil combustion, industrial process and solvent and other products, agricultural activities, forest fire, waste treatment and natural source.

2.4.1 Fuel consumption

Sector relating to fuel consumption activity consists of two categories, stationary and mobile sources. The emission estimation method is described below.

2.4.1.1 Stationary source

Stationary source refers to energy industry, manufacturing industry, construction industry, and fuel consumption in other sub-categories (such as commercial/facility, residential houses and agriculture/forestry/fishery).

2.4.1.2 Mobile source

Mobile source refers to cars, aircrafts, vessels, and railroad fuel consumption.

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[5] Sekiguchi Kazuhiko: $PM_{2.5}$ - Course No.1 - $PM_{2.5}$ features, Air Environment Study Society Magazine 2010, 4 , A54 - A60

2.4.2 Fossil fuel leakage

Leakage from fossil fuel refers to non-burning activities such as fossil fuel extraction, processing, storage, transportation, and its usage.

2.4.3 Industrial process

Industrial process refers to chemical industry, steel industry, pulp and paper industry, drinks/foods products industry; and includes the emission from usage of coal and cokes as raw materials. In stationary source, in order to treat emission from fuel consumption, emission from combustion in industrial process is not included.

2.4.4 Solvent and other products use

Solvent and other products refer to “usage of painting, adhesives, and glue”, “dry-cleaning”, “specific chemical product manufacturing” categories.

2.4.5 Agricultural activities

Agricultural activities refer to livestock breeding, savanna fires (both intentional and accidental fires), burning of agricultural carcass, fertilizer usage categories.

2.4.6 Forest fire

Forest fire refers to forest and natural grassland (except savanna). The forest fire is caused by either human or natural.

2.4.7 Waste treatment

Waste treatment refers to general waste, industrial waste, and toxic waste (medical waste) incinerated emissions. Waste incineration and open burning are the main sub-categories. In East Asia, open burning and small scale incineration are used in general waste treatment.

2.4.8 Natural sources

In GAP Forum Manual, natural sources are not included in the sector, but large emission exists compared to other sectors. Therefore, in this guideline, the emission estimation method is explained for the sources expected with large emission, such as NMVOC from plant, SOx from volcanic activity, NOx and NH_3 from soil.

2.5 Temporal change and spatial distribution

In air pollution inventory, not only annual total emission data, temporal change and spatial distribution are also important indices. The settings of inventory temporal change and spatial distribution are as follows.

2.5.1 Temporal change

For reviewing air pollution policy or setting input data of simulation model, use the temporal change distribution index by source area as shown in Table 2.5-1, when setting the temporal change of total emission of a country/area. Also according to actual emission condition of the source, set the emission hours like season, month, week, day of the week, daytime or nighttime. However, in the detailed method of plant/facilities (fuel consumption of stationary source, industrial process, and large scale waste incinerator) and fuel consumption of mobile source, collect information of each source individually by questionnaire survey, interview survey and traffic volume survey. Then set temporal change from operation hours of stationary sources and hourly traffic volume. Therefore, details of setting method of temporal change are explained in Chapter 3.

Table 2.5-1 Temporal change distribution index and distribution method

Generating source	Distribution index	Distribution method
Stationary source (from fuel consumption, Simple method)	Operating time of plant/facility Fuel consumption trend of plant/power plant/temporary facility	・24 hours Air pollutant emitted from plant changes according to operating time. Emission from power plant depends on demands in lighting and air-conditioner. Emission from fuel consumed by cooking changed depending on meal time. ・Day of the week Set by the trend in fuel consumption of plant/power plant/household on weekends and weekdays.. ・Season The usage of air conditioner changes according to temperature change and seasons (spring/summer/autumn/winter, wet/dry season), so the air pollutant emission from air conditioner and power plant also changes. Time of fuel used is different for countries/areas because they have different standard time and settings/no-settings of summer time. Also, long holiday and Muslim fasting also cause temporal change.
Mobile source (from fuel consumption, Simple method)	Traffic volume survey result	・Cars Set temporal change based on traffic volume by car type and time. ・Aircrafts Set based on changes in typical passenger boarding time and load time. ・Vessels Set based on changes in typical passenger boarding time and loading time ・Railroads Set based on changes in typical passenger boarding time and loading time
Fossil fuel leakage	Statistics, existing data and survey data Operating time of plant/facility	For each activity, if the operating (activity) time is identifiable using statistics, existing data and survey data of each activity, and also assumed the emission only occur during operation time, then the emission is distributed along the time according to the operation time . If the activity data can not be identified by method above, use the average emission. In other words, divide annual emission so pollution is emitted equally for 24 hours a day for 1 year..

Industrial process	Operating time of plant/facility	In large plant/facility the temporal change is set based on the operation pattern by time. For instance, the operating time pattern of the plant by detailed industry classification is calculated based on plant questionnaire survey or interviews for mining products, chemical industry or metal products,. The obtained time pattern will be applied to the industrial process of the plant. If these data are not available, survey the practice particular to the country to determine the time of operating pattern of the plant, such as 24-hour non-stop operation or batch operation from 8am to 6pm. Also, if the operating time pattern particular to the country is not available, use the ordinary daytime working hours.
Solvent and other products	Operating time of plant/facility	If the time operating pattern of large plant/facility is available, use the pattern to set temporal change. Otherwise, survey the practice particular to the country to determine the time of operating pattern of the plant, such as 24-hour non-stop operation or batch operation from 8am to 6pm. Also, if the operating time pattern particular to the country is not available, use the ordinary daytime working hours.
Agricultural activities (livestock)	Livestock quantity	If the quantity of livestock is identified for time span of less than 1 year, the emission is distributed evenly based on the temporal change. In such case, attention is required to calculate annual emission from emission factor and activity data of time span less than 1 year.
Agricultural activities (fertilizer)	Fertilizer quantity	The emission is distributed evenly hourly for 1 year. If fertilizer quantity is identified for time span of less than 1 year, the emission is distributed evenly based on the temporal change.
Agricultural activities (savanna burning)	Local survey (existing document study, interview survey with relevant ministries, bureaus)	Apply local survey to identify the temporal change of savanna burning. Local survey is assumed to be existing document study, interview survey with relevant ministries, bureaus. If they cannot be identified by local survey, set the temporal change as follows: If only the savanna burning area for 1 specific year is available, distribute the emission evenly for 1 year, which means 24 hours/day, and 365 days/year. If the savanna burning area is identified by month, or season, or day, distribute the emission over each hour of the identified month.
Agricultural activities (agricultural carcass burning)	Interview survey	Basically, burning of agricultural carcass occurs after the harvest, so interview the harvest time, and distributes the emission evenly for the period of harvest accordingly.

Forest fire	Forest fire area	If the forest fire area by year, or month and time is identified, the emission is distributed evenly over year, or month and time. If monthly area is identified, the emission is distributed evenly over each hour of the month.
Waste treatment	Incinerator furnace operating time	Waste incinerator furnace: If the time operating pattern is identified, use the time pattern for the waste incinerator furnace; otherwise, survey the practice particular of the country, such as 24-hour non-stop operation or batch operation from 8am to 6pm, and set accordingly. Open burning: If existing survey result is available, use the time pattern; otherwise, assume that burning is carried out during daytime hours which average peoples are working, for instance for 12 hours, from 6am to 6pm, to set the distribution . NH_3 emission from non-water washed toilet in the open air: Assume that the NH_3 is emitted while assuming the urine is gradually reacting and so evenly distribute for 24 hours.
Plant (NMVOC)	Sunlight volume	Set the temporal change based on temperature / solar radiation data by month and by time.
Volcano (SOx)	Smithsonian database	Set the temporal change based on volcano's longitude / latitude and eruption starting/ending time.
Soil (NH_3,NOx)	Soil/water ratio, soil temperature	Controlled based on soil/water ratio and temporal change of soil temperature.

2.5.2 Spatial distribution

Considering air pollution policy or input data of simulation model, and when setting the more detailed spatial distribution of a country/area based emission, use the spatial distribution index by source shown in Table 2.5-2. However, in the detailed method of stationary source, industrial process, and waste incineration which are relating to fuel consumption, information of each source is collected separately by questionnaire survey, interview survey and set as point source of the inventory. Also, for details of mobile source, collect each emission data from traffic volume survey and set as line source of the inventory. Therefore, the details of setting spatial distribution are description in Chapter 3.

Table 2.5-2 Spatial distribution index

Generating source	Distribution index	Distribution method
Stationary source (derive from fuel consumption, Simple method)	GDP, temperature, number of facility, agricultural production volume, fuel sales	Set spatial distribution based on available statistics, and fuel consumption data
Mobile source (derive from fuel consumption, Simple method)	Fuel consumption	・Car Distribution based on fuel consumption of car by region ・Aircraft Emission from aircraft parking place, apron, runway and flight paths are considered. Set parking lot as a stationary source, and apron and runway as line sources, whereas flight path as both point and line source ・Vessel Spatial distribution is based on total vessel weight (ton) by each port against the total vessel weight of the entire country. ・Railroad Spatial distribution is based on transportation statistics of rail line of the entire country.
Fossil fuel leakage	Production location; production volume by each administrative region	・Fossil fuel production, refining Distribution based on each production facility (coal mining, oil field, and gas field) location ・Cokes production, refinery Distributed based on plant / facility location ・Gasoline product delivery Car (mobile source) distribution index or gasoline total sales of each administrative region as the distribution index
Industrial process	Plant/facility number, population and city area by industry type (mining product, chemical industry, metal products or more detailed classification)	Set the spatial distribution as point source for facility that can be identified by questionnaire survey or interviews of plant/facility. For other emission, use distribution index of area source to set spatial distribution.
Solvent and other products	City area by administrative region or	Use distribution index to set spatial distribution

	by mesh, population, and plant/facility number by industry type. Construction coating: City area by administrative region or mesh, Plant/facility numbers by industry type. Industrial product coating , metal surface treatment, chemical product manufacturing	
Agricultural activities (livestock)	Livestock numbers statistics by region (province, city, village)	Use distribution index to set spatial distribution
Agricultural activities (fertilizer)	Agricultural land	Set spatial distribution based on existing survey, other data, and interviews with related bureaus; otherwise, set as follows: - If fertilizer volume for the entire country can be identified, use one of the following two methods to calculate spatial distribution. Also, the agricultural area that can be used as distribution index will be the sum of the agricultural land by mesh. In addition, if fertilizer volume by crop can be identified, the agricultural area of corresponding crop will be used as distribution index, and air pollutant emission from fertilizer by crop will be distributed evenly. If fertilizer volume can be identified for detailed area than province or country, use one of the following two methods to calculate spatial distribution. Also, if fertilizer volume by crop can be identified, the agricultural area of corresponding crop will be used as distribution index, and air pollutant emission from fertilizer by crop will be distributed evenly. Air pollutant emission from fertilizer by province/ county will be distributed evenly, according to total agricultural area by mesh, not based on crops of each province/county. If agricultural data, more detailed than province/ county can be identified (such as city and districts), the agricultural area will be used as distribution index to distribute the air pollutant emission from fertilizer.
Agricultural activities (savanna	Existing survey result, burnt area of the entire country	Collect existing survey data and conduct interviews with local authorities regarding the spatial distribution of savanna burning. If the data is not available, set as follows:

burning)		If only the savanna burning area of the entire country is available, use one of the following two methods to calculate spatial distribution. Use mesh-based savanna area as distribution index to distribute air pollutant emission equally, which is caused by savanna burning. Use savanna area data more detailed than provincial/county and national level as distribution index to distribute air pollutant emission equally, which is caused by savanna burning. If more detailed savanna area than provincial/county and national level is available, use one of the following two methods to calculate spatial distribution. Equally distribute the air pollutant emission in provincial/county, in accordance with each mesh of savanna area by each province. If savanna area data more detailed than province level is available (such as city/district), use the detailed savanna area as distribution index to equally distribute the air pollutant emission caused by savanna burning.
Agricultural activities (agricultural carcass burning)	Production volume by crop for the entire country or each province	Use crop type and production volume of the entire country or each province to distribute the air pollutant emission from agricultural land.
Forest fire	Forest fire area	Use mesh-based forest area as distribution index to distribute forest fire area in the entire country. Use forest area more detailed than provincial/county as distribution index to distribute forest fire area. If forest fire area more detailed than provincial/county and national level is available, use one of the following two methods to calculate spatial distribution. Use mesh-based forest area as distribution index to distribute forest fire area of each province. If more detailed forest area such as of administrative region, which is more detailed than provincial/county and national level, is available, use the detailed forest area to distribute forest fire area.
Waste treatment	Population distribution or city area	・Waste incineration furnace Set the spatial distribution as point source for facility that can be identified through plant/facility questionnaire survey or interviews. For other waste incineration furnaces, use area source as

		index to distribute emission. However, it is unlikely to set waste incineration furnace in population concentrated area, so pay special attention to distribution index. ・Open burning Spatial distribution is based on population distribution. ・Emission of NH_3 from non-flush toilet (that is non-water) For spatial distribution, distribute emission by using population as index of area assumed to have many flush toilet. For instance, in agricultural area, low income residential area, parks and markets, and plant; the non-flushed toilet is assumed to be located in the wild. However, areas with flush toilets are impossible to locate, use population distribution as distribution index instead.
Plant (NMVOC)	Land use, solar radiation and temperature data	Use activity data as index to calculate regional emission.
Volcano (SOx)	Smithsonian database	Set in accordance with longitude / latitude of volcano, and eruption beginning / end time.
Soil (NH_3,NOx)	Land use classification	Distribute based on spatial distribution of soil use classification.

2.6 Correlation with other inventory manual

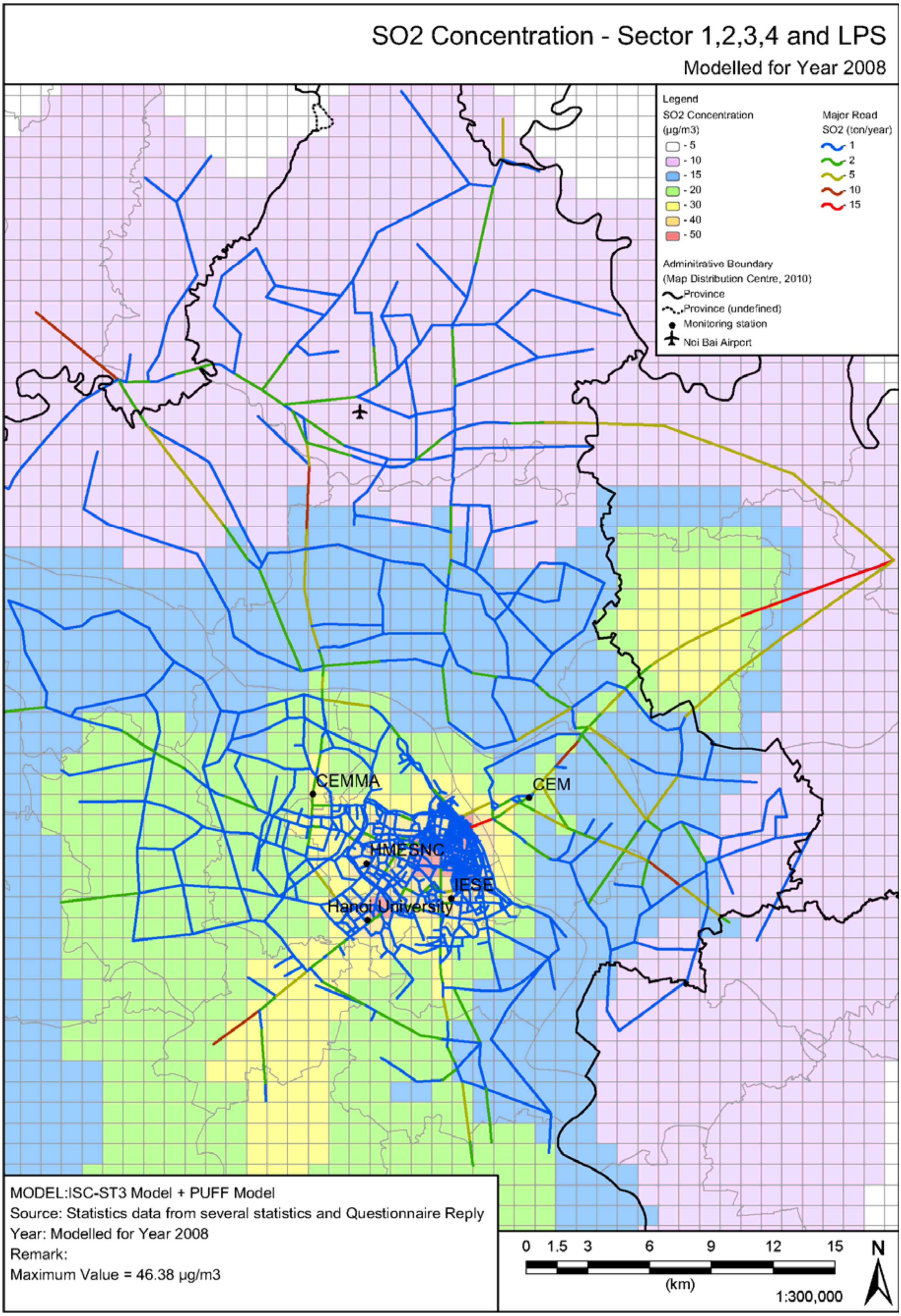
EMEP/EEA Guidebook is a manual to estimate the emission of air pollutants (SO_2, NOx, NMVOC, CH_4, NH_3, and CO) in order to easily report the emission inventory of countries under long range transboundary air pollution convention of United Nation Economic Commission for Europe (UNECE), or under the national upper limit emission command of European Union (EU). Also, as manuals to compile National Greenhouse Gas Inventories, there are IPCC-compiled “Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories” (”1996 IPCC Guidelines”), “Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventory” (GPG 2000), “Good Practice Guidance for Land Use, Land-Use Change and Forestry” (GPG-LULUCF) and “2006 IPCC Guidelines for National Greenhouse Gas Inventories” (“2006 IPCC Guidelines”). These reports are collectively referred to as “IPCC Guidelines”. Currently (March 2011), for countries under United Nations Framework Convention on Climate Change and Kyoto Protocol, the use of 1996 IPCC Guidelines is mandatory for contracting State of the convention. In 1996 IPCC, the method to estimate emission of six types of Greenhouse Gas (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) and ozone and aerosol precursors such as NOx, CO, NMVOC, and SO_2 are indicated. For each year, the emission (without spatial distribution) is estimated at national level using IPCC Guidelines. Whereas, in EMEP/EEA Guidebook, spatial distribution is estimated for emission (point and area source) in the technical base. IPCC Guidelines and EMEP/EEA Guidebook are compiled based on the following basic principles.

1) All human sources are targets (EMEP/EEA Guidebook also involves natural sources)
2) The emission of a country is based on the sum of emission of each emission category.
3) Clearly identifying the differences of energy and non-energy relationship.
4) Transparency and validation of emission factor and active data.

This guideline is based on GAP Forum Manual, which uses the methods in IPCC Guidelines and EMEP/EEA Guidebook. Therefore, this guideline’s emission categories follow IPCC Guidelines.

2.7 Application of guideline

As an example of inventory application, concentrations were calculated through applying estimated result of SOx, NOx emission inventory to a simulation model (US-EPA's ISC-ST3 Model of Plume combined with Puff Model) in 2008, in Hanoi city. The results of SOx, NOx calculation are indicated in Figure 2.7-1 and Figure 2.7-2. The estimated emission inventory and using the simulation model, the effective anti-pollution measures can be considered, which will lower the calculated concentrations to the level below the air quality standards.



SO2 Concentration - Sector 1,2,3,4 and LPS

Modelled for Year 2008

MODEL:ISC-ST3 Model + PUFF Model
Source: Statistics data from several statistics and Questionnaire Reply
Year: Modelled for Year 2008
Remark:
Maximum Value = 46.38 μg/m3

Figure 2.7-1 SOx simulation result

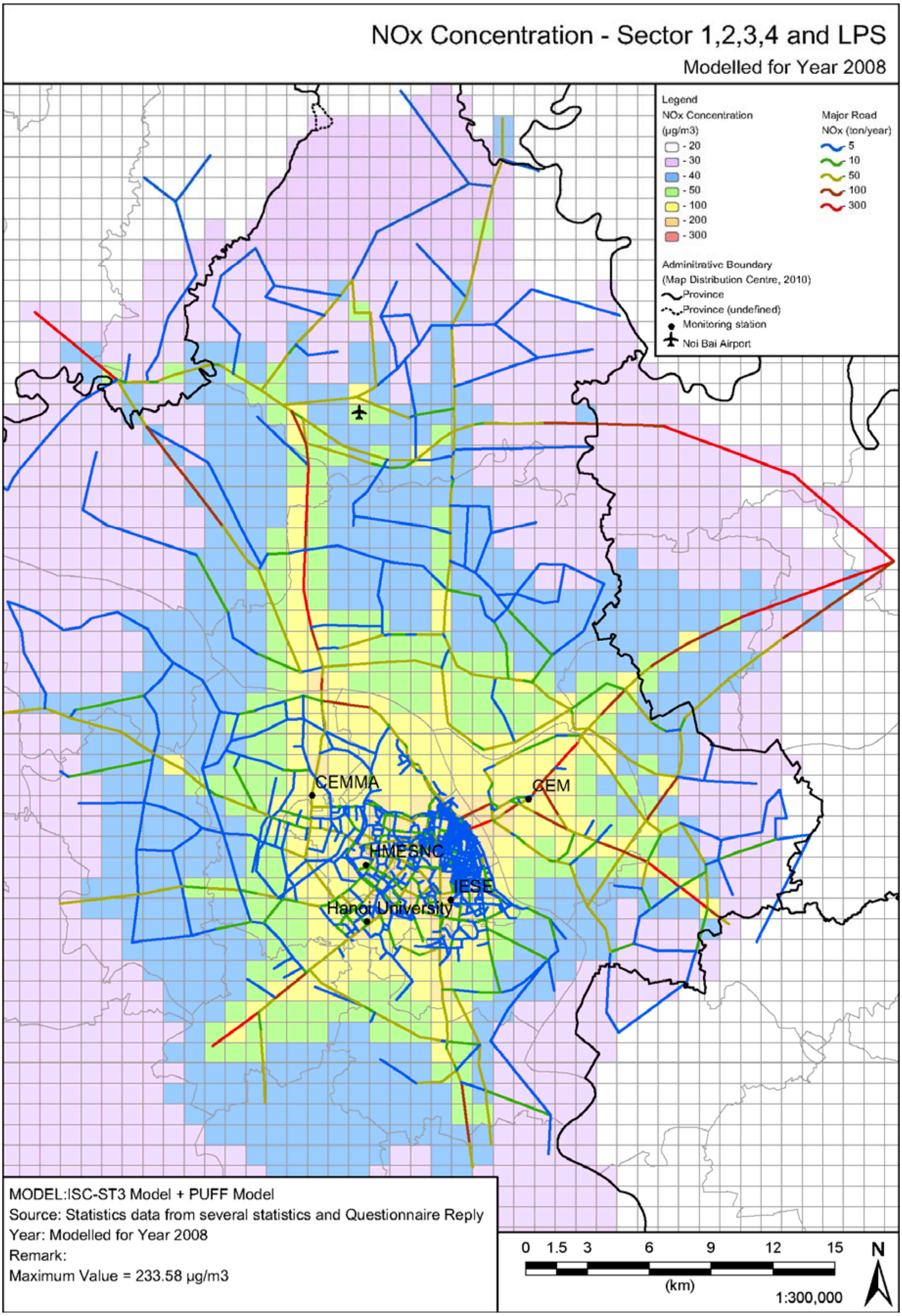


Figure 2.7-2 NOx simulation result

3 Estimating emissions of air pollutants from fuel consumption

3.1 Targets of estimation

“Fuel consumption” sector is classified into stationary source and mobile source. In this guideline, mobile source refers to aviation, road transport, railways, and marine transport - including small boats. Other sources belong to stationary source. Therefore, off-road mobile source often used in manufacturing, construction and agricultural industry is also treated as stationary source.

Table 3.1-1 Fuel consumption sector emission category

Classification	Category	Sub-category
Stationary source	Energy industry	Public electricity and heat production; Petroleum refining; manufacture of solid fuels
	Manufacturing, industries and construction	Iron and steel; non-ferrous metals; chemicals; pulp, paper and print; food processing, beverages and tobacco; other
	Small combustion	Commercial/institutional; residential; agricultural/forestry; and other (stationary combustion)
	Off-road	Mobile combustion in manufacturing industries and construction land-based mobile machinery; commercial and institutional land-based mobile machinery; mobile combustion used in residential areas: household and gardening land-based mobile machinery; off-road vehicles and other machinery used in agriculture/forestry land-based mobile machinery (excluding fishing); other mobile including military land based mobile machinery.
Mobile source	Aviation	International airport traffic (LTO-cycles < 300 ft (914m); domestic airport traffic (LTO-cycles < 300 ft (914m); and except military aircrafts
	Road transport	Passenger cars; light-duty vehicles; heavy-duty vehicles and buses; mopeds and motorcycles; road vehicle tyre and brake wear; road surface wear; gasoline evaporation from vehicles
	Railways	Diesel locomotives (shunting locomotives; rail-cars; line-haul locomotives); steam locomotives
	Navigation	Water-bone navigation; international water-borne navigation; domestic water-borne navigation; fishing; mobile (all remaining water-borne mobile emissions from fuel combustion that are not specified elsewhere); multi-lateral operation (water-borne navigation component)

In manufacturing industries and construction, the combustion facilities are not only the conventional boilers, gas turbines and stationary engines, but also blast furnaces, kilns and other specific facilities. In addition, the emission of air pollutants depends on the fuel types and facilities/technologies. Therefore, as shown in Table 3.1-2, emissions from manufacturing industries and construction are estimated by fuel types and facility types. Emissions from the conventional boilers, gas turbines, stationary engines or other combustion devices are also estimated by the methods of "Energy industries" and "Small combustion".

Table 3.1-2 Calculation type applicable by facility type

Category	Activity	Calculation procedure category
Energy industry	Boilers, gas turbines, fixed engines	Energy industry
Manufacturing, construction industry	Steel industry (facility other than boilers, gas turbines, fixed engines) Non-ferrous metal industry (facility other than boilers, gas turbines, fixed engines) Others: Gypsum heating furnace, cement industry, asphalt industry, glass industry, mineral wools, bricks, tiles, fine ceramics products manufacturing	Manufacturing, construction industry
	Boilers, gas turbines, fixed engines	Energy industry or small scale facility
	Others	Small scale facility
	Other mobile machinery	Off-road
Other small scale facility	Private works, households (refer to Table 3.1-1)	Other small scale facility
Off-road	Off-road facilities (refer to Table 3.1-1)	Off-road

Pollutants in each category are as shown in Table 3.1-3.

Table 3.1-3 Fuel consumption air pollutant emission source type and the matters

Category (source) classification		SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Stationary source	Energy industry	○	○	○	○	○	○	○	○	○	○	○	○	○
	Manufacturing, construction industry													
	Other sectors: Commercial /facilities, residential, agricultural, forestry, fishery industry													
Mobile source	Road transport	○	○	○	○	○	○	○	○	○	○	○	○	○
	Aviation	○	○	○	○	○	○	○	○	○	○	○	○	○
	Marine transport	○	○	○	○	○	○	○	○	○	○	○	○	○
	Railways	○	○	○	○	○	○	○	○	○	○	○	○	○

3.2 Stationary source

3.2.1 Simple method

3.2.1.1 Outline of emission estimation method

For simple method, fuel consumption by sub-category and by fuel type of national level energy statistics is multiplied with Emission Factor.

$$\text{Emissions} = \sum \text{AD} \times \text{EF} \quad \cdots\cdots\cdots\cdots (3.2\text{-}1)$$

Where,

Emissions: Emission of air pollutants and greenhouse gas

AD: Fuel consumption by sub-category and by fuel type (ex. GJ/year)

EF: Emission factor by sub-category and by fuel type (g/GJ)

In simple method, there is a possibility of emission double-count or omission in industrial process emission and fuel consumption emission. If more accurate estimation is required, “3.2.2 Detailed method” is required.

3.2.1.2 Activity data estimation

Fuel consumption statistics by sub-category and by fuel type is to be used as activity data. Generally it is compiled in “Energy Statistics”.

Statistics published by the statistics bureau, the industrial ministry, trade ministry, customs, etc of the country are primary data to be used. If any of them is not available, IEA energy statistics (Energy Statistics of Non-OECD Countries) is to be used.

Activity data is basically compiled in Net Calorific Value unit, because most emission factors are available in Net Calorific Value unit. On the other hand, in energy statistics, activity data (fuel consumption) may not be compiled in Net Calorific Value unit. It may be compiled in weight or volume. In such case, activity data is to be converted into Net Calorific Value unit, using the following formula.

$$\mathrm{AD} = \mathrm{Fuel\,Consumption} \times \mathrm{Net\,Calorific\,Value} \cdots\cdots\cdots\cdots (3.2\text{-}2)$$

Where,

AD: fuel consumption in Net Calorific Value unit by sub-category and by fuel type (TJ/year)

Fuel Consumption: Fuel consumption rate by sub-category and by fuel type (Gg/year)

Net Calorific Value: Net Calorific Value per weight (TJ/Gg)

Net Calorific Value normally varies according to country, due to fuel production region and fuel standards of the country. Therefore, Net Calorific Value data of the country should be obtained as much as possible. Otherwise, the default figure shown in Table 3.2-1 could be used.

Table 3.2-1 Net Calorific Value by default fuel type

Fuel type	Net Calorific Value (TJ/Gg)	Fuel type	Net Calorific value (TJ/Gg)	Fuel type	Net Calorific value (TJ/Gg)
Crude Oil	42.3	Refinery Gas	49.5	Oxygen Steel Furnace Gas	7.06
Orimulsion	27.5	Paraffin Waxes	40.2	Natural Gas	48.0
Natural Gas Liquids	44.2	White Spirit and SBP	40.2	Municipal Wastes (non-biomass fraction)	10
Motor Gasoline	44.3	Other Petroleum Products	40.2	Industrial Wastes	NA
Aviation Gasoline	44.3	Anthracite	26.7	Waste Oil	40.2
Jet Gasoline	44.3	Coking Coal	28.2	Peat	9.76
Jet Kerosene	44.1	Other Bituminous Coal	25.8	Wood/ Wood Waste	15.6
Other Kerosene	43.8	Sub-Bituminous Coal	18.9	Sulphite Lyes (black liquor)	11.8
Shale Oil	38.1	Lignite	11.9	Other Primary Solid Biomass	11.6
Gas/Diesel Oil	43.0	Oil Shale and Tar Sands	8.9	Charcoal	29.5
Residual Fuel Oil	40.4	Brown Coal Briquettes	20.7	Bio-gasoline	27.0
Liquefied Petroleum Gases	47.3	Patent Fuel	20.7	Bio-diesels	27.0
Ethane	46.4	Coke Oven Coke and Lignite Coke	28.2	Other Liquid Bio-fuels	27.4
Naphtha	44.5	Gas Coke	28.2	Landfill Gas	50.4
Bitumen	40.2	Coal Tar	28.0	Sludge Gas	50.4
Lubricants	40.2	Gas Work Gas	38.7	Other Biogas	50.4
Petroleum Coke	32.5	Coke Oven Gas	38.7	Municipal Waste (biomass fraction)	11.6
Refinery Feedstock	43.0	Blast Furnace Gas	2.47		

Source: 2006 IPCC Guidelines - Volume 2: Energy Table 1.2

3.2.1.3 Setting of emission factors

Emission factor is emission rate of air pollutants per fuel use unit by sub-category and by fuel type. In simple method, energy statistics in sub-categories are to be summarized into matrix of categories ("energy industry", "manufacturing, construction industry", "other small scale facility") and fuel types (as shown in Table 3.2-2) to set the emission factor. Activity data of which fuel type is unknown is also to be classified into Table 3.2-2 by inventory compiler

Table 3.2-2 Category and fuel type for simple method - Part 1

Category classification	Typical fuel type	Fuel type details
Energy industry	Hard coal	Coking coal, other bituminous coal, sub-bituminous coal, coke, manufactured 'patent' fuel
	Brown coal	Lignite, oil shale, manufactured 'patent' fuel , peat
	Natural gas	Natural gas
	Derived gas	Gas works gas, coke oven gas, blast furnace gas
	Heavy fuel oil	Residual fuel oil, refinery feedstock, petroleum gas
	Other liquid fuels	Gas oil, kerosene, naphtha, natural gas liquids, liquefied petroleum gas, orimulsion, bitumen, shale oil, refinery gas
	Biomass	Wood, charcoal, vegetable (agricultural) waste
Manufacturing, and construction industry	Hard coal and brown coal	Coking coal, other bituminous coal, sub-bituminous coal, coke, manufactured 'patent' fuel, Lignite, oil shale, manufactured 'patent' fuel , peat
	Natural Gas and derived gas	Natural gas Gas works gas, coke oven gas, blast furnace gas
	Heavy fuel oil and other liquid fuels	Residual fuel oil, refinery feedstock, petroleum gas Gas oil, kerosene, naphtha, natural gas liquids, liquefied petroleum gas, orimulsion, bitumen, shale oil, refinery gas
	Biomass	Wood, charcoal, vegetable (agricultural) waste

Table 3.2-3 Category and fuel type for simple method - Part 2

Category classification	Typical fuel type	Fuel type details
Residential combustion	Hard coal and brown coal	Coking coal, other bituminous coal, sub-bituminous coal, coke, manufactured 'patent' fuel, Lignite, oil shale, manufactured 'patent' fuel , peat
	Natural gas	Natural gas
	Other liquid fuels	Gas oil, kerosene, naphtha, natural gas liquids, liquefied petroleum gas, orimulsion, bitumen, shale oil, refinery gas
	Biomass	Wood, charcoal, vegetable (agricultural) waste
Non-residential combustion	Hard coal and brown coal	Coking coal, other bituminous coal, sub-bituminous coal, coke, manufactured 'patent' fuel, Lignite, oil shale, manufactured 'patent' fuel , peat
	Natural gas	Natural gas, gas works gas, coke oven gas, blast furnace gas
	Other liquid fuels	Gas oil, kerosene, naphtha, natural gas liquids, liquefied petroleum gas, orimulsion, bitumen, shale oil, refinery gas
	Biomass	Wood, charcoal, vegetable (agricultural) waste

BC and OC emission factors are taken from "A technology-based global inventory of black and organic carbon emissions from combustion, Tami C. Bond et al., 2004, Journal of Geophysical Research, Vol. 109, D14203".

CO_2,CH_4 and N_2O greenhouse gas emission factors are taken from "2006 IPCC Guidelines for National Greenhouse Gas Inventories" ("2006 IPCC Guidelines").

SO_x emission factor is to be calculated obtaining sulfur content of each country by fuel type and by sub-category, and then using the following formula.

$$EF = \frac{2 \times B}{100} \times \frac{10^6}{E} \times \frac{(100 - C)}{100} \times \frac{(100 - D)}{100} \cdots\cdots (3.2\text{-}3)$$

EF	Emission factor (SO_2-kg / Fuel - TJ)
B	Sulfur content of fuel (%)
C	Sulfur retention in ash (%)
D	Efficiency of SO_2 emission control (%)
E	Net Calorific Value (TJ/kton)

If sulfur content for the country is not available, Table 3.2-4 to Table 3.2-6 are applicable

Table 3.2-4 Example of sulfur content by country and by fuel type (unit: %)

Country	Hard Coal	Brown Coal	Motor Gasoline	Kerosene	Diesel Oil			Residual Oil
					Industrial	Road	Marine	
China	1.35		0.120	0.032	0.40	0.16	1.20	1.50
Japan	0.67	1.01	0.004	0.004	0.40	0.40	0.40	1.09
India	0.63	0.95	0.180	0.200	1.44	0.80	1.44	3.20
Indonesia	0.60	0.60	0.005	0.160	0.50	0.50	0.50	2.80
South Korea	0.74	0.74	0.005	0.012	0.40	0.40	0.40	2.64
North Korea	0.32	0.48	0.120	0.032	0.40	0.16	1.20	1.50
Taiwan	1.03		0.125	0.080	1.00	0.50	1.00	1.70
Thailand	2.80	2.80	0.035	0.020	0.50	0.66		2.92
Pakistan	3.65	3.65	0.001	0.160	1.00	1.00	1.00	3.20
Philippines	0.65	0.98	0.035	0.020	1.00	1.00	1.00	3.20
Malaysia	0.62		0.140	0.160	0.96	0.96	0.96	3.20
Bangladesh	0.62		0.180	0.200	1.44	0.80	1.44	3.20
Viet Nam	0.20		0.120	0.032	0.40	1.16	1.20	1.50
Hong Kong	0.53		0.020	0.080	0.50	0.50	0.50	2.20
Singapore	0.62	0.93	0.140	0.020	0.46	0.46	0.46	1.60
Nepal	0.62		0.180	0.200	1.44	0.80	1.44	3.20
Myanmar	0.86	0.86	0.180	0.200	1.44	0.80	1.44	3.20
Sri Lanka	0.66		0.180	0.200	1.44	0.80	1.44	3.20
Afghanistan	0.50		0.180	0.200	1.44	0.80	1.44	3.20
Mongolia	0.70	0.70	0.120	0.032	0.40	0.16	1.20	1.50
Brunei	0.62		0.005	0.160	0.50	0.50	0.50	2.80
Cambodia	0.62		0.120	0.032	0.40	0.16	1.20	1.50
Laos	0.62		0.120	0.200	0.40	0.80	1.20	1.50
Macau	0.62		0.020	0.032	0.50	0.50	0.50	2.20
Maldives	0.62		0.180	0.200	1.44	0.80	1.44	3.20

Source: Anthropogenic Emissions of SO2 and NOx in ASIA: Emission Inventories, Nobuo Kato and Hajime Akimoto, Atmospheric Environment Vol. 26A (1992)

Note: The sulfur content of Brown Coal in Japan, India, N. Korea, Philippines and Singapore is 1.5 times Hard Coal. The sulfur content of Hard Coal includes those of Brown Coal is countries that use Brown Coal.

Table 3.2-5 Example of sulfur retention-in-ash by fuel type (unit: %)

Fuel	Sub-Category	Sulfur retention-in-ash (%)
Hard Coal	Power generation and Industry	5
	Transport and Other Sub-Category	22.5
Brown Coal	All Sub-Categories	25
Solid Biomass	All Sub- Categories	Negligible
Liquid and Gaseous Fuels	All Sub- Categories	0

Source: Gap Forum Manual

Table 3.2-6 Example of sulfur retention-in-ash by fuel type (unit: %)

Fuel	Sub-Category	Sulfur retention-in-ash (%)
Hard Coal and Brown Coal	Electric Power Generation	2.5
	Other combustion sources	22.5
	Other Sub-Category (residential, agriculture, commerce, etc.)	40
Hard Coal and Brown Coal (Cement Industry) (Calculated according to emission control levels estimated by economy condition in 1991)	Japan	85
	South Korea, Taiwan, Malaysia, Hong Kong, Singapore	80
	Other country	75
Natural Gas (Gas Works)	All Sub-Categories	99
Diesel and Residual Oil (Gas Works)	All Sub-Categories	90
Other fuel (Gas Works)	All Sub-Categories	90

Source: Anthropogenic Emissions of SO_2 and NOx in Asia: Emission Inventories, Nobuo Kato and Hajime Akimoto, Atmospheric Environment Vol. 26A (1992)

Table 3.2-7 shows SOx emission factor for other fuel use condition taken from “Anthropogenic Emissions of SO_2 and NOx in Asia: Emission Inventories, Nobuo Kato and Hajime Akimoto, Atmospheric Environment Vol. 26A (1992)”.

Table 3.2-7 Example of SOx emission factor by fuel type

Fuel type	Emission factor	Remarks
Cokes	17.7 S (kg/ton)	62% of sulfur content in coal remains in cokes, and 38% in cokes furnace gas.
Cokes furnace gas (gas plant)	3.8 S (kg/10^{10} cal)	62% of sulfur content in coal remains in cokes, and 38% in cokes furnace gas. Assuming that 90% of sulfur is removed from cokes furnace gas in gas plant, and 0% in others.
Cokes furnace gas (others)	38 S (kg/10^{10} cal)	
Molded coal, BKB	10.0 (kg/ton)	
Natural gas	0.0092 (kg/10^{10} cal)	Natural gas burning emission factor is converted from : 9.2 kg/10^6 m^3
NGL, refinery gas	0.013 (kg/ton)	Equivalent of NGL 1kg=1.4m^3
LPG	0.0136 (kg/ton)	
Other gas	0.01 (kg/10^{10} cal)	Same level as natural gas
Bagasse	1.1 (kg/toe)	Bagasse sulfur content is 0.1 weight % or less
Wood	0.2 (g/kg)	Woodstoves and residential firespace
Charcoal	1.0 (kg/toe)	Also includes other non-commercial use
“Oil refinery” naphtha, crude oil, refinery fuel oil	0.023 S (%)	In refinery, 2.3% of material used in naphtha, crude oil, and fuel in refinery becomes SOx through Fluid Catalytic Cracking (FCC) and emitted
“Steel industry” Cokes	0.297 S + 1.55 (kg/ton)	In steel industry, the sulfur content in cokes emitted is about 1/6. And the sulfur emitted from iron ore is 86%. As a result, when emission factor of cokes is assessed, sulfur content rises by 0.0774(%).
“Metal refining” Copper, zinc, lead, tin	12, 20, 33 (kg/ton H_2SO_4)	Large amount of SO_2 are discharged in refining process of non-ferrous metal like copper, zinc. Most of SO2 are used to produce sulfur acid and 2 to 5% of SO_2 are emitted to air.

Note: S denotes sulfur content (%)

If sulfur content of the country is not available and if Table 3.2-4 to Table 3.2-6 is not suitable, “EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009” (”EMEP/EEA Guidebook 2009”) can be applied. However, SOx emission factor in “EMEP/EEA Guidebook 2009” is calculated assuming that sulfur content of any fuel is 1%. It should be remarked whenever it is applied.

Emission factors of other pollutants, shown in Table 3.2-8 to Table 3.2-20, are taken from “EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009” (”EMEP/EEA Guidebook 2009”).

Table 3.2-8 NOx emission factors for simple method

NOx Emission Factor (g/GJ)	Hard coal			Brown coal					OLF	HFO		OLF	OLF			OLF		HFO	OLF	HFO		NG	Derived gases								
Supply and Consumption	Cooking Coal	Other bit.coal	Sub-bit.coal	Lignite	Peat	Oven and gas coke	Pat.fuel and BKB	Crude oil	NGL	Feed-stocks	Additives	Refinery gas	LPG & ethane	Motor gasoline	Aviation fuel	Kerosene	Gas/diesel	Heavy fuel oil	Naphtha	Petroleum coke	Other products	Natural gas	Gas work	Coke oven	Blast fuenace	Solid biomass	Biogas	Liquid biomass	Waste other	Electricity	Heat
Electricity and CHP plant	310	310	310	360	360		360		180	215		180	180			180		215	180	215		89	140	140	140	211			211		
Pertoleum refineries									180	215		60	180			180		215	180	215		89									
Other transform. Sector	22																														
ENERGY SECTOR																															
Distribution losses																															
FINAL CONSUMPTION																															
INDUSTRY SECTOR																															
Iron and steel	173	173	173	173	173	173	173		100			100	100			100			100			70	70	70	70	150			150		
Chemical and petrochem.									100			100	100			100			100			70	70	70	70	150			150		
Non-metallic minerals									100			100	100			100			100			70	70	70	70	150			150		
Other/non-specified									100			100	100			100			100			70	70	70	70	150			150		
TRANSPORT SECTOR																															
Domestic aciation																															
Road																															
Other/non-specified																															
OTHER SECTORS																															
Resicential	110	110	110	110	110		110		68			68	68	*7117*		68			68			57				74.5			74.5		
Comm.and public services	173	173	173	173	173		173		100			100	100	*7117*		100	*32792*		100			70	70	70	70	150			150		
Agriculture/forestry													*61093*	*7117*			*35043*														
Other/non-specified																															
NON-ENERGY USE																															

Note) Emission factor shown in itallc font is for off-road vehicles, and their unit is (g/tone fuel) OLF: Other liquid fuel HFO: Heavy fuel oil

Source: "EMEP/EEA Emission Inventory Guidebook 2009"

Table 3.2-9 CO emission factors for simple method

CO Emission Factor (g/GJ)	Hard coal			Brown coal					OLF	HFO		OLF	OLF			OLF		HFO	OLF	HFO		NG	Derived gases								
Supply and Consumption	Cooking Coal	Other bit.coal	Sub-bit.coal	Lignite	Peat	Oven and gas coke	Pat.fuel and BKB	Crude oil	NGL	Feed-stocks	Additives	Refinery gas	LPG & ethane	Motor gasoline	Aviation fuel	Kerosene	Gas/diesel	Heavy fuel oil	Naphtha	Petroleum coke	Other products	Natural gas	Gas work	Coke oven	Blast fuenace	Solid biomass	Biogas	Liquid biomass	Waste other	Electricity	Heat
Electricity and CHP plant	150	150	150	113	113		113		15	5		15	15			15		5	15	5		39	10	10	10	258			258		
Pertoleum refineries									15	5		39	15			15		5	15	5		39									
Other transform. Sector	525																														
ENERGY SECTOR																															
Distribution losses																															
FINAL CONSUMPTION																															
INDUSTRY SECTOR																															
Iron and steel	931	931	931	931	931	931	931		40			40	40			40			40			25	25	25	25	1596			1596		
Chemical and petrochem.									40			40	40			40			40			25	25	25	25	1596			1596		
Non-metallic minerals									40			40	40			40			40			25	25	25	25	1596			1596		
Other/non-specified									40			40	40			40			40			25	25	25	25	1596			1596		
TRANSPORT SECTOR																															
Domestic aciation																															
Road																															
Other/non-specified																															
OTHER SECTORS																															
Resicential	4600	4600	4600	4600	4600		4600		46			46	46	*770368*		46			46			31				5300			5300		
Comm.and public services	931	931	931	931	931		931		40			40	40	*770368*		40	*10722*		40			25	25	25	25	1600			1600		
Agriculture/forestry													*4823*	*770368*			*10939*														
Other/non-specified																															
NON-ENERGY USE																															

Note) Emission factor shown in itallc font is for off-road vehicles, and their unit is (g/tone fuel) OLF: Other liquid fuel HFO: Heavy fuel

Source: "EMEP/EEA Emission Inventory Guidebook 2009"

Table 3.2-10 NMVOC emission factors for simple method

NMVOC Emission Factor (g/GJ)	Hard coal			Brown coal					OLF	HFO		OLF	OLF			OLF		HFO	OLF	HFO		NG	Derived gases								
Supply and Consumption	Cooking Coal	Other bit.coal	Sub-bit.coal	Lignite	Peat	Oven and gas coke	Pat.fuel and BKB	Crude oil	NGL	Feed-stocks	Additives	Refinery gas	LPG & ethane	Motor gasoline	Aviation fuel	Kerosene	Gas/diesel	Heavy fuel oil	Naphtha	Petroleum coke	Other products	Natural gas	Gas work	Coke oven	Blast fuenace	Solid biomass	Biogas	Liquid biomass	Waste other	Electricity	Heat
Electricity and CHP plant	1.2	1.2	1.2	1.7	1.7		1.7		0.8	0.8		0.8	0.8			0.8		0.8	0.8	0.8		1.5	2.5	2.5	2.5	7.3			7.3		
Pertoleum refineries									0.8	0.8		2.6	0.8			0.8		0.8	0.8	0.8		1.5									
Other transform. Sector	2.4																														
ENERGY SECTOR																															
Distribution losses																															
FINAL CONSUMPTION																															
INDUSTRY SECTOR																															
Iron and steel	88.8	88.8	88.8	88.8	88.8	88.8	88.8		10			10	10			10			10			2.5	2.5	2.5	2.5	146			146		
Chemical and petrochem.									10			10	10			10			10			2.5	2.5	2.5	2.5	146			146		
Non-metallic minerals									10			10	10			10			10			2.5	2.5	2.5	2.5	146			146		
Other/non-specified									10			10	10			10			10			2.5	2.5	2.5	2.5	146			146		
TRANSPORT SECTOR																															
Domestic aciation																															
Road																															
Other/non-specified																															
OTHER SECTORS																															
Resicential	484	484	484	484	484		484		15.5			15.5	15.5	*17602*		15.5			15.5			10.5				925			925		
Comm.and public services	88.8	88.8	88.8	88.8	88.8		88.8		10			10	10	*17602*		10	*3385*		10			2.5	2.5	2.5	2.5	146			146		
Agriculture/forestry													*6720*	*17602*			*3366*														
Other/non-specified																															
NON-ENERGY USE																															

Note) Emission factor shown in itallc font is for off-road vehicles, and their unit is (g/tone fuel)   OLF: Other liquid fuel   HFO: Heavy fuel

Source: "EMEP/EEA Emission Inventory Guidebook 2009"

Table 3.2-11 SOx emission factors for simple method

SOx Emission Factor (g/GJ)	Hard coal			Brown coal					OLF	HFO		OLF	OLF			OLF		HFO	OLF	HFO		NG	Derived gases								
Supply and Consumption	Cooking Coal	Other bit.coal	Sub-bit.coal	Lignite	Peat	Oven and gas coke	Pat.fuel and BKB	Crude oil	NGL	Feed-stocks	Additives	Refinery gas	LPG & ethane	Motor gasoline	Aviation fuel	Kerosene	Gas/diesel	Heavy fuel oil	Naphtha	Petroleum coke	Other products	Natural gas	Gas work	Coke oven	Blast fuenace	Solid biomass	Biogas	Liquid biomass	Waste other	Electricity	Heat
Electricity and CHP plant	820	820	820	820	820		820		460	485		460	460			460		485	460	485		0.3	0.3	0.3	0.3	11			11		
Pertoleum refineries									460	485		0.3	460			460		485	460	485		0.3									
Other transform. Sector	55																														
ENERGY SECTOR																															
Distribution losses																															
FINAL CONSUMPTION																															
INDUSTRY SECTOR																															
Iron and steel	900	900	900	900	900	900	900		140			140	140			140			140			0.5	0.5	0.5	0.5	38.4			38.4		
Chemical and petrochem.									140			140	140			140			140			0.5	0.5	0.5	0.5	38.4			38.4		
Non-metallic minerals									140			140	140			140			140			0.5	0.5	0.5	0.5	38.4			38.4		
Other/non-specified									140			140	140			140			140			0.5	0.5	0.5	0.5	38.4			38.4		
TRANSPORT SECTOR																															
Domestic aciation																															
Road																															
Other/non-specified																															
OTHER SECTORS																															
Resicential	900	900	900	900	900		900		140			140	140	*165*		140			140			0.5				20			20		
Comm.and public services	900	900	900	900	900		900		140			140	140	*165*		140	*400*		140			0.5	0.5	0.5	0.5	38.4			38.4		
Agriculture/forestry													140	*165*			*400*														
Other/non-specified																															
NON-ENERGY USE																															

Note) Emission factor shown in itallc font is for off-road vehicles, and their unit is (g/tone fuel) OLF: Other liquid fuel HFO: Heavy fuel
Power plant emission factor is for fuel gas with S content of 0.01g/m2, and biomass fuel uses USA average of 28 plants
For other fuels, calculation is based on sulfur content of 1%. For details including other sub-categories, refer to EMEP/ EEA Guidebook 2009.

Source: “EMEP/EEA Emission Inventory Guidebook 2009”

Table 3.2-12 NH_3 emission factors for simple method

NH3 Emission Factor (g/GJ)	Hard coal			Brown coal					OLF	HFO		OLF	OLF			OLF		HFO	OLF	HFO		NG	Derived gases								
Supply and Consumption	Cooking Coal	Other bit.coal	Sub-bit.coal	Lignite	Peat	Oven and gas coke	Pat.fuel and BKB	Crude oil	NGL	Feed-stocks	Additives	Refinery gas	LPG & ethane	Motor gasoline	Aviation fuel	Kerosene	Gas/diesel	Heavy fuel oil	Naphtha	Petroleum coke	Other products	Natural gas	Gas work	Coke oven	Blast fuenace	Solid biomass	Biogas	Liquid biomass	Waste other	Electricity	Heat
Electricity and CHP plant																							0.9	0.9	0.9						
Pertoleum refineries																															
Other transform. Sector	1.3																														
ENERGY SECTOR																															
Distribution losses																															
FINAL CONSUMPTION																															
INDUSTRY SECTOR																															
Iron and steel																															
Chemical and petrochem.																															
Non-metallic minerals																															
Other/non-specified																															
TRANSPORT SECTOR																															
Domestic aciation																															
Road																															
Other/non-specified																															
OTHER SECTORS																															
Resicential	0.3	0.3	0.3	0.3	0.3		0.3							*4*												3.8			3.8		
Comm.and public services														*4*			*8*														
Agriculture/forestry													*10*	*4*			*8*														
Other/non-specified																															
NON-ENERGY USE																															

Note) Emission factor shown in itallc font is for off-road vehicles, and their unit is (g/tone fuel) OLF: Other liquid fuel HFO: Heavy fuel

Source: "EMEP/EEA Emission Inventory Guidebook 2009"

Table 3.2-13 TSP emission factors for simple method

TSP Emission Factor (g/GJ)	Hard coal			Brown coal					OLF	HFO		OLF	OLF			OLF		HFO	OLF	HFO		NG	Derived gases								
Supply and Consumption	Cooking Coal	Other bit.coal	Sub-bit.coal	Lignite	Peat	Oven and gas coke	Pat.fuel and BKB	Crude oil	NGL	Feed-stocks	Additives	Refinery gas	LPG & ethane	Motor gasoline	Aviation fuel	Kerosene	Gas/diesel	Heavy fuel oil	Naphtha	Petroleum coke	Other products	Natural gas	Gas work	Coke oven	Blast fuenace	Solid biomass	Biogas	Liquid biomass	Waste other	Electricity	Heat
Electricity and CHP plant	30	30	30	30	30		30		3	25		3	3			3		25	3	25		0.9	5	5	5	51			51		
Pertoleum refineries									3	25		0.89	3			3		25	3	25		0.9									
Other transform. Sector	81																														
ENERGY SECTOR																															
Distribution losses																															
FINAL CONSUMPTION																															
INDUSTRY SECTOR																															
Iron and steel	124	124	124	124	124	124	124		27.5			27.5	27.5			27.5			27.5			0.5	0.5	0.5	0.5	156			156		
Chemical and petrochem.									27.5			27.5	27.5			27.5			27.5			0.5	0.5	0.5	0.5	156			156		
Non-metallic minerals									27.5			27.5	27.5			27.5			27.5			0.5	0.5	0.5	0.5	156			156		
Other/non-specified									27.5			27.5	27.5			27.5			27.5			0.5	0.5	0.5	0.5	156			156		
TRANSPORT SECTOR																															
Domestic aciation																															
Road																															
Other/non-specified																															
OTHER SECTORS																															
Resicential	444	444	444	444	444		444		6			6	6	*157*		6			6			0.5				730			730		
Comm.and public services	124	124	124	124	124		124		27.5			27.5	27.5	*157*		27.5	*2086*		27.5			0.5	0.5	0.5	0.5	156			156		
Agriculture/forestry													*225*	*157*			*1738*														
Other/non-specified																															
NON-ENERGY USE																															

Note) Emission factor shown in itallc font is for off-road vehicles, and their unit is (g/tone fuel)   OLF: Other liquid fuel   HFO: Heavy fuel

Source: "EMEP/EEA Emission Inventory Guidebook 2009"

Table 3.2-14 PM$_{10}$ emission factors for simple method

PM10 Emission Factor (g/GJ)	Hard coal			Brown coal					OLF	HFO		OLF	OLF			OLF		HFO	OLF	HFO		NG	Derived gases								
Supply and Consumption	Cooking Coal	Other bit.coal	Sub-bit.coal	Lignite	Peat	Oven and gas coke	Pat.fuel and BKB	Crude oil	NGL	Feed-stocks	Additives	Refinery gas	LPG & ethane	Motor gasoline	Aviation fuel	Kerosene	Gas/diesel	Heavy fuel oil	Naphtha	Petroleum coke	Other products	Natural gas	Gas work	Coke oven	Blast fuenace	Solid biomass	Biogas	Liquid biomass	Waste other	Electricity	Heat
Electricity and CHP plant	20	20	20	20	20		20		2	18		2	2			2		18	2	18		0.9	5	5	5	38			38		
Pertoleum refineries									2	18		0.89	2			2		18	2	18		0.9									
Other transform. Sector	49																														
ENERGY SECTOR																															
Distribution losses																															
FINAL CONSUMPTION																															
INDUSTRY SECTOR																															
Iron and steel	117	117	117	117	117	117	117		21.5			21.5	21.5			21.5			21.5			0.5	0.5	0.5	0.5	150			150		
Chemical and petrochem.									21.5			21.5	21.5			21.5			21.5			0.5	0.5	0.5	0.5	150			150		
Non-metallic minerals									21.5			21.5	21.5			21.5			21.5			0.5	0.5	0.5	0.5	150			150		
Other/non-specified									21.5			21.5	21.5			21.5			21.5			0.5	0.5	0.5	0.5	150			150		
TRANSPORT SECTOR																															
Domestic aciation																															
Road																															
Other/non-specified																															
OTHER SECTORS																															
Resicential	404	404	404	404	404		404		3.7			3.7	3.7	*157*		3.7			3.7			0.5				695			695		
Comm.and public services	117	117	117	117	117		117		21.5			21.5	21.5	*157*		21.5	*2086*		21.5			0.5	0.5	0.5	0.5	150			150		
Agriculture/forestry													*225*	*157*			*1738*														
Other/non-specified																															
NON-ENERGY USE																															

Note) Emission factor shown in itallc font is for off-road vehicles, and their unit is (g/tone fuel)   OLF: Other liquid fuel   HFO: Heavy fuel

Source: "EMEP/EEA Emission Inventory Guidebook 2009"

Table 3.2-15 $PM_{2.5}$ emission factors for simple method

PM2.5 Emission Factor (g/GJ)	Hard coal			Brown coal					OLF	HFO		OLF	OLF			OLF		HFO	OLF	HFO		NG	Derived gases								
Supply and Consumption	Cooking Coal	Other bit.coal	Sub-bit.coal	Lignite	Peat	Oven and gas coke	Pat.fuel and BKB	Crude oil	NGL	Feed-stocks	Additives	Refinery gas	LPG & ethane	Motor gasoline	Aviation fuel	Kerosene	Gas/diesel	Heavy fuel oil	Naphtha	Petroleum coke	Other products	Natural gas	Gas work	Coke oven	Blast fuenace	Solid biomass	Biogas	Liquid biomass	Waste other	Electricity	Heat
Electricity and CHP plant	9	9	9	9	9		9		1	13		1	1			1		13	1	13		0.9	5	5	5	33			33		
Pertoleum refineries									1	13		0.89	1			1		13	1	13		0.9									
Other transform. Sector	38																														
ENERGY SECTOR																															
Distribution losses																															
FINAL CONSUMPTION																															
INDUSTRY SECTOR																															
Iron and steel	108	108	108	108	108	108	108		16.5			16.5	16.5			16.5			16.5			0.5	0.5	0.5	0.5	149			149		
Chemical and petrochem.									16.5			16.5	16.5			16.5			16.5			0.5	0.5	0.5	0.5	149			149		
Non-metallic minerals									16.5			16.5	16.5			16.5			16.5			0.5	0.5	0.5	0.5	149			149		
Other/non-specified									16.5			16.5	16.5			16.5			16.5			0.5	0.5	0.5	0.5	149			149		
TRANSPORT SECTOR																															
Domestic aciation																															
Road																															
Other/non-specified																															
OTHER SECTORS																															
Resicential	398	398	398	398	398		398		3.7			3.7	3.7	*157*		3.7			3.7			0.5				695			695		
Comm.and public services	108	108	108	108	108		108		16.5			16.5	16.5	*157*		16.5	*2086*		16.5			0.5	0.5	0.5	0.5	149			149		
Agriculture/forestry													*225*	*157*			*1738*														
Other/non-specified																															
NON-ENERGY USE																															

Note) Emission factor shown in itallc font is for off-road vehicles, and their unit is (g/tone fuel) OLF: Other liquid fuel HFO: Heavy fuel

Source: "EMEP/EEA Emission Inventory Guidebook 2009"

Table 3.2-16 Range of Emission Factors for BC [g/ kg-Fuel]

Fuel Type		Power Plant	Industry	Residential
Fossil fuels	Briquettes, coke	0.011	0.005	0.15
	Brown coal, peat	0.000-0.002	0.001-0.15	0.18
	Diesel fuel	0.25	3.4-4.4	0.06-4.0
	Hard coal, coking coal	0.002-0.009	0.013-1.2	0.76-5.4
	Heavy fuel oil	0.04	0.04	0.07
	Gasoline, aviation fuel, kerosene	-	0.14	0.9
	LPG	-	-	0.20
	Natural gas	0	0	0
	Waste	0.013	0.013	4.2
Biofuels	Animal wastes	-	-	0.53
	Charcoal	-	w/coke	1.0
	Agricultural residues	-	w/wood	1.0
	Wood	0.044	0.08-0.55	0.3-1.4

Source: Tami C. Bond et al., 2004[6]

Table 3.2-17 Range of Emission Factors for Primary OC [g/ kg-Fuel]

Fuel Type		Power Plant	Industry	Residential
Fossil fuels	Briquettes, coke	0.004	0.008	0.14
	Brown coal, peat	0.003-0.04	0.03-0.68	2.7
	Diesel fuel	0.001	1.1-1.4	0.03-1.1
	Hard coal, coking coal	0-0.001	0.001-0.9	0.4-4.3
	Heavy fuel oil	0.015	0.015	0.015
	Gasoline, aviation fuel, kerosene	-	0.04	0.09
	LPG	-	-	0.05
	Natural gas	0.001	0.001	0.001
	Waste	0.002	0.002	0.4
Biofuels	Animal wastes	-	-	1.8
	Charcoal	-	w/coke	1.3
	Agricultural residues	-	w/wood	3.3
	Wood	0.18	0.31-3.2	1/.7-7.8

Source: Tami C. Bond et al., 2004[7]

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[6] A technology-based global inventory of black and organic carbon emission s from combustion, Tami C. Bond et al., 2004, Journal of Geophysical Research, Vol. 109, D14203

[7] Same as above

Table 3.2-18 CO_2 emission factors for simple method

CO2 EF (g/GJ)	Energy	Manufacturing	Commercial	Others
Crude Oil	73300	73300	73300	73300
Orimulsion	77000	77000	77000	77000
Natural Gas Liquids	64200	64200	64200	64200
Motor Gasoline	69300	69300	69300	69300
Aviation Gasoline	70000	70000	70000	70000
Jet Gasoline	70000	70000	70000	70000
Jet Kerosene	71500	71500	71500	71500
Other Kerosene	71900	71900	71900	71900
Shale Oil	73300	73300	73300	73300
Gas/Diesel Oil	74100	74100	74100	74100
Residual Fuel Oil	77400	77400	77400	77400
Liquefied Petroleum Gases	63100	63100	63100	63100
Ethane	61600	61600	61600	61600
Naphtha	73300	73300	73300	73300
Bitumen	80700	80700	80700	80700
Lubricants	73300	73300	73300	73300
Petroleum Coke	97500	97500	97500	97500
Refinery Feedstocks	73300	73300	73300	73300
Refinery Gas	57600	57600	57600	57600
Paraffin Waxes	73300	73300	73300	73300
White Spirit and SBP	73300	73300	73300	73300
Other Petroleum Products	73300	73300	73300	73300
Anthracite	98300	98300	98300	98300
Coking Coal	94600	94600	94600	94600
Other Bituminous Coal	94600	94600	94600	94600
Sub-Bituminous Coal	96100	96100	96100	96100
Lignite	101000	101000	101000	101000
Oil Shale and Tar Sands	107000	107000	107000	107000
Brown Coal Briquettes	97500	97500	97500	97500
Patent Fuel	97500	97500	97500	97500
Coke Oven Coke and Lignite Coke	107000	107000	107000	107000
Gas Coke	107000	107000	107000	107000
Coal Tar	80700	80700	80700	80700
Gas Work Gas	44400	44400	44400	44400
Coke Oven Gas	44400	44400	44400	44400
Blast Furnace Gas	260000	260000	260000	260000
Oxygen Steel Furnace Gas	182000	182000	182000	182000
Natural Gas	56100	56100	56100	56100
Municipal Wastes (non-biomass fraction)	91700	91700	91700	91700
Industrial Wastes	143000	143000	143000	143000
Waste Oil	73300	73300	73300	73300
Peat	106000	106000	106000	106000
Wood/ Wood Waste	112000	112000	112000	112000
Sulphite Lyes (black liquor)	95300	95300	95300	95300
Other Primary Solid Biomass	100000	100000	100000	100000
Charcoal	112000	112000	112000	112000
Biogasoline	70800	70800	70800	70800
Biodiesels	70800	70800	70800	70800
Other Liquid Biofuels	79600	79600	79600	79600
Landfill Gas	54600	54600	54600	54600
Sludge Gas	54600	54600	54600	54600
Other Biogas	54600	54600	54600	54600
Municipal Waste (biomass fraction)	100000	100000	100000	100000

Source; 2006 IPCC Guidelines

Note; Energy: Energy Industries, Manufacturing: Manufacturing Industries and Construction,
Commercial: Commercial/Institutional, Others: Residential and Agriculture/ Forestry/Fishing

Table 3.2-19 CH_4 emission factors for simple method

CH4 EF (g/GJ)	Energy	Manufacturing	Commercial	Others
Crude Oil	3	3	10	10
Orimulsion	3	3	10	10
Natural Gas Liquids	3	3	10	10
Motor Gasoline	3	3	10	10
Aviation Gasoline	3	3	10	10
Jet Gasoline	3	3	10	10
Jet Kerosene	3	3	10	10
Other Kerosene	3	3	10	10
Shale Oil	3	3	10	10
Gas/Diesel Oil	3	3	10	10
Residual Fuel Oil	3	3	10	10
Liquefied Petroleum Gases	1	1	5	5
Ethane	1	1	5	5
Naphtha	3	3	10	10
Bitumen	3	3	10	10
Lubricants	3	3	10	10
Petroleum Coke	3	3	10	10
Refinery Feedstocks	3	3	10	10
Refinery Gas	1	1	5	5
Paraffin Waxes	3	3	10	10
White Spirit and SBP	3	3	10	10
Other Petroleum Products	3	3	10	10
Anthracite	1	10	10	300
Coking Coal	1	10	10	300
Other Bituminous Coal	1	10	10	300
Sub-Bituminous Coal	1	10	10	300
Lignite	1	10	10	300
Oil Shale and Tar Sands	1	10	10	300
Brown Coal Briquettes	1	10	10	300
Patent Fuel	1	10	10	300
Coke Oven Coke and Lignite Coke	1	10	10	300
Gas Coke	1	1	5	5
Coal Tar	1	10	10	300
Gas Work Gas	1	1	5	5
Coke Oven Gas	1	1	5	5
Blast Furnace Gas	1	1	5	5
Oxygen Steel Furnace Gas	1	1	5	5
Natural Gas	1	1	5	5
Municipal Wastes (non-biomass fraction)	30	30	300	300
Industrial Wastes	30	30	300	300
Waste Oil	30	30	300	300
Peat	1	2	10	300
Wood/ Wood Waste	30	30	300	300
Sulphite Lyes (black liquor)	3	3	3	3
Other Primary Solid Biomass	30	30	300	300
Charcoal	200	200	200	200
Biogasoline	3	3	10	10
Biodiesels	3	3	10	10
Other Liquid Biofuels	3	3	10	10
Landfill Gas	1	1	5	5
Sludge Gas	1	1	5	5
Other Biogas	1	1	5	5
Municipal Waste (biomass fraction)	30	30	300	300

Source; 2006 IPCC Guidelines

Note; Energy: Energy Industries, Manufacturing: Manufacturing Industries and Construction, Commercial: Commercial/Institutional, Others: Residential and Agriculture/ Forestry/Fishing

Table 3.2-20 N_2O emission factors for simple method

N2O EF (g/GJ)	Energy	Manufacturing	Commercial	Others
Crude Oil	0.6	0.6	0.6	0.6
Orimulsion	0.6	0.6	0.6	0.6
Natural Gas Liquids	0.6	0.6	0.6	0.6
Motor Gasoline	0.6	0.6	0.6	0.6
Aviation Gasoline	0.6	0.6	0.6	0.6
Jet Gasoline	0.6	0.6	0.6	0.6
Jet Kerosene	0.6	0.6	0.6	0.6
Other Kerosene	0.6	0.6	0.6	0.6
Shale Oil	0.6	0.6	0.6	0.6
Gas/Diesel Oil	0.6	0.6	0.6	0.6
Residual Fuel Oil	0.6	0.6	0.6	0.6
Liquefied Petroleum Gases	0.1	0.1	0.1	0.1
Ethane	0.1	0.1	0.1	0.1
Naphtha	0.6	0.6	0.6	0.6
Bitumen	0.6	0.6	0.6	0.6
Lubricants	0.6	0.6	0.6	0.6
Petroleum Coke	0.6	0.6	0.6	0.6
Refinery Feedstocks	0.6	0.6	0.6	0.6
Refinery Gas	0.1	0.1	0.1	0.1
Paraffin Waxes	0.6	0.6	0.6	0.6
White Spirit and SBP	0.6	0.6	0.6	0.6
Other Petroleum Products	0.6	0.6	0.6	0.6
Anthracite	1.5	1.5	1.5	1.5
Coking Coal	1.5	1.5	1.5	1.5
Other Bituminous Coal	1.5	1.5	1.5	1.5
Sub-Bituminous Coal	1.5	1.5	1.5	1.5
Lignite	1.5	1.5	1.5	1.5
Oil Shale and Tar Sands	1.5	1.5	1.5	1.5
Brown Coal Briquettes	1.5	1.5	1.5	1.5
Patent Fuel	1.5	1.5	1.5	1.5
Coke Oven Coke and Lignite Coke	1.5	1.5	1.5	1.5
Gas Coke	0.1	0.1	0.1	0.1
Coal Tar	1.5	1.5	1.5	1.5
Gas Work Gas	0.1	0.1	0.1	0.1
Coke Oven Gas	0.1	0.1	0.1	0.1
Blast Furnace Gas	0.1	0.1	0.1	0.1
Oxygen Steel Furnace Gas	0.1	0.1	0.1	0.1
Natural Gas	0.1	0.1	0.1	0.1
Municipal Wastes (non-biomass fraction)	4	4	4	4
Industrial Wastes	4	4	4	4
Waste Oil	4	4	4	4
Peat	1.5	1.5	1.4	1.4
Wood/ Wood Waste	4	4	4	4
Sulphite Lyes (black liquor)	2	2	2	2
Other Primary Solid Biomass	4	4	4	4
Charcoal	4	4	1	1
Biogasoline	0.6	0.6	0.6	0.6
Biodiesels	0.6	0.6	0.6	0.6
Other Liquid Biofuels	0.6	0.6	0.6	0.6
Landfill Gas	0.1	0.1	0.1	0.1
Sludge Gas	0.1	0.1	0.1	0.1
Other Biogas	0.1	0.1	0.1	0.1
Municipal Waste (biomass fraction)	4	4	4	4

Source; 2006 IPCC Guidelines

Note; Energy: Energy Industries, Manufacturing: Manufacturing Industries and Construction,
Commercial: Commercial/Institutional, Others: Residential and Agriculture/ Forestry/Fishing

3.2.1.4 Temporal change and spatial distribution

To indicate the temporal change and spatial distribution of air pollutant emission or to simulate air pollution dispersion, temporal change and spatial distribution models are required.

1. Temporal change

Temporal change model is to be developed for each region and sector. Followings are samples: -

1) 24-hour model
   Air pollutant emission from factories changes according to the operation condition of the equipment. For instance, air pollutant emission from power plants changes according to the demand of lighting and air-conditioning. Air pollutant emission of cooking fuel use varies according to cooking cycle.
2) Week model
   Fuel consumption in factory, power plant and households is generally different between weekdays and weekends. Air pollutant emission is also different.
3) Seasonal model
   Air-conditioning usage varies as air temperature and season changes (spring, summer, autumn and winter; or wet and dry season). Air pollutant emission rate from heating and power plant changes accordingly. In countries or territories that use summer time system, fuel usage changes as a result of change of standard time change. Holiday season and Muslim fasting month also causes temporal change.

2. Spatial distribution

Spatial distribution model is to be developed in accordance with statistics availability and fuel consumption sector characteristics. Population, GDP per capita, air temperature, number of workplace, agricultural production rate, fuel sales volume and other indices by region are to be investigated. Emission is to be distributed by available and appropriate index for each sector.

3. Matrix of temporal change and spatial distribution

In countries that expand quite far from the east to the west, different temporal change may have to be applied for different location.

For instance, in Indonesia, there are three time-zones. In China, although one time-zone applies to the entire country, daily model is adjusted to the time of sun rises of each region. For the purpose of inventory, 24-hour temporal change models may necessary for each region.

3.2.2 Detailed method

3.2.2.1 Outline of emission estimation method

In simple method, fuel consumption of national level energy statistics by sub-category and by fuel type is multiplied with emission factor.

In energy industry, detailed method is almost the same as simple method. In detailed method, more technically detailed emission factor is applied, that is, emission factor not only by fuel type but also by facility type is applied. Therefore, for activity data fuel consumption data by facility type is also required.

In manufacturing industry, pollutant emission is not only from fuel but also from material. Although air pollutant from material should be calculated in industrial process sector, it is very difficult to separate emission between fuel source and material source. Therefore, for the sub-categories and pollutants shown in Table

3.2-29 to Table 3.2-32, emission factor is defined by production volume of manufacturing industry and emission is calculated in fuel consumption sector.

The detailed method for household and small business emission is almost the same as simple method. In detailed method, more technically detailed emission factor is applied, that is emission factor not only by fuel type but also by facility type is applied. Therefore, for activity data, fuel consumption data by facility type is also required.

The formula to calculate emission rate in detailed method is common to each category and is almost the same as simple method, which means the fuel consumption rate by sub-category and by facility type is multiplied with emission factor.

$$\text{Emissions} = \sum \text{AD} \times \text{EF} \quad \cdots\cdots (3.2\text{-}4)$$

Where,

Emissions: Emission of air pollutants and greenhouse gas

AD: Fuel consumption rate by sub-category and by fuel type (GJ/year or ton/year)

EF: Emission factor by sub-category and by fuel type (g/GJ or g/ton)

For air pollution assessment, especially by air simulation model, emission from so-called Large Point Source (LPS) is particularly important. Typical LPS example is large scale fired power plant, regional heating facility, steel manufacturing, large scale cement plant, refinery, large scale boiler, etc. These facilities normally emit large amount of air pollutant from high chimney. Since LPS emits large amount of pollutants from high location in high temperature compared to other sources, their effect is generally much different from other sources in the viewpoint of pollutants dispersion and atmospheric chemistry.

LPS is normally surveyed by questionnaires and interviews. If some survey result is available, it could be used as LPS data too. Since LPS survey will identify the activity data and emission by facility and by fuel type, it is one of detailed method.

LPS emission is necessary not to be counted double in non LPS emission in the same sub-category already. Therefore, the activity data of energy statistics for the same sub-category as LPS is to be subtracted with LPS activity data (fuel consumption rate). Otherwise, emission calculated from energy statistics is to be subtracted with LPS emission total of same sub-category.

LPS emission temporal change is important too. For instance in a power plant, air pollutant emission changes according to the change of demand and electricity production daily, weekdays or weekends, and seasonally. In large scale industry, air pollution emission varies wildly between operation and non-operation hours. Survey on these temporal emission changes are mandatory in LPS survey.

Since LPS alone has an effect on air environment in its surrounding areas, location information is extremely important. Additionally, as mentioned above, height of chimney is also an important parameter for pollution assessment. If there is more than one chimney in any factory, emission is generally different between chimneys. Therefore, not only the location of the plant or workplace, the position and height of the chimney too are mandatory to be included in report.

Because of LPS characteristics mentioned above LPS questionnaire survey or interview should contain survey items as shown in Table 3.2-21.

Table 3.2-21 LPS survey contents

Survey item	Survey content	Survey proof
Plant/workplace outline	Name, location, main products, sales, employee count, land area, name of person responding to survey, etc	Plant basic information, information to classify into sub-category
Plant plan drawing	Plant/workplace plan drawing, production process outline	Location information on emission source, such as chimney and process
Product information	Monthly production volume by product, or more detailed data on temporal change if available (it is generally available in power plant)	Basic information on emission calculation Basic information on temporal change of emission
Fuel information	Fuel properties (type, specific gravity, net calorific value, sulfur content, nitrogen content, ash content, and main source), and monthly volume of fuel used	Basic information on emission calculation Basic information on temporal change of emission
Operation (running) information	Monthly operation hours, weekday operation condition, hourly operation condition and temporal change information on operation (continuous, intermittent or batch operation)	Basic information on temporal change of emission
Chimney information	Location, height and outlet diameter of chimney, gas temperature, gas volume and/or gas speed at chimney outlet	Basic information on emission calculation and emission outlet location
Pollution mitigation facility	Pollution mitigation facility and its treatment capacity, removal rate, operating time, and temporal change information on (continuous, intermittent or batch operation)	Basic information on emission calculation
Emission gas measurement result	Emission gas measurement result	Basic information on emission calculation and emission factor calculation, check on operation control
Future plan	New construction plan and/or revision plan on existing facility on chimney, boiler, furnace and production facility	Basic information for future emission calculation

Temporal change model obtained from LPS survey should be evaluated by sub-categories whether it is applicable to small scale industries in the same sub-category.

Article 3.2-1 Case study of questionnaire and interview survey conducted in Vietnam

1) Selecting factories for questionnaire

Large plant with high fuel consumption are mainly selected based on pre-existing survey result on air pollution, list of companies and plant owned by Ministry of Industry and Commerce, fuel sale statistics and/or production statistics. Some small and medium sized companies should be selected for each sub-category, of which survey result will be used as samples for emission factor modeling of non LPS sources.

2) Preparing survey forms

Survey form must be improved in order for the repliers to fill all the information mentioned below. For examples, survey form is to be prepared based on the forms used in Japan or other countries, and is to be revised according to any characteristics of the region and/or any item to be focused in inventory usage.

3) Sending and collecting survey forms

The survey forms should be sent to the plant and be collected.

4) Checking and correcting preliminary contents of survey forms

It is commonly found that replies is not clear or does not match to questions. Extreme values, decimal point errors or unit errors are also commonly found. Some information which is minimum requirement for emission calculation may not be filled It is necessary to investigate the replies. If any issue is found, it is necessary to ask it by phone or some alternative methods, and update questionnaire reply.

However, it is also common that the plant itself may not have measured data and impossible to fill the questionnaire. In such case, do not force plant to fill, keep questionnaire blank and estimate it in the later procedures. It is mentioned from Step 8 below.

5) Selecting factories for interview, and carrying out interview survey

If the survey form is not been returned, and the factory cannot be contacted by phone, make a visit to interview them to complete the survey questionnaire and improve.

6) Checking and revising questionnaire and interview survey result

Check the response again, and search for any potential errors and revise them. If any correct data cannot be obtained even after interview with the factory, delete the error data. For instance, when comparing more than one factory that use the same coal coming from the same source, if one of them shows an extreme calorific value, take note of the difference, and the response from the other factories may be the correct one. The data required in inventory calculation can be estimated from similar factory with similar production process, and fuel from the same source.

7) Compiling questionnaire replies and inputting them into database

After checking and correcting of Step 6), enter the data on factory, chimney, fuel type and facility into database.

As shown below, activity data and emission are to be calculated. In the process of calculation, data is to be validated. If suspicious data is found, it is necessary to be confirmed with factory, and update it if it is not correct.

8) Calculating activity data and SOx emission

Emission of PM and NOx depend on burning condition. Emission of SOx depends on fuel volume, fuel sulfur content, existence and capacity of emission gas treatment facility, and does not depend on burning condition. Therefore, calculation of SOx emission is appropriate for data reliability verification.

Table 3.2-22 Net Calorific Value by fuel type

Fuel class	Fuel type	Default Net Calorific Value Terajoules per kilotonne (TJ/kt)
Coal	Cooking Coal	28.2 b
	Other bit.coal	25.8 b
	Sub-bit.coal	18.9 b
	Lignite	11.9 b
	Peat	9.76 b
	Oven and gas coke	27.21 a
	Pat.fuel and BKB	20.7 b
Oil	Crude oil	42.61 a
	NGL	44.2 b
	Feed-stocks	43.0 c
	Additives	40.2 c
	Refinery gas	48.15 c
	LPG & ethane	53 d
	Motor gasoline	44.8 c
	Aviation fuel	44.8 c
	Kerosene	43.75 c
	Gas/diesel	43.34 c
	Heavy fuel oil	40.19 c
	Naphtha	44.5 c
	Petroleum coke	30.98 c
	Other products	40.19 c
Gas	Natural gas	50.81 c
	Gas work	28 c
	Coke oven	38.7 c
	Blast fuenace	2.47 c
Combustible renewable/wastes	Solid biomass (TJ)	15 c
	Biogas (TJ)	17.7 c
	Liquid biomass (kt)	17.7 c
	Waste other (TJ)	15 c

Note)
a1996 IPCC Guideline Reference Manual Vietnam value
b 2006 IPCC guideline for National GHG inventories values
c Gap Forum Manual values
d Based on plant questionnaire survey results, the current values in Vietnam

Calculate SOx emission at 1st, and review any issues in questionnaire data and/or any entry error.

SOx emission is calculated for each facility, by multiplying emission gas volume with emission gas concentration and operation hours. Alternatively, SOx emission is calculated by multiplying SOx emission factor with fuel consumption. Effect of emission gas treatment facility is to be multiplied also if it exists and in operation, SOx emission factor is calculated based on the following formula for each fuel type and each sub-category.

$$EF = \frac{2 \times B}{100} \times \frac{10^6}{E} \times \frac{(100 - C)}{100} \times \frac{(100 - D)}{100} \cdots\cdots (3.2\text{-}5)$$

EF	Emission factor (SO_2-kg / Fuel - TJ)
B	Sulfur content of fuel (%)
C	Sulfur retention in ash (%)
D	Efficiency of SO_2 emission control (%)
E	Net Calorific Value (TJ/kton)

If data for the calculation above is not available, assume as follows.

If emission gas concentration measurement data is not written in questionnaire, but if emission gas concentration at similar facility is available, assume that the concentration is the same. If similar facility data is not available, but if sulfur content, ash content and annual fuel usage data are available, multiply to calculate SOx emission. SOx reduction rate is to be multiplied also if SOx treatment device is in operation.

If sulfur and ash content data is not available for any factory, data stated in questionnaire from any other factory that uses similar fuel, emission factor mentioned of "Non-large scale source emission factor" explained later, or emission factor mentioned in "Simple Method" are applicable. If SOx emission factor is applied to calculate SOx emission, basically, Net Calorific Value replied in the questionnaire should be applied. When Net Calorific Value is not replied in survey form, Net Calorific Value of the fuel from same source, or the value listed in Table 3.2-22 are to be applied.

9) Validating SOx emission

By comparing SOx emission calculated based on questionnaire survey with SOx emission calculated by simple method, SOx emission is to be validated. If difference is large, it is necessary to find reasons of differences.

10) Reviewing all the input for SOx emission calculation (fuel consumption, sulfur content, etc.) and SOx emission factor and revising some of them

If difference is large and its reason is related to input data for LPS emission calculation, it is necessary to correct or re-measure input values, and re-calculate the SOx emission rate.

11) Calculating emission of other pollutants

Emission of other pollutants is to be calculated.

12) Validation of emission of other pollutants

For other pollutants, emission is to be calculated according to simple method, and compare it with the total emission of the factories calculated with questionnaire information. If difference is large, it is necessary to find reasons of differences.

13) Reviewing all the input for emission calculation (fuel consumption rate, dust removal rate, etc.) and emission factors and revising some of them

As same as in SOx, if difference is large, and its reason is related to input data for LPS emission calculation, it is necessary to correct or re-measure input values, and re-calculate the value.

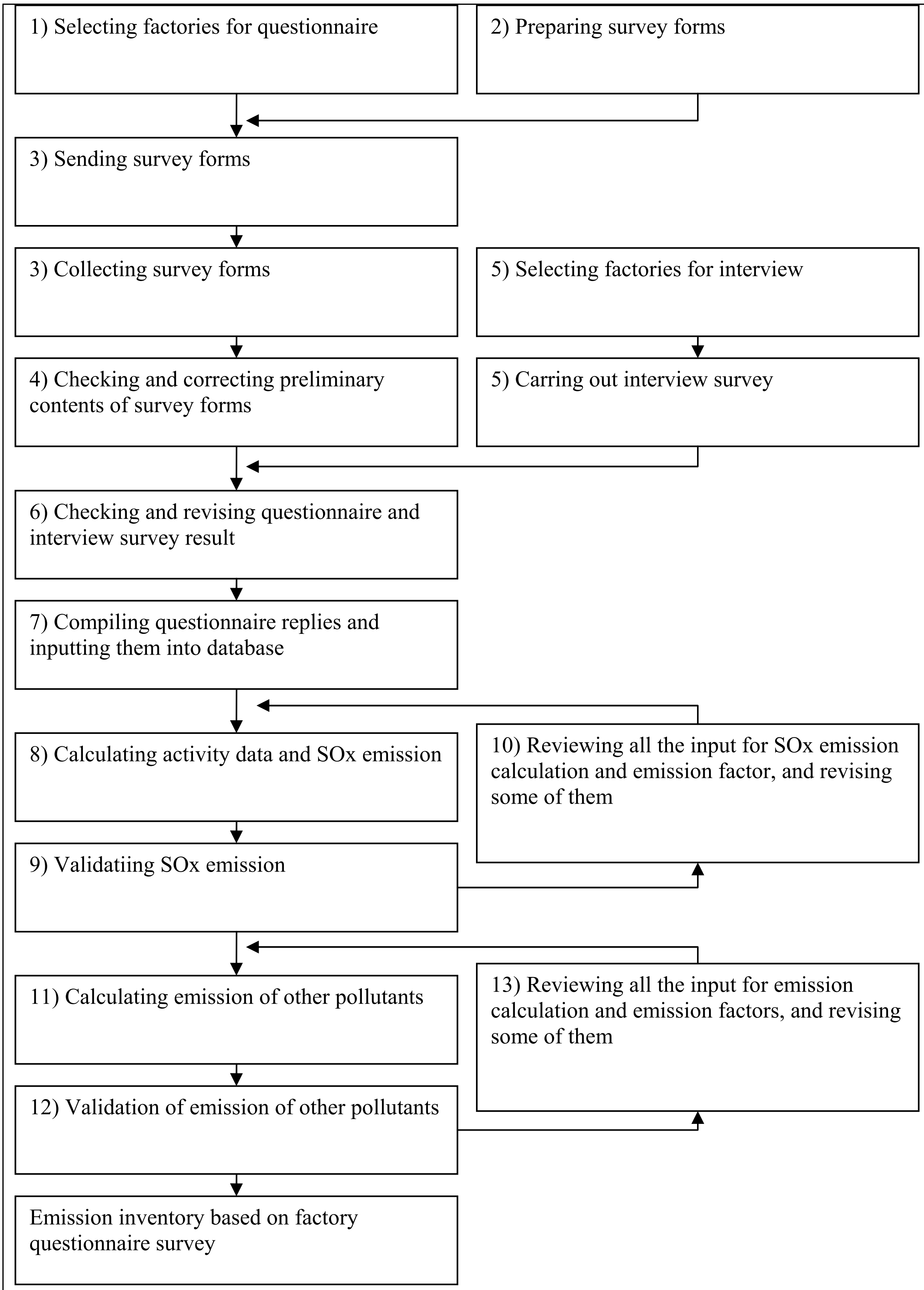

Figure 3.2-1 Outline of emission calculation of large scale sources

3.2.2.2 Activity data estimation

Fuel consumption by facility type is not generally published in energy statistics. Fuel consumption of energy industry by facility type and by fuel type is necessary to be found in statistics or survey result related to electric power of the country. Additionally, if fuel consumption rate by facility type and by fuel type is surveyed by LPS questionnaire survey or visit interview, emission can be calculated using “3.2.2 Detailed method”.

Active volume in manufacturing sector is production volume if emission is calculated by the emission factor of Table 3.2-29 to Table 3.2-32. Fuel consumption is not treated as activity data in Manufacturing sector. To be more precise, activity data shown in Table 3.2-23 are required.

Table 3.2-23 Example of activity data in manufacturing sector for detailed method -

Sub-category	Technical classification	Unit	Sub-category	Technical classification	Unit
Iron and Steel	Blast Furnace	ton pig iron/yr	Non-ferrous metals	Nickel Production	ton/yr
	Sinter Plants	ton sinter/yr		Magnesium	ton/yr
	Pelletizing Plants	ton pellet/yr		Alumina production	ton/yr
	Reheating Furnace	ton /yr	Plaster(gypsum) furnace	Plaster(gypsum) furnace	ton/yr
	Grey Iron Furnace	g/ton chgd	Lime production	Lime production	ton/yr
Non-ferrous metals	Primary Copper production	ton/yr	Cement	Cement manufacture	te clinker/yr
	Second Copper production	ton/yr	Roadstone Coating Plants	Asphalt	ton/yr
	Primary Lead production	ton/yr	Glass Production		ton/yr
	Second Lead production	ton/yr	Mineral Wool Production		ton/yr
	Primary Zinc production	ton/yr	Bricks and Tiles		ton/yr
	Second Zinc production	ton/yr	Fine Ceramic		ton/yr
	Second Aluminum	ton/yr	Enamel		ton/yr

These activity data should be compiled using all types of statistics of the country. If some of activity data is not found in any statistics of the country, following international statistics data can be used as alternative.

1) Industrial Commodity Statistics Yearbook
2) International Industrial Steel Institute (IISI: http://www.worldsteel.org/pictures/publicationfiles/SSY%202010.pdf)
3) United States Geo-Survey (USGS) Minerals Yearbook (http://minerals.usgs.gov/minerals/pubs/country)
4) Food Agricultural Organization Statistics Database (FAOSTAT: http://faostat.fao.org/Collection)

There is emission from manufacturing other than the sub-category above, or emission from small facility that has no direct relationship with the industrial process of the sub-category, which is to be calculated as small facility described below.

Small facility mainly consists of consumer industry, household, and similar facilities. Fuel consumption of these facilities is activity data. According to IEA energy statistics, it consists of consumer industry, household , agriculture, fisheries, and so forth. Biomass that is widely used in East Asia region is classified into fuel type categories, such as solid biomass, biogas, liquid biomass, waste and other unaccountable items. Therefore, when detailed method is employed, activity data other than IEA energy statistics is required.

For instance, United Nations Energy Statistics Yearbook (classified into firewood, coal and bagasse) and FAOSTAT (classified into firewood and charcoal) are available. For emission calculation, these data is assumed as Consumption = Production + Import - Export.

In some region of East Asian, it is expected that there are many household stoves and fireplaces for heating and cooking fires. On top of that, firewood, coal and carcass are used as fuel in some regions, which may contribute the air pollution of the region deeply. Biomass not only for commercial purpose but for consumption is expected to be huge, which makes that activity data is difficult to calculate from statistics. In other words, biomass statistics are normally not reliable, as there is a tendency to underestimate its consumption. Therefore, it is preferable to survey biomass consumption rate at additional private household and private business. Main survey items are fuel consumption rate by fuel type, fuel consumption rate by time, as well as burning condition within the scope identifiable.

3.2.2.3 Setting of emission factors

In detailed method, emission factor is prepared in accordance with technical (burning facility) type and fuel type, as shown in Table 3.2-24. Manufacturing and construction sector is sub-divided into technical (burning facility) type for each sub-category, rather than fuel type. For them, emission factor is prepared per production volume instead of per fuel usage. Therefore, it is not shown in Table 3.2-24.

Table 3.2-24 Detailed Method - by category and by fuel type

Category	Technical type (or sub-category)	Fuel type
Energy sector	Dry bottom boiler	Coking coal, steam coal, sub-bituminous coal, brown coal, lignite, wood, peat, coke, oven coke, residual oil, natural gas, wood
	Wet bottom boiler	Coking coal, steam coal, sub-bituminous coal, brown coal, lignite
	Fluid bed boiler	Hard coal, brown coal, wood, peat
	Gas turbine	Natural gas, gas oil, refinery gas, blast furnace gas
	Stationary engine	Natural gas, gas oil
Residential combustion	Fireplace/ sauna/ outdoor	Hard and brown coal, biomass
	Stoves	Hard and brown coal, biomass, gas, oil
	Water heaters/boilers	Hard and brown coal, biomass, gas, oil
Private business	Boilers	Hard and brown coal, biomass, heavy fuel oil, gas
	CHP (smaller-scale combined heat and power generation)	Gas, Gas oil

Emission factor for energy sector is prepared by technical type and fuel type, as shown in Table 3.2-25 to Table 3.2-28. CO_2 emission factor for detailed method based on ”2006 IPCC Guidelines” Tier2 is not mentioned in this guideline, since it is the emission factor peculiar to the country. BC and OC emission factors for simple method is also applied in detailed method since those emission factors by technical subclassification are not available until now,.

SOx emission factor of energy sector for detailed method is, as same as that for simple method, based on fuel type and sub-category to obtain the sulfur content in fuel of the country, ash content, SOx removal efficiency, which is calculated using formula 3.2.3 of “3.2.1 Simple method” and “3.2.1.3 Emission factor”. If the data of the country is not available, emission factors shown in Table 3.2-25 to Table 3.2-28 are applicable.

Table 3.2-25 Energy sector emission factors for detailed method (Part 1)

Sub-category (by technical type, and fuel type)	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Dry Bottom Boilers														
Coking Coal, Steam Coal, Sub-Bituminous Coal	g/GJ	820	324	10	1.2	NE	30	20	9	-	-	-	1	1.5
Residual Oil	g/GJ	485	210	15.1	2.3	NE	20	15	9.0	-	-	-	1	0.6
Natural Gas	g/GJ	0.3	89	39	1.5	NE	0.9	0.9	0.9	-	-	-	1	0.1
Wood and Wood waste (clean wood waste)	g/GJ	11	211	258	7.3	NE	35	25	12	-	-	-	30	4
Wet Bottom Boilers														
Coking Coal, Steam Coal, Sub-Bituminous Coal	g/GJ	820	461	10	0.8	NE	15	12	6	-	-	-	1	1.5
Wet and Dry Bottom Boiler														
Brown Coal/Lignite	g/GJ	820	286	20	1.7	NE	40	30	14	-	-	-	1	1.5

Source: CO_2, CH_4 and N_2O are from”2006 IPCC Guidelines”, the rest are from” EMEP/EEA emission inventory guidebook 2009”.

Note: “NE: Not estimated”, ”NA: Not applicable”, “Not available”, CO_2, BC and OC are to be calculated using simple method.

The range indicated in CH_4 and N_2O comes from”2006 IPCC Guidelines”, or included in”2006 IPCC Guidelines” multiple fuel type. SOx emission factor is calculated with assumption that the sulfur content in fuel is 1%.

Table 3.2-26 Energy sector emission factors for detailed method (Part 2)

Sub-category (by technical type, and fuel type)	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Fluid Bed Boilers														
Hard Coal	g/GJ	820	83	70	1.2	NE	15	12	6	-	-	-	1	61
Brown Coal	g/GJ	820	61	0.07	1.7	NE	40	30	14	-	-	-	1	61
Wood and similar wood waste	g/GJ	11	96	42	7.3	NE	35	25	12	-	-	-	11	7
Gas Turbines														
Gaseous Fuels	g/GJ	0.281	153	39.2	1	NE	0.908	0.908	0.908	-	-	-	4	1
Gas Oil	g/GJ	46	398	1.5	0.2	NE	3.0	3.0	3.0	-	-	-	4	1
Large stationary Cl reciprocating engines														
Gas Oil	g/GJ	46	1450	385	37	NE	28.1	22.4	21.7	-	-	-	0.9	0.4
Stationary reciprocating Engines														
Gas fuel (includes dual fuel 95% gas + 5% gas oil)	g/GJ	0.3	1416	407	46	NE	1.5	1.5	1.5	-	-	-	258	NA

Source: CO_2, CH_4 and N_2O are from ”2006 IPCC Guidelines”, the rest are from ” EMEP/EEA emission inventory guidebook 2009”.

Note: “NE: Not estimated”, “NA: Not applicable”, “Not available”, CO_2, BC and OC are calculated using simple method.

The range indicated in CH_4 and N_2O comes from”2006 IPCC Guidelines”, or included in”2006 IPCC Guidelines” multiple fuel type. SOx emission factor is calculated with assumption that the sulfur content in fuel is 1%.

Table 3.2-27 Energy sector (Refinery) emission factors for detailed Method

Sub-category (by technical type, and fuel type)	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Process Furnaces, Heaters and Boilers														
Residual Oil (Refinery Fuel Oil)	g/GJ	485	125	15	2.3	NE	20	15	9	-	-	-	3	0.3
Gas Oil	g/GJ	46	60	16	1.1	NE	6.5	3.2	0.8	-	-	-	0.2	0.4
LPG	g/GJ	0.3	64	37	4.0	NE	0.99	0.99	0.99	-	-	-	0.9	4
Natural Gas	g/GJ	0.3	60	39	2.6	NE	0.89	0.89	0.89	-	-	-	1	1
Reciprocating Engines - Gas fired														
Natural Gas	g/GJ	0.3	410	270	60	NE	0.89	0.89	0.89	-	-	-	110 - 693	-
Reciprocating Engines (compression injection)														
Gas Oil	g/GJ	46	1450	385	37	NE	28.1	22.4	21.7	-	-	-	-	-

Source: CO_2, CH_4 and N_2O are from “2006 IPCC Guidelines”, the rest are from “EMEP/EEA emission inventory guidebook 2009”.

Note: NE: “Not estimated”, NA: “Not applicable”, “Not available”, CO_2, BC and OC are calculated using simple method.

The range indicated in CH_4 and N_2O comes from “2006 IPCC Guidelines”, or included in “2006 IPCC Guidelines” multiple fuel type. SOx emission factor is calculated with assumption that the sulfur content in fuel is 1%.

Table 3.2-28 Energy sector (Cokes furnace) emission factors for detailed method

Sub-category (by technical type, and fuel type)	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Coke oven (with byproduct recovery)														
Coal	g/Mg Coal	515	880	15000	96	39	1810	905	653	-	-	0.56	0.10	-
Coke oven (without byproduct recovery)														
Coal	g/Mg Coal	2700	420	15000	41	39	2900	1900	1600	-	-	0.56	0.10	-

Source: CO_2, CH_4 and N_2O are from “2006 IPCC Guidelines”, the rest are from “EMEP/EEA emission inventory guidebook 2009”.

Note: NE: “Not estimated”, NA: “Not applicable”, “Not available”, CO_2, BC and OC are calculated using simple method.

The range indicated in CH_4 and N_2O comes from “2006 IPCC Guidelines”, or included in “2006 IPCC Guidelines” multiple fuel type. SOx emission factor is calculated with assumption that the sulfur content in fuel is 1%.

Manufacturing sector emission factor is shown in Table 3.2-29 to Table 3.2-32.

Table 3.2-29 Manufacturing sector (metal product) emission factors for detailed method

Sub-category	Technical classification	Unit	SOx emission factor	NOx emission factor	CO emission factor
Iron and Steel	Blast Furnace	g/ton pig iron	38	8	354
	Sinter Plants	g/ton sinter	220	558	18000
	Pelletizing Plants	g/ton pellet	11	329	64
	Reheating Furnace	g/ton	13	170	65
	Grey Iron Furnace	g/ton chgd	1720	285	26200
Non-ferrous metals	Primary Copper production	g/ton	10276	7062	-
	Second Copper production	g/ton	1225	400	4690
	Primary Lead production	g/ton	6192	-	-
	Second Lead production	g/ton	2203	186	-
	Primary Zinc production	g/ton	5292	-	-
	Second Zinc production	g/ton	12232	1501	-
	Second Aluminum	g/ton	603	449	-
	Nickel Production	g/ton	18000	-	-
	Magnesium	g/ton	335	3050	-
	Alumina production	g/ton	637	945	135

Source: “EMEP/EEA emission inventory guidebook 2009”

Table 3.2-30 Manufacturing sector (Mining product, Part 1) emission factors for detailed method

Sub-category	Technical classification	Unit	SOx emission factor	NOx emission factor	CO emission factor
Plaster(gypsum) furnace	Plaster(gypsum) furnace	g/ton	-	1058	-
Lime production	Lime production	g/ton	1414	2236	1936

Source: “EMEP/EEA emission inventory guidebook 2009”

Table 3.2-31 Manufacturing sector (Mining product, Part 2) emission factors for detailed method

Sub-category	Technical classification	Unit	SOx emission factor	NOx emission factor	CO emission factor	NMVOC emission factor
Cement	Cement manufacture	g/te clinker	374	1550	2000	100

Source: "EMEP/EEA emission inventory guidebook 2009"

Table 3.2-32 Manufacturing sector (Mining product, Part 3) emission factors for detailed method

Sub-category	Technical classification	Unit	SOx emission factor	NOx emission factor	CO emission factor
Roadstone Coating Plants	Asphalt	g/ton	17.7	35.6	200
Glass Production		g/ton	1962	2931	6.1
Mineral Wool Production		g/ton	223	1625	525
Bricks and Tiles		g/ton	166	142	415
Fine Ceramic		g/ton	247	850	456
Enamel		g/ton	4770	3373	2400

Source: "EMEP/EEA emission inventory guidebook 2009"

SOx emission factor in detailed method of small scaled facility such as household and private business is calculated based on formula (3.2-3) of "3.2.1.3 Setting of emission factors" in "3.2.1 Simple method", after obtaining sulfur content and ash content of the fuel in the country, and de-SOx removal efficiency, that is similar to Simple method. If the data for the country is not available, Table 3.2-33 to Table 3.2-36 could be applied.

The emission factor of other pollutant in detailed method of small scaled facility such as household and private business are shown in Table 3.2-33 to Table 3.2-36.

Table 3.2-33 Household emission factors (Part 1) for detailed method

Sub-category (by technical and by fuel type)	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Fireplaces, Saunas and Outdoor Heaters														
Solid Fuel (not biomass)	g/GJ	500	60	5000	6000	5	350	330	330	-	-	-	147	-
Gaseous Fuels	g/GJ	0.5	50	50	20	NE	0.5	0.5	0.5	-	-	-	1	1
Biomass	g/GJ	10	50	6000	1300	10	900	860	850	-	-	-	NA	9
Stoves														
Solid Fuel (not biomass)	g/GJ	900	100	5000	600	NE	500	450	450	-	-	-	267 - 2650	-
Wood and similar wood waste	g/GJ	10	50	6000	1200	5	850	810	810	-	-	-	230 - 4190	1.6 - 27
Natural Gas	g/GJ	0.5	50	30	10	NE	0.5	0.5	0.5	-	-	-	1	1
Liquid Fuels	g/GJ	140	50	100	20	NE	15	10	10	-	-	-	0.9 - 2.3	0.7 - 3.5

Source: CO_2, CH_4 and N_2O are from “2006 IPCC Guidelines”, the rest are from “EMEP/EEA emission inventory guidebook 2009”.

Note: NE: “Not estimated”, NA: “Not applicable”, “Not available”, CO_2, BC and OC are calculated using simple method.

The range indicated in CH_4 and N_2O comes from “2006 IPCC Guidelines”, or included in “2006 IPCC Guidelines” multiple fuel type.

Table 3.2-34 Household emission factors (Part 2) detailed method

Sub-category (by technical and by fuel type)	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Small (single household scale) boilers														
Solid Fuel (not biomass)	g/GJ	900	130	4000	300	NE	400	380	360	-	-	-	147	-
Wood and similar wood waste	g/GJ	30	120	4000	400	3.8	500	475	475	-	-	-	200	-
Natural Gas	g/GJ	0.5	70	30	10	NE	0.5	0.5	0.5	-	-	-	1	1
Liquid Fuels	g/GJ	140	70	40	15	NE	5	3	3	-	-	-	0.7 - 5.8	0.2
Advanced wood combustion techniques < 1MWth - Advanced stove														
Coal Fuels	g/GJ	450	150	2000	300	NE	250	240	220	-	-	-	147	-
Wood	g/GJ	20	90	3000	250	NE	250	240	240	-	-	-	200	-
Advanced wood combustion techniques < 1MWth - Advanced fireplaces														
Wood	g/GJ	20	90	4500	450	NE	250	240	240	-	-	-	200	-
Advanced wood combustion techniques < 1MWth - Pellet stove														
Wood	g/GJ	20	90	500	20	NE	80	76	76	-	-	-	200	-

Source: CO_2, CH_4 and N_2O are from “2006 IPCC Guidelines”, the rest are from “EMEP/EEA emission inventory guidebook 2009”.

Note: NE: “Not estimated”, NA: “Not applicable”, “Not available”, CO_2, BC and OC are calculated using simple method.

The range indicated in CH_4 and N_2O comes from “2006 IPCC Guidelines”, or included in “2006 IPCC Guidelines” multiple fuel type.

Table 3.2-35 Private business (small scale) emission factors (Part 1) for detailed method

Sub-category (by technical and by fuel type)	Unit	SO_x	NO_x	CO	NM VOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Medium size (> 50 kWth to <=1 MWth) boilers														
Coal Fuels	g/GJ	900	160	2000	200	NE	200	190	170	-	-	-	0.7 - 14	0.5 - 1.4
Natural Gas	g/GJ	0.5	70	30	3	NE	0.5	0.5	0.5	-	-	-	1	1
Medium size (> 1 MWth to <=50 MWth) boilers														
Coal Fuels	g/GJ	900	180	200	20	NE	80	76	72	-	-	-	0.7 - 14	0.5 - 1.4
Natural Gas	g/GJ	0.5	70	20	2	NE	0.5	0.5	0.5	-	-	-	1	1
Advanced coal combustion techniques <1MWth - Manual Boiler														
Coal Fuels	g/GJ	450	200	1500	100	NE	150	140	130	-	-	-	87	0.7
Wood	g/GJ	20	150	3000	250	NE	80	76	76	-	-	-	11	7
Advanced coal combustion techniques <1MWth - Automatic Boiler														
Coal Fuels	g/GJ	450	200	400	20	NE	80	76	72	-	-	-	1 - 14	0.7
Wood	g/GJ	20	150	300	20	NE	70	66	66	-	-	-	11	7

Source: CO_2, CH_4 and N_2O are from “2006 IPCC Guidelines”, the rest are from “EMEP/EEA emission inventory guidebook 2009”.

Note: NE: “Not estimated”, NA: “Not applicable”, “Not available”, CO_2, BC and OC are calculated using simple method.

The range indicated in CH_4 and N_2O comes from “2006 IPCC Guidelines”, or included in “2006 IPCC Guidelines” multiple fuel type.

Table 3.2-36 Private business (small scale) emission factors (Part 2) for detailed method

Sub-category (by technical and by fuel type)	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Gas Turbines														
Natural Gas	g/GJ	0.281	153	39.2	1	NE	0.908	0.908	0.908	-	-	-	4	1.4
Gas Oil	g/GJ	46.1	398	1.49	0.19	NE	3	3	3	-	-	-	0.7	0.4
Stationary reciprocating Engines –gas-fired, includes dual fuel														
Gas Fuels (includes dual fuel 95% gas +5% gas oil)	g/GJ	0.281	1420	407	46	NE	1.5	1.5	1.5	-	-	-	4	1.4
Reciprocating Engines														
Gas oil	g/GJ	46.1	1450	385	37.1	NE	28.1	22.4	21.7	-	-	-	0.7	0.4

Source: CO_2, CH_4 and N_2O are from “2006 IPCC Guidelines”, the rest are from “EMEP/EEA emission inventory guidebook 2009”.

Note: NE: “Not estimated”, NA: “Not applicable”, “Not available”, CO_2, BC and OC are calculated using simple method.

3.2.2.4 Temporal change and spatial distribution

The same as in simple method, set the spatial distribution and temporal change model, and distribute the emission rate.

3.3 Mobile source

3.3.1 Estimation Target

Target sources are composed of cars, motorbikes, aircrafts, railways, and vessels. Off-road mobile to be included “manufacturing and construction” and “agricultural, forestry and fishery” is excluded. Emission from cars and motorbikes occupies most of mobile source emission. Also, emission of mobile source includes SO_2, NOx, CO, NMVOC, NH_3, PM_{10} and PM2.5. NMVOC of non-combustion emission from car gasoline evaporation exists. Evaporation emission of NMVOC from diesel cars is much less.

3.3.2 Estimation of air pollutants emission from automobiles

All air pollutants emission can be estimated using the same method as fuel combustion of stationary source. The method is similar to IPCC Tier-1, but its difference is classification of fuel types in details. Emission is estimated by multiplying average emission factor for certain fuel and annual fuel consumption of the sub-categories (cars, motorbikes, aircrafts, railcars, vessels). It is recommended that simple method of emission estimation is used for SO_2 and CO_2 about combustion portion of fuel. For other air pollutants, simple method can only provide rough emission. Simple method can not clearly identify 3-dimensional catalysts or other emission reduction using technology, so simple method is restricted to use for countries where they are hard to use detailed method.

The default emission factors in simple method are mainly based on 1996 IPCC Guidelines, and EMEP/EEA Guidebook. The activity data is annual fuel consumption rate of each sector, and data to be reported by IEA Energy Statistics is available.

Car emission comes from fuel combustion, evaporation loss from cars (except losses during fuel filling), car tire wear, railroad dusts and so forth. In other words, air pollutants from cars have emission during travel (when hot, start and cold), evaporated gas (DBL, hot soak loss, running loss), lifting, tire and brake wear. Emission can be estimated following formula.

Emission = During travel (when hot, start and cold) + Evaporated gas (DBL [Diurnal bridging loss], hot soak loss, running loss) + Lifting + Tire and brake wear emission ·································(3.3-1)

In this guideline, estimation of emission during travel (when hot, start and cold) and evaporated gas (DBL, hot soak loss, running los) is targeted.

3.3.2.1 Automobile emission by fuel combustion

1. Simple method

1) Outline of emission estimation method

Estimation method to be similar of IPCD Tier1 of emission from automobiles is used.

$$Ei = \sum_{j}\sum_{m} (FC_{j,m} \times EF_{i,j,m}) \qquad \cdots\cdots (3.3\text{-}2)$$

E_i = Targeted air pollutant i [g],

$FC_{j,m}$ = car type j, fuel m consumption [kg],

$EF_{i,j,m}$ = Emission factor (targeted air pollutant i, car type j, fuel m [g/kg].)

The automobile category is composed of passenger car, light and heavy duty truck, motorbikes and so on. The fuel is classified into gasoline, gas oil, LPG, natural gas. In the above formula is required fuel consumption by country and by car type, and the average factor by car type.

2) Fuel consumption rate measuring

Fuel consumption (gasoline, gas oil, LPG) by country can mostly be identified. However, if vehicles such as CNG buses are relatively small fuel consumption, they can be ignored.

In EMEP/EEA Guidebook Tier-1, the fuel consumption rate by fuel type for 4 types of cars to be shown in Table 3.3-1 is set up. Using this table, the energy statistics of fuel consumption can be classified into each car type: passenger cars, light truck, small buses, heavy truck, large buses and motorbikes.

Table 3.3-1 Fuel consumption rate by fuel type

Car type	Fuel type	Fuel consumption rate (g/km)
Passenger cars	Gasoline	70
	Gas oil	60
	LPG	57.5
Light truck, small buses	Gasoline	100
	Gas oil	57.5
Heavy Truck, large buses	Gas oil	240
	CNG (Bus)	240
Motorbikes	Gasoline	35

Source: EMEP/EEA Guidebook

3) Setting of emission factors

Emission factors by air pollutants and by car types to be based on IPCC Tier-1 are shown in Table 3.3-2. Tier1 emission factors are based on cold start and European traffic characteristics. The emission factors are based on 1995 European activity data and Tremove 2.52 version. The maximum value is emission factor for uncontrolled cars, minimum value shows average European emission factors in 2005, pre-application of EURO4. The PM of cars is equivalent to $PM_{2.5}$, so TSP, PM_{10}, and $PM_{2.5}$ are treated as the same emission factors as PM. BC and OC is set by PM emission factor and Bond thesis.

Table 3.3-2 Emission factor by target pollutant and by car type[8]

Car Type	Fuel Type	CO (g/kg fuel)			NMVOC (g/kg fuel)			NOx (g/kg fuel)		
		Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum
Passenger car	Gasoline	132	50	350	14	5	40	14.5	6	35
	Diesel oil	4.7	2	11	1.1	0.5	2.5	11	9	14
	LPG	68	40	115	10	6	18	15.5	6	40
Small truck, small bus	Gasoline	155	80	300	14	5	40	24	14	40
	Diesel oil	11	8	15	1.75	1.5	2	15	13	19
Large truck, large bus	Diesel oil	8	6.5	10	1.6	1	2.5	37	30	45
	CNG (bus)	5.7	2.2	15	0.26	0.1	0.67	13	5.5	30
Motorbike	Gasoline	490	340	700	114	65	200	9.5	11	8

Car Type	Fuel Type	PM (g/kg fuel)			N_2O (g/kg fuel)			NH_3 (g/kg fuel)		
		Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum
Passenger car	Gasoline	0.037	0.030	0.045	0.213	0.130	0.350	0.173	0.030	1.000
	Diesel oil	1.700	0.700	4.000	0.087	0.050	0.150	0.018	0.016	0.020
	LPG	0.000	0.000	0.000	0.194	0.090	0.420	0.173	0.150	0.200
Small truck, small bus	Gasoline	0.030	0.020	0.045	0.197	0.130	0.300	0.140	0.030	0.650
	Diesel oil	2.800	2.000	4.000	0.069	0.040	0.120	0.014	0.013	0.015
Large truck, large bus	Diesel oil	1.200	0.700	2.000	0.061	0.025	0.120	0.015	0.012	0.020
	CNG (bus)	0.020	0.010	0.036	n.a			n.a		
Motorbike	Gasoline	2.700	1.500	5.000	0.059	0.050	0.070	0.063	0.050	0.080

Car Type	Fuel Type	BC (g/kg fuel)	OC (g/kg fuel)
Passenger car	Gasoline	0.013	0.014
	Diesel oil	2.280	0.720
	LPG	0.000	0.000
Small truck, small bus	Gasoline	0.013	0.014
	Diesel oil	2.280	0.720
Large truck, large bus	Diesel oil	1.140	0.360
	CNG (bus)	0.000	0.000
Motorbike	Gasoline	1.450	1.550

Car Type	Fuel Type	kgCO_2/kg fuel	CH_4 (kg/TJ)	SO_2 (g/kg fuel)
All car types	Gasoline	3.180	33.000	20×S content (%)
	Diesel oil	3.140	3.900	20×S content (%)
	LPG	3.017	62.000	20×S content (%)
	CNG or LNG	2.750	3.900	20×S content (%)

Source: EMEP/EEA Guidebook, 2006 IPCC Guidelines

4) *Temporal change and spatial distribution*

Traffic count survey in major cities is implemented, and temporal change is estimated from hourly traffic volume by car type.

Spatial distribution is assigned from fuel consumption by province and by district.

2. Detailed method

1) *Definition of terminology*

Road-link is roads from one junction to the next junction, where the traffic that does not fluctuate too much, as shown in Figure 3.3-1.

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[8] A technology-based global inventory of black and organic carbon emission s from combustion, Tami C. Bond et al., 2004, Journal of Geophysical Research, Vol. 109, D14203

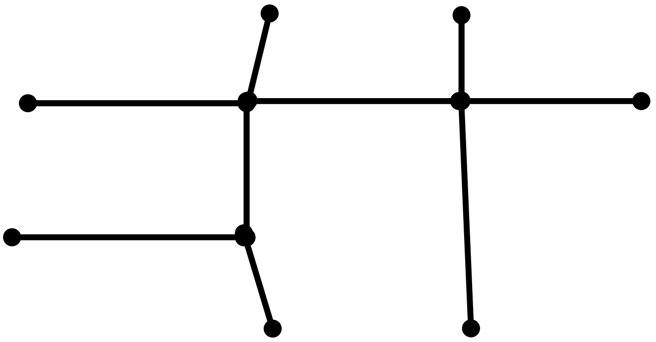

Figure 3.3-1 Example of road link

OD survey is due to survey mainly automobiles from starting point to arrival point, and traffic volume is summed up by regional (zone) as totalization unit. OD survey by questionnaire method, car operation per day such as purpose of use, destination and parking areas for car users and owners is surveyed. Status of ownership and use for private passenger cars par household, movement of one day operation, and loading good status (items, weight) for trucks is surveyed.

Table 3.3-3 OD questionnaire survey

	Starting point, arrival point, address	Travel distance meter indicator (km)	
1st location		1st Start time :	Moving distance (km)
		. km	2nd - 1st Km
2nd location		2nd Start time :	
		. km	3rd - 2nd Km
3rd location		3rd Start time :	
		. km	4th - 3rd Km
4th location		4th Start time :	
		. km	5th - 4th Km
5th location		5th Start time :	
		. km	

2) Outline of emission estimation method

Emission from vehicles including motorcycles, is shown in Figure 3.3-2, is calculated by multiplying travel volume and emission factor. That is, activity data is the travel volume. Travel volume (number of vehicles·km) is estimated by main roads as major roads and other roads as minor roads. Emission by each road link is estimated for major roads. Emission of minor roads is estimated as the total of target area, or per mesh of emission to be based on objective of inventory. The travel volume of major roads and minor roads is calculated by multiplying the traffic volume by time and by car type, and travel kilometers.

Major road emission (g/h)
=Travel volume by road link (number of vehicles·km/h)×Emission factor (g/ number of vehicles·km):(3.3-3)
Minor roads emission (g/h)
=Minor roads travel volume (number of vehicles·km/h)×Emission factor (g/ number of vehicles·km): (3.3-4)

The travel volume of major roads by car type, by hour and by road link is required for estimation. Using the result of travel count survey or traffic volume assignment simulation result, the traffic volume at survey points by car type, by hour and by road-link is estimated, traffic volume by zone, by car type and by hour is estimated by the above results and its road link distance. Based on above results, pattern by road type and by road hour is arranged, and then road link not to be surveyed is assigned traffic volume by hour and by car type. The emission factors are set by composition of car type by exhaust gas regulation and its corresponding emission standard of regulation cars.

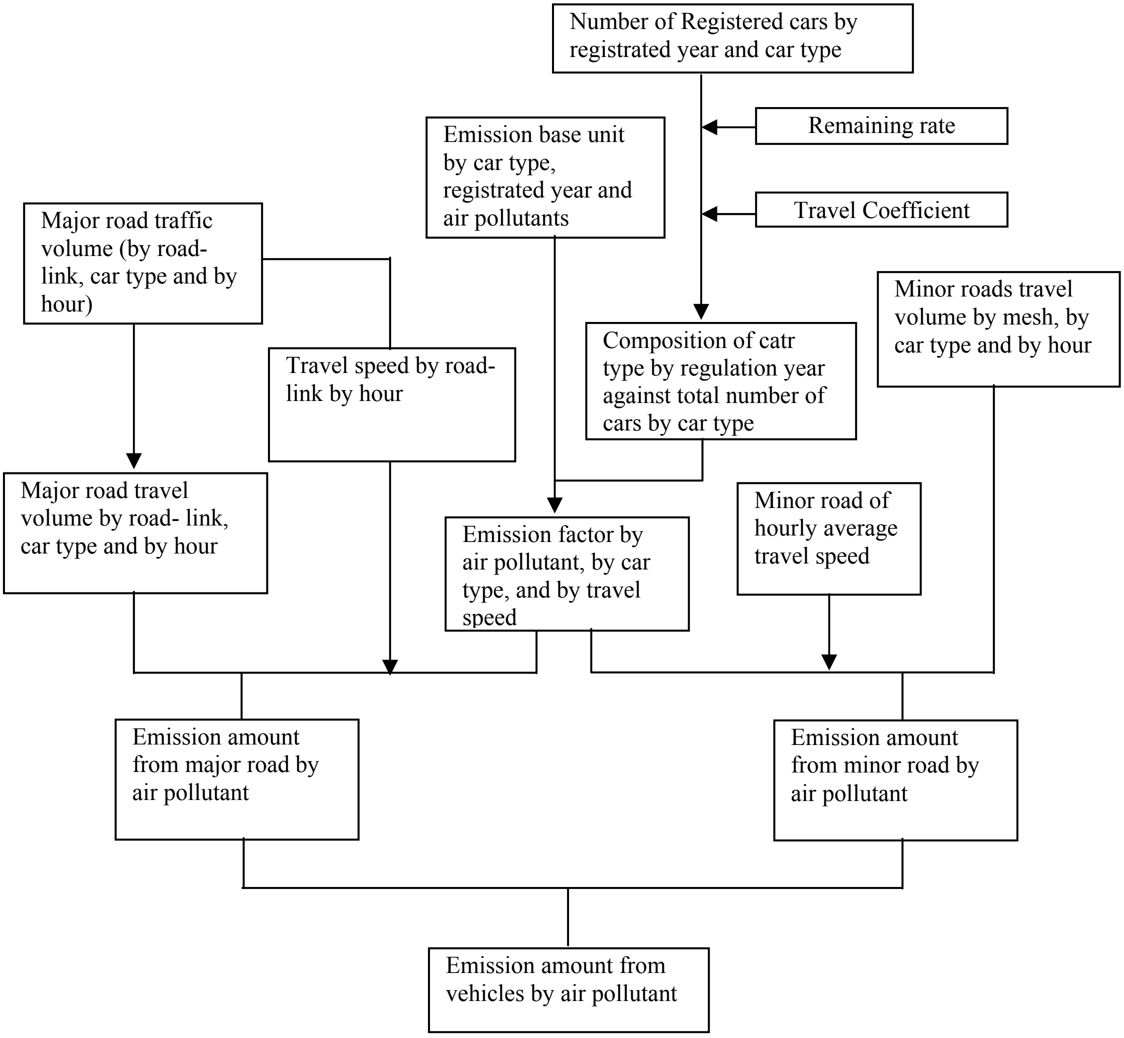

Figure 3.3-2 Estimation flow of emission from automobile

3) Estimation of active data

Activity data, that is, travel volume (number of vehicles·km) is estimated by roads to be classified into major road and minor road for inventory target area. The estimation methods of travel volume are arranged as follows.

Table 3.3-4 Estimation methods list of travel volume (activity data)

Source to measure travel volume	Major road	Minor road
Use of traffic count survey	Implementation of actual survey of traffic count in the target area inventory (”A”)	
Use of OD data	Method of traffic assignment simulation to be based on OD Table (”B”)	Method based on OD Table(”C.”)
Use of energy statistics		Method of travel volume estimation at minor roads from energy statistics (“D”)

Major roads information of target area for road status and vicinity information needs to be arranged for line source diffusion calculation (simulation).

- Road position coordinates and end point distance as line sources
- Road structure
- Number of lanes
- Road width and sidewalk width
- Road surface height
- Traffic flow (2-way, or 1-way traffic)

A. Method using traffic count survey result (major roads)

Automobile travel volume for inventory target area to be calculated from actual traffic count survey is ideal. If actual survey result exists, its use can be considered. East-Asia area is rapid economic growth, number of registered cars grows rapidly, and the latest traffic volume to be based on actual survey is preferable. Therefore, actual survey of traffic volume is required.

Method of actual traffic count survey is described as follows.

A) Number of survey points

Number of survey points is determined by consideration of population, size and number of registration vehicle in target area. Road traffic census in Japan, roads with more than provincial road level and 12-hour day time traffic volume to be more than 10,000 are selected for survey points.

B) Setting of location for survey points

In traffic volume survey for emission inventory estimation, based on the objective of inventory use, survey points are determined. The locations of existing survey are also good candidates for survey points. And it is also necessary to set the survey points based on the aspect of air pollution simulation verification. The survey area should cover the city center and the major roads to the suburbs areas. The priority survey points are as follows:

- Ambient air monitoring station or roadside air monitoring station
- Roads that represent road type (highway, state roads, provincial roads, country roads, town and village roads)
- Downtown, suburbs
- Most heavy traffic junctions in the downtown
- Major roads and its equivalent road
- Downtown is classified into some areas, some area to be considered important is allocated as emphasized survey points
- Setting of survey points are selected among the traffic volume of road link is not fluctuate too much (from junction to junction), do not have problems about security and safety.

C) Setting car type

Typical car types are set, and traffic volume by car type is counted. Car types are classified into approximately 8. Typical car types are classified into motorcycles, passenger cars, truck (light, medium, heavy), bus (small, medium, large) etc.

D) Measurement time zone

Day time 12-hour or 24-hour measurement is implement. If possible, implementation of 14-hour, 16-hour survey instead of 12-hour survey is desirable.

24-hour survey points are set to select among points such as neighborhood of monitoring station and junction of the heaviest traffic volume.

For setting of survey points, 12-hour survey points is selected more, and traffic volume points are allocated to calculate hourly pattern from results of 24-hour survey points.

E) Preparation of survey plan

・Weekday survey

Weekday survey should be considered the condition of the country, the survey to be selected the day with average traffic volume during one year is implemented. In Japan, most of the selection method is as follows: weekday survey when traffic volume does not fluctuate too much during the season, and weekday is selected from Tuesday to Thursday. However, before and after holiday, bad weather day, and other days expected to have irregular traffic condition is excluded.

・Holiday survey

Holiday survey is implemented on Saturday, Sunday, or public holidays to be selected one day. However, bad weather day, and other days expected to have irregular traffic condition is excluded for holiday survey.

F) Survey method

Team formation and number of persons at the survey points is assigned for counting of 2-way traffic simultaneously. The survey is implemented by using over 4 times-counters. The survey is implemented following standard pattern: 30 minutes survey and 30 minutes break for one hour. In such case, the traffic volume for one hour is calculated double of 30 minutes traffic survey count. Actual survey count is basically used, but there are big cities which have many motorcycles traffic count so much such as Hanoi and Ho Chi Minh City, video camera can be used for counting.

G) Estimation method of travel volume by using traffic count survey result

Estimation method of automobile travel volume by using traffic count survey result is shown in Figure 3.3-3. Travel volume is estimated by multiplying the traffic volume and distance of road link.

- Estimation of day/night ratio

For 12-hour traffic volume survey, 24-hour traffic volume is estimated from day/night ratio from the 24-hour traffic volume survey. Day/night ratio by area, by road type and by car type is calculated from 24-hour traffic volume survey result. And 24-hour traffic volume is estimated by multiplying the day/night ratio and daytime 12-hour traffic volume.

Day/night ratio = 24-hour traffic volume / daytime 12-hour traffic volume····························(3.3-5)

- Estimation of hourly traffic volume pattern

For hourly traffic volume pattern, distribution ratio of hourly traffic volume by area, by road type and by car type is calculated from traffic volume at 24-hour survey points. Hourly traffic volume is estimated by multiplying the distribution ratio and 24-hour traffic volume.

- Estimation of annual average traffic volume

As traffic volume fluctuates depending on the day, for estimation of annual average traffic volume, if possible, survey of traffic volume during weekdays and holidays is implemented, weekday traffic volume is modified by using above results, and annual average of traffic volume is estimated.

- Estimation of traffic volume by link

Road links near survey points are assigned from the above hourly traffic volume of survey points.

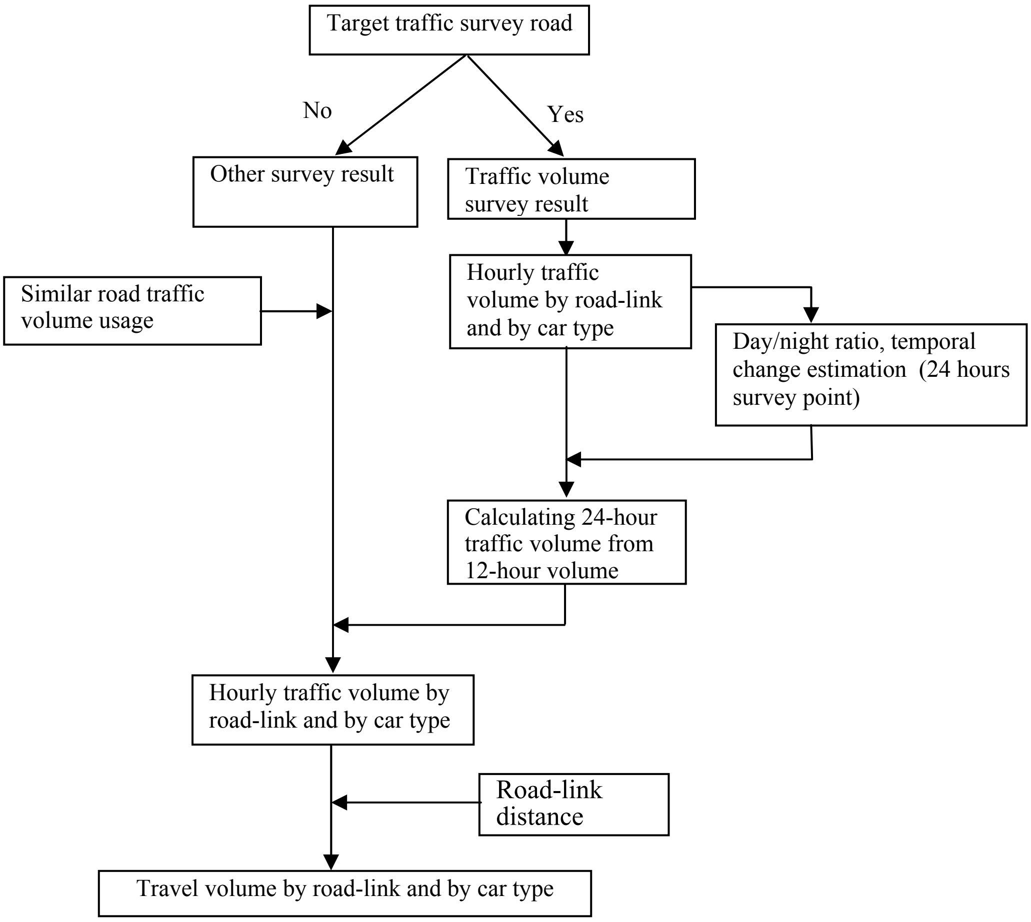

Figure 3.3-3 Estimation method of automobile travel volume by using traffic survey result

- Setting of traffic volume by road link of non-targeted survey points

If other survey data is available, the data is used. Otherwise, total traffic volume is estimated from traffic volume of road next to the survey points and similar roads. And roads are categorized by traffic volume, by composition ratio and temporal change, roads to be categorized by composition ratio and by temporal change is estimated, hourly traffic volume by road link and by car type is estimated the above as the reference.

B. Estimation method of travel volume by using traffic assignment simulation result (major roads)

Based on base-year OD data, the shortest time routes from departing to arrival zone is searched, that route is assigned each OD travel volume, and traffic volume by road line or route is estimated, travel volume is estimated by multiplying the travel volume and distance of route and line.

The distributed traffic volume to be estimated is not number of target car type, based on PCU (Passenger Car Unit) where each passenger car is treated as 1, and traffic volume by car type is estimated. Number of target car types can be 3 to 4. Therefore, traffic volume by car type is assigned by estimation target car types of traffic assignment simulation.

Hourly traffic volume by road link and by car type is estimated from assignment traffic volume which is applied to distribution ratio by car type and pattern of hourly traffic volume from traffic count survey result.

C. Method using OD Table (minor roads)

As number of trips for in-in, in-out and out-in of zone of OD Table as certain pre-conditions, the minor road traffic volume or travel volume is estimated based.

The zone in-in traffic volume is, vehicle run on the minor roads, and the travel volume is estimated by multiplying the traffic volume and average trip length.

The zone in-out traffic volume and out-in volume is supposed to be from the starting point to the major road, or get off from the major road and reach the destination by using the minor roads, and the travel volume is estimated by multiplying in-out and out-in traffic volume by zone with average access distance.

*Reference: Methods that use traffic volume assignment simulation based on OD Table (Source: NOx total mass emission control standards manual)

[City model]

City model is a model which is based on assumption of assignment target road network and other minor road as grid type. Minor road travel volume of area (a) is estimated following formula.

Minor road travel volume (number of vehicles·km) = $Q \times L$ ···(3.3-6)

Q: Generated concentration of traffic volume (except in-in)

L: Average trip length (km)

$L = a / LT + a / 4P$ ··(3.3-7)

a: Zone area (km^2)

LT: Total length of assignment road network (major road and semi-major road) (km)

P: Total length of minor roads (km)

[Suburban model]

Suburban model is based on assumption minor roads are regularly intersected by major road to be targeted assignment. In the area (within the major road), the minor road travel volume is estimated following formula.

Minor road travel volume (number of vehicles·km) = $Q \times L$ ···(3.3-8)

Q: Generated concentration of traffic volume (except in-in)

L: Average trip length (km)

S: Minor roads interval length (km)

P: Total length of minor roads (km)

LT: Total length of major roads and semi-major roads (km)

D. Method of using energy statistics data (minor roads)

If OD data can not be obtained, energy statistics and traffic volume actual survey or existing traffic volume data is used to estimate minor roads travel volume. Estimation flow of minor road travel volume is shown in Figure 3.3-4.

The travel volume of minor roads by car type of target country can be estimated by subtracting the car travel total distance (km) by car type of the country from energy statistics with car travel distance total by car type of major roads.

Total vehicle kilometers by car type of minor roads (km)

= Whole country total vehicle kilometers by vehicle type (km) - Major roads total vehicle kilometers by vehicle type (km) (3.3-9)

Traffic volume by car type of minor roads (number of vehicles·km) is estimated by multiplying vehicle kilometers by vehicle type of minor roads (km) with traffic volume (number of vehicles) by vehicle type, time frame. Traffic volume by vehicle type, time frame is set using traffic count survey result or existing survey result.

Traffic volume total by car type of minor roads (number of vehicles·km)
= Minor roads travel distance total by vehicle type (km) × Travel volume by vehicle type, time frame (number of vehicles) ···(3.3-10)

However, if statistics data of the country for vehicle travel total kilometers (km) is available, the year of survey or survey contents is checked if it is available, vehicle kilometers of minor roads are estimated.

Also, minor roads of travel volume can be estimated by questionnaire survey using OD survey form as shown in Table 3.3-3. Travel volume of minor roads by province, and by county is distributed existing travel volume data and energy consumption rate data, or questionnaire OD survey result.

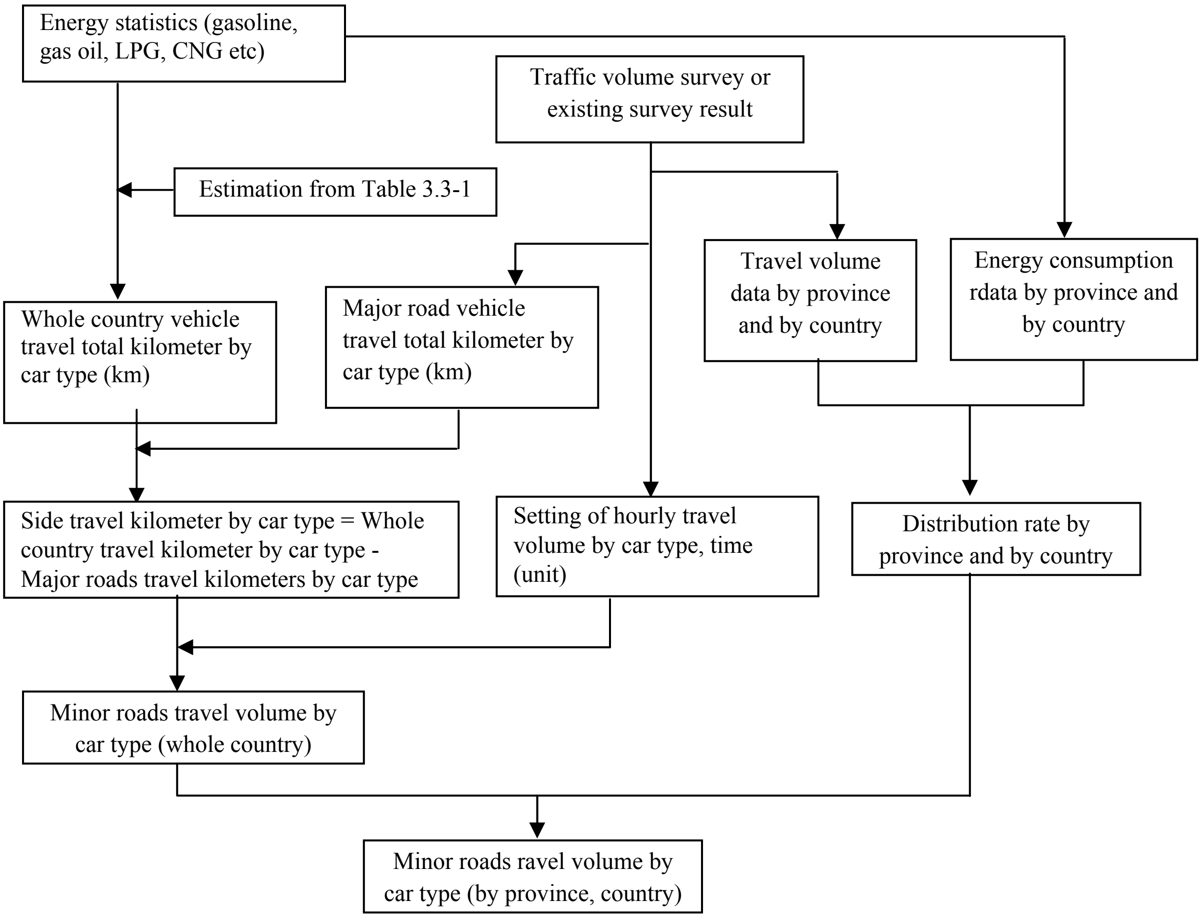

Figure 3.3-4 Estimation flow of minor roads travel volume by energy statistics

E. The gap between fuel consumption and emission to be estimated by travel volume and energy statistics

Estimation of minor road fuel consumption, the fuel consumption of vehicle in energy statistics is subtracted from fuel consumption of major road, and the result is treated as minor road fuel consumption; and if the total emission is distributed in the area targeted, the emission from travel volume do not have gap from emission based on energy statistics.

Fuel consumption is estimated by each travel volume of major roads and minor roads, and the fuel consumption of energy statistics to have gap with the fuel consumption by the above estimation is high probability. In such case, it is necessary to verify the conformity of energy statistics and fuel consumption. The conformity verification method is to restrict particular area for compliance of fuel consumption and emission factor, the differences of fuel consumption are analyzed.

4) Setting of emission factors

Emission factors are divided into two factors: average emission factor and detailed emission factor.

A. Average emission factor

Based on EMEP/EEA Guidebook Tier-2, average emission factor for passenger cars, light duty trucks, heavy duty trucks, large buses and motorcycles is determined, as shown from Table 3.3-5 to Table 3.3-9. These values derive from EMEP/EEA Guidebook Tier-3 emission factors to be estimated by European typical travel speed, outside temperature, combination mode for highways, suburban roads and city roads, and trip length.

BC and OC emission factor is determined by $PM_{2.5}$ emission factor and its ratio, as shown in Table 3.3-10.

By using these emission factors, emission is estimated by using emission factor for pre and post measure, the emission reduction effect is compared with control measures technology.

Table 3.3-5 Passenger car average emission factor

Type	Technology	CO	NMVOC	NOx	N_2O	NH_3	$PM_{2.5}$
Units		g/km	g/km	g/km	g/km	g/km	g/km $PM_{2.5}$=PM_{10}=TSP
Gasoline <1.4L	PRE ECE	39.2	3.65	1.89	0.010	0.0025	0.0024
Gasoline <1.4L	ECE 15/00-01	30.5	3.05	1.89	0.010	0.0025	0.0024
Gasoline <1.4L	ECE 15/02	22.8	2.94	2.06	0.010	0.0025	0.0024
Gasoline <1.4L	ECE 15/03	23.2	2.94	2.23	0.010	0.0025	0.0024
Gasoline <1.4L	ECE 15/04	13.6	2.51	2.02	0.010	0.0025	0.0024
Gasoline <1.4L	Open Loop	11.9	2.22	1.49	0.010	0.0025	0.0024
Gasoline <1.4L	PC Euro1 - 91/441/EEC	4.23	0.564	0.441	0.023	0.0731	0.0024
Gasoline <1.4L	PC Euro2 - 94/12/EEC	2.39	0.301	0.242	0.012	0.0958	0.0024
Gasoline <1.4L	PC Euro3 - 98/69/EE I	2.14	0.169	0.098	0.005	0.0276	0.0011
Gasoline <1.4L	PC Euro4 - 98/69/EE II	0.710	0.123	0.062	0.005	0.0276	0.0011
Gasoline 1.4 -2.0L	PRE ECE	39.2	3.80	2.47	0.010	0.0025	0.0024
Gasoline 1.4 -2.0L	ECE 15/00-01	30.5	3.19	2.47	0.010	0.0025	0.0024
Gasoline 1.4 -2.0L	ECE 15/02	22.8	3.081	2.33	0.010	0.0025	0.0024
Gasoline 1.4 -2.0L	ECE 15/03	23.2	3.08	2.43	0.010	0.0025	0.0024
Gasoline 1.4 -2.0L	ECE 15/04	13.8	2.66	2.58	0.010	0.0025	0.0024
Gasoline 1.4 -2.0L	Open Loop	6.68	1.73	1.26	0.010	0.0025	0.0024
Gasoline 1.4 -2.0L	PC Euro1 - 91/441/EEC	3.93	0.645	0.441	0.0023	0.0731	0.0024
Gasoline 1.4 -2.0L	PC Euro2 - 94/12/EEC	2.18	0.349	0.243	0.012	0.0958	0.0024
Gasoline 1.4 -2.0L	PC Euro3 - 98/69/EE I	1.96	0.193	0.098	0.005	0.0276	0.0011
Gasoline 1.4 -2.0L	PC Euro4 - 98/69/EE II	0.658	0.136	0.062	0.005	0.0276	0.0011
Gasoline >2.0L	PRE ECE	39.2	4.01	3.70	0.010	0.0025	0.0024
Gasoline >2.0L	ECE 15/00-01	30.5	3.41	3.70	0.010	0.0025	0.0024
Gasoline >2.0L	ECE 15/02	22.8	3.30	2.62	0.010	0.0025	0.0024
Gasoline >2.0L	ECE 15/03	23.2	3.30	3.44	0.010	0.0025	0.0024
Gasoline >2.0L	ECE 15/04	13.8	3.51	2.80	0.010	0.0025	0.0024
Gasoline >2.0L	PC Euro1 - 91/441/EEC	3.33	0.520	0.419	0.023	0.0731	0.0024
Gasoline >2.0L	PC Euro2 - 94/12/EEC	1.74	0.273	0.226	0.012	0.0958	0.0024
Gasoline >2.0L	PC Euro3 - 98/69/EE I	1.58	0.157	0.091	0.005	0.0276	0.0011
Gasoline >2.0L	PC Euro4 - 98/69/EE II	0.549	0.116	0.058	0.005	0.0276	0.0011
Diesel <2.0L	Conventional	0.713	0.162	0.561	0.000	0.0012	0.246
Diesel <2.0L	PC Euro1 - 91/441/EEC	0.449	0.051	0.691	0.003	0.0012	0.0877
Diesel <2.0L	PC Euro2 - 94/12/EEC	0.333	0.036	0.726	0.006	0.0012	0.0594
Diesel <2.0L	PC Euro3 - 98/69/EE I	0.097	0.020	0.780	0.010	0.0012	0.0412
Diesel <2.0L	PC Euro4 - 98/69/EE II	0.097	0.016	0.601	0.010	0.0012	0.0342
Diesel >2.0L	Conventional	0.713	0.162	0.890	0.000	0.0012	0.246
Diesel >2.0L	PC Euro1 - 91/441/EEC	0.449	0.0077	0.691	0.003	0.0012	0.0877
Diesel >2.0L	PC Euro2 - 94/12/EEC	0.333	0.110	0.726	0.006	0.0012	0.0594
Diesel >2.0L	PC Euro3 - 98/69/EE I	0.097	0.019	0.780	0.010	0.0012	0.0412
Diesel >2.0L	PC Euro4 - 98/69/EE II	0.097	0.016	0.601	0.010	0.0012	0.0342
LPG	Conventional	6.75	1.10	2.31	0.000	0.0100	n.a.
LPG	PC Euro1 - 91/441/EEC	3.80	0.771	0.444	0.000	0.0100	n.a.
LPG	PC Euro2 - 94/12/EEC	2.65	0.369	0.199	0.013	0.0120	n.a.
LPG	PC Euro3 - 98/69/EE I	2.22	0.206	0.115	0.005	0.0050	n.a.
LPG	PC Euro4 - 98/69/EE II	1.04	0.100	0.063	0.005	0.0050	n.a.
2-Stroke	Conventional	13.1	10.0	0.642	0.008	0.0019	n.a.
Hybrid Gas 1.4-2.0L	PC EURO 4 - 98/69/EC II	0.001	0.021	0.009	0.005	0.0276	n.a.

Source: EMEP/EEA Guidebook

Table 3.3-6 Light truck average emission factor

Type	Technology	CO	NMVOC	NOx	N_2O	NH_3	$PM_{2.5}$
Units		g/km	g/km	g/km	g/km	g/km	g/km $PM_{2.5}$=PM_{10} =TSP
Gasoline <3.5t	Conventional	25.5	3.44	3.09	0.010	0.0025	0.0023
Gasoline <3.5t	PC Euro1 - 91/441/EEC	8.82	0.614	0.563	0.025	0.0758	0.0023
Gasoline <3.5t	PC Euro2 - 94/12/EEC	5.89	0.304	0.230	0.025	0.0910	0.0023
Gasoline <3.5t	PC Euro3 - 98/69/EE I	5.06	0.189	0.129	0.028	0.0302	0.0011
Gasoline <3.5t	PC Euro4 - 98/69/EE II	2.01	0.128	0.064	0.013	0.0302	0.0011
Diesel <3.5t	Conventional	1.34	0.133	1.66	0.000	0.0012	0.356
Diesel <3.5t	PC Euro1 - 91/441/EEC	0.577	0.141	1.22	0.003	0.0012	0.117
Diesel <3.5t	PC Euro2 - 94/12/EEC	0.577	0.149	1.22	0.006	0.0012	0.117
Diesel <3.5t	PC Euro3 - 98/69/EE I	0.473	0.094	1.03	0.009	0.0012	0.0783
Diesel <3.5t	PC Euro4 - 98/69/EE II	0.375	0.035	0.831	0.009	0.0012	0.0409

Source: EMEP/EEA Guidebook

Table 3.3-7 Heavy duty trucks average emission factor

Type	Technology	CO	NMVOC	NOx	N_2O	NH_3	$PM_{2.5}$
Units		g/km	g/km	g/km	g/km	g/km	g/km $PM_{2.5}$=PM_{10} =TSP
Gasoline >3.5t	Conventional	59.5	5.25	6.60	0.006	0.0019	0.000
Rigid <=7.5 t	Conventional	1.85	1.07	4.70	0.029	0.0029	0.333
Rigid <=7.5 t	HD Euro I - 91/542/EEC I	0.657	0.193	3.37	0.005	0.0029	0.129
Rigid <=7.5 t	HD Euro II -91/542/EEC II	0.537	0.123	3.49	0.004	0.0029	0.061
Rigid <=7.5 t	HD Euro III -2000	0.584	0.115	2.63	0.003	0.0029	0.0566
Rigid <=7.5 t	HD Euro IV -2005	0.047	0.005	1.64	0.006	0.0029	0.0106
Rigid <=7.5 t	HD Euro V -2008	0.047	0.005	0.933	0.017	0.0029	0.0106
Rigid <=7.5 t	HD Euro VI	0.047	0.005	0.180	0.017	0.0029	0.0005
Rigid 12 -14 t	Conventional	2.13	0.776	8.92	0.029	0.0029	0.3344
Rigid 12 -14 t	HD Euro I - 91/542/EEC I	1.02	0.326	5.31	0.008	0.0029	0.201
Rigid 12 -14 t	HD Euro II -91/542/EEC II	0.902	0.207	5.50	0.008	0.0029	0.104
Rigid 12 -14 t	HD Euro III -2000	0.972	0.189	4.30	0.004	0.0029	0.0881
Rigid 12 -14 t	HD Euro IV -2005	0.071	0.008	2.65	0.012	0.0029	0.0161
Rigid 12 -14 t	HD Euro V - 2008	0.071	0.008	1.51	0.034	0.0029	0.0161
Rigid 12 -14 t	HD Euro VI	0.071	0.008	0.291	0.033	0.0029	0.0008
Rigid 20 -26 t	Conventional	1.93	0.486	10.7	0.029	0.0029	0.418
Rigid 20 -26 t	HD Euro I - 91/542/EEC I	1.55	0.449	7.52	0.008	0.0029	0.297
Rigid 20 -26 t	HD Euro II -91/542/EEC II	1.38	0.29	7.91	0.007	0.0029	0.155
Rigid 20 -26 t	HD Euro III -2000	1.49	0.278	6.27	0.004	0.0029	0.13
Rigid 20 -26 t	HD Euro IV -2005	0.105	0.010	3.83	0.012	0.0029	0.0239
Rigid 20 -26 t	HD Euro V - 2008	0.105	0.010	2.18	0.034	0.0029	0.0239
Rigid 20 -26 t	HD Euro VI	0.105	0.010	0.422	0.032	0.0029	0.0012
Rigid >32 t	Conventional	2.25	0.534	12.8	0.029	0.0029	0.491
Rigid >32 t	HD Euro I - 91/542/EEC I	1.90	0.510	9.04	0.012	0.0029	0.358
Rigid >32 t	HD Euro II -91/542/EEC II	1.69	0.326	9.36	0.012	0.0029	0.194
Rigid >32 t	HD Euro III -2000	1.79	0.308	7.43	0.007	0.0029	0.151
Rigid >32 t	HD Euro IV -2005	0.121	0.012	4.61	0.018	0.0029	0.0268
Rigid >32 t	HD Euro V - 2008	0.121	0.012	2.63	0.053	0.0029	0.0268
Rigid >32 t	HD Euro VI	0.121	0.012	0.507	0.049	0.0029	0.0013

Source: EMEP/EEA Guidebook

Table 3.3-8 Large bus average emission factor

Technology	CO	NMVOC	NOx	N_2O	NH_3	$PM_{2.5}$
	g/km	g/km	g/km	g/km	g/km	g/km
						$PM_{2.5}$=PM_{10} =TSP
HD Euro I -91/542/EEC I	8.40	0.371	16.5	n.a.	n.a.	0.02
HD Euro II - 91/542/EEC II	2.70	0.313	15.0	n.a.	n.a.	0.01
HD Euro III - 2000	1.00	0.052	10.0	n.a.	n.a.	0.01
EEV	1.00	0.045	2.50	n.a.	n.a.	0.005
Conventional	5.71	1.99	16.5	0.029	0.0029	0.909
HD Euro I - 91/542/EEC I	2.71	0.706	10.1	0.012	0.0029	0.479
HD Euro II -91/542/EEC II	2.44	0.463	10.7	0.012	0.0029	0.22
HD Euro III -2000	2.67	0.409	9.38	0.001	0.0029	0.207
HD Euro IV -2005	0.223	0.022	5.42	0.012	0.0029	0.0462
HD Euro V -2008	0.223	0.022	3.09	0.032	0.0029	0.0462
HD Euro VI	0.223	0.022	0.597	0.040	0.0029	0.0023
Conventional	2.27	0.661	10.6	0.029	0.0029	0.47
HD Euro I - 91/542/EEC I	1.85	0.624	8.10	0.009	0.0029	0.362
HD Euro II -91/542/EEC II	1.60	0.416	8.95	0.008	0.0029	0.165
HD Euro III -2000	1.91	0.399	7.51	0.004	0.0029	0.178
HD Euro IV -2005	0.150	0.021	4.51	0.012	0.0029	0.0354
HD Euro V -2008	0.150	0.021	2.57	0.034	0.0029	0.0354
HD Euro VI	0.150	0.021	0.496	0.033	0.0029	0.0018

Source: EMEP/EEA Guidebook

Table 3.3-9 Motorcycle average emission factor

Technology	CO	NMVOC	NOx	N_2O	NH_3	$PM_{2.5}$
	g/km	g/km	g/km	g/km	g/km	g/km
						$PM_{2.5}$=PM_{10} =TSP
<50cm^3	13.8	13.8	0.020	0.001	0.0010	0.188
<50cm^3	5.60	2.82	0.020	0.001	0.0010	0.0755
<50cm^3	1.30	1.66	0.260	0.001	0.0010	0.0376
<50cm^3	1.00	1.31	0.260	0.001	0.0010	0.0114
4-stroke <250cm^3	32.8	2.06	0.225	0.001	0.0010	0.014
4-stroke <250cm^3	13.6	1.08	0.445	0.001	0.0010	0.014
4-stroke <250cm^3	7.17	0.839	0.317	0.001	0.0010	0.0035
4-stroke <250cm^3	3.03	0.465	0.194	0.001	0.0010	0.0035
4-stroke 250-750 cm^3	25.7	1.68	0.233	0.001	0.0010	0.014
4-stroke 250-750 cm^3	13.8	1.19	0.477	0.001	0.0010	0.014
4-stroke 250-750 cm^3	7.17	0.918	0.317	0.001	0.0010	0.0035
4-stroke 250-750 cm^3	3.03	0.541	0.194	0.001	0.0010	0.0035
4-stroke >750 cm^3	21.1	2.75	0.247	0.001	0.0010	0.014
4-stroke >750 cm^3	10.1	1.50	0.579	0.001	0.0010	0.014
4-stroke >750 cm^3	7.17	0.994	0.317	0.001	0.0010	0.0035
4-stroke >750 cm^3	3.03	0.587	0.194	0.001	0.0010	0.0035

Source: EMEP/EEA Guidebook

Table 3.3-10 BC,OC ratio against PM emission factor

Fuel type	BC (g/km)	OC (g/km)
Gasoline	PM×0.29	PM×0.31
Gas oil	PM×0.57	PM×0.18

Note: PM=$PM_{2.5}$ emission factor (g/km)

Source: A technology-based global inventory of black and organic carbon emission s from combustion, Tami C. Bond et al., 2004, Journal of Geophysical Research, Vol. 109, D14203

SOx emission, based on sulfur contents in fuel for target country, SO_2 is emitted as S (S element×2) contained in the fuel, is estimated by multiplying it with vehicle travel consumption by travel of automobile. CO_2 emission factor is shown in Table 3.3-11.

Table 3.3-11 CO_2 emission factors

Car type	Fuel	kgCO_2/kg fuel
All types	Gasoline	3.180
All types	Diesel	3.140
All types	LPG	3.017
All types	CNG or LNG	2.750

Source: EMEP/EEA Guidebook

B. Detailed emission factor

The setting method of emission factor using emission factor model is shown in Figure 3.3-5. The emission factors, exhaust gas regulation by year, vehicle composition by registered year, and vehicle kilometers by registered year and by vehicle age is set by number of registered cars and by year, and number of scrapped car data by year and by vehicle composition. These data applies to emission factor models (COPERT, MOBILE, etc.) If measurement data is not sufficiently existed, measurement data of chassis dynamo can be used as supplement.

Detailed emission factors are generally compiled as a function of car traveling speed. Therefore, the average traveling speed for target roads is required in order to estimate emission. Car travelling speed by hour and by road link is basically set. However, if setting of the hourly speed is difficult, traveling speed by time zone (morning, afternoon, evening, night, mid-night) is estimated by road regulation speed and actual travel speed survey results. Travel speed means the travelled distance divided by travel time including stops at traffic light and traffic jam.

Car travel speed is basically set by actual survey. Actual survey is implemented in same day of traffic count survey day. Travel route by road type, by area and by time zone is set. In actual survey, cars drive road flow, and the selected roads are travelled several times, and it should be the average and typical one. Travel speed is estimated from positioning and recorded time of GPS, or record of car distance meter and measurement time.

However, SOx emission uses the same method as average emission factor. Also CO_2, BC and OC emission factor uses the same method as average emission factor.

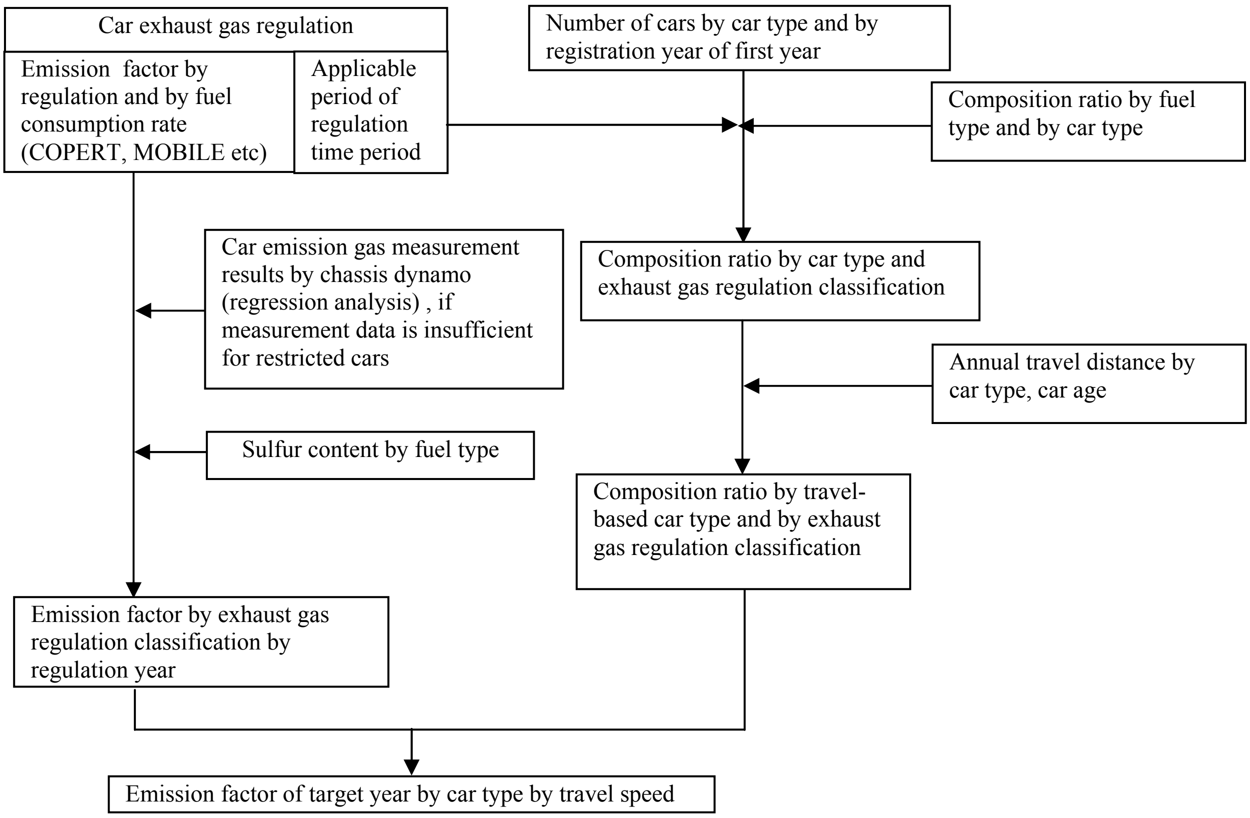

Figure 3.3-5 Setting method of emission factor

The typical emission factor by COPERT is described. Normal emission factors during hot is added, and emission factor for cold start is modified hot case, modification formula is as follows.

$$EF_{COLD}=\beta \times EF_{HOT} \times (e^{COLD}/e^{HOT} - 1) \cdots\cdots (3.3\text{-}11)$$

β : Ratio of vehicle kilometer for cold start or catalyst operating case

EF_{COLD} : Cold start emission factor

EF_{HOT} : Hot emission factor

e^{COLD}/e^{HOT}: Cold/Hot ratio

A) Gasoline passenger cars

- Pre Euro

Emission factors for CO, VOC and NOx, and fuel consumption by gasoline passenger car during hot is shown from Table 3.3-12 to Table 3.3-15. Pre-Euro passenger car e^{COLD}/e^{HOT} coefficient and cold start parameter β is shown in Table 3.3-16 and Table 3.3-17.

Table 3.3-12 CO emission factors (gasoline passenger cars)

Class	Engine capacity	Car speed V(km/h)	CO emission factor (g/km)	R^2
PRE ECE	All emission rate	10-100 100-130	$281V^{-0.630}$ $0.112V+4.32$	0.924 -
ECE 15-00/01	All emission rate	10-50 50-130	$313V^{-0.760}$ $27.22-0.406V+0.0032V^2$	0.898 0.158
ECE 15-02	All emission rate	10-60 60-130	$300V-0.797$ $26.260-0.440V+0.00377V^2$	0.747 0.102
ECE 15-03	All emission rate	10-20 20-130	$161.36-45.62\ln(V)$ $37.92-0.680V+0.00377V^2$	0.790 0.247
ECE 15-04	All emission rate	10-60 60-130	$260.788V^{-0.910}$ $14.653-0.220V+0.001163V^2$	0.825 0.613
Improved conventional	cc<1.4 1.41<cc<2.01	10-130 10-130	$14.577-0.294V+0.002478V^2$ $8.273-0.151V+0.000957V^2$	0.781 0.767
Open Loop	cc<1.41 1.41<cc<2.01	10-130 10-130	$17.882-0.377V+0.002825V^2$ $9.446-0.230V+0.002029V^2$	0.656 0.719

Source: EMEP/EEA Guidebook

Table 3.3-13 VOC emission factors (gasoline passenger cars)

Class	Engine capacity	Car speed V(km/h)	VOC emission factor (g/km)	R^2
PRE ECE	All emission rate	10-100 100-130	$30.34V^{-0.693}$ 1.247	0.980 -
ECE 15-00/01	All emission rate	10-50 50-130	$24.99V^{-0.704}$ $4.85V^{-0.318}$	0.901 0.095
ECE 15-03	All emission rate	10-20 20-130	$25.75V-0.174$ $1.95-0.019v+0.00009V$	0.895 0.198
ECE 15-04	All emission rate	10-60 60-130	$19.079V^{-0.693}$ $2.608-0.037V+0.000179V^2$	0.838 0.341
Improved conventional	cc<1.41 1.41<cc<2.01	10-130 10-130	$2.189-0.034V+0.000201V^2$ $1.999-0.034V+0.000214V^2$	0.766 0.447
Open Loop	cc<1.41 1.41<cc<2.01	10-130 10-130	$2.185-0.0423V+0.000256V^2$ $0.808-0.016V+0.000099V^2$	0.636 0.49

Source: EMEP/EEA Guidebook

Table 3.3-14 NOx emission factors (gasoline passenger cars)

Class	Engine capacity	Car speed V(km/h)	NOx emission factor (g/km)	R^2
PRE ECE ECE 15-00/01	cc<1.41	10-130	$1.173+0.0225V-0.00014V^2$	0.916
	1.41<cc<2.01	10-130	$1.360+0.0217V-0.0000V^2$	0.960
	cc>2.01	10-130	$1.5+0.03V+0.0001V^2$	0.972
ECE 15-02	cc<1.41	10-130	$1.479-0.0037V+0.00018V^2$	0.711
	1.41<cc<2.01	10-130	$1.663-0.0038V+0.00020V^2$	0.839
	cc>2.01	10-130	$1.87-0.0039V+0.00022V^2$	-
ECE 15-03	cc<1.41	10-130	$1.616-0.0084V+0.00025V^2$	0.844
	1.41<cc<2.01	10-130	$1.29e0.0099V$	0.798
	cc>2.01	10-130	$2.784-0.0112V+0.000294V^2$	0.577
ECE 15-04	cc<1.41	10-130	$1.432+0.003V+0.000097V^2$	0.669
	1.41<cc<2.01	10-130	$1.484+0.013V+0.000074V^2$	0.722
	cc>2.01	10-130	$2.427-0.014V+0.000266V^2$	0.803
Improved conventional	cc<1.41	10-130	$-0.926+0.719\ln(V)$	0.883
	1.41<cc<2.01	10-130	$1.387+0.0014V+0.000247V^2$	0.876
Open Loop	cc<1.4	10-130	$-0.921+0.616\ln(V)$	0.791
	1.41<cc<2.01	10-130	$-0.761+0.515\ln(V)$	0.495

Source: EMEP/EEA Guidebook

Table 3.3-15 FC: Fuel consumption (gasoline passenger cars)

Class	Engine capacity	Car speed V(km/h)	Fuel consumption (g/km)	R^2
PRE ECE	cc<1.41	10-60	$521V^{-0.554}$	0.941
		60-80	55	-
		80-130	$0.386V+24.143$	-
	1.41<cc<2.01	10-60	$681V^{-0.583}$	0.931
		60-80	67	-
		80-130	$0.471V+29.286$	-
	cc>2.01	10-60	$979V^{-0.628}$	0.918
		60-80	80	-
		80-130	$0.414V+46.867$	-
ECE 15-00/01	cc<1.41	10-60	$595V^{-0.63}$	0.951
		60-130	$95-1.324V+0.0086V^2$	0.289
	1.41<cc<2.01	10-60	$864V^{-0.69}$	0.974
		60-130	$59-0.407V+0.0042V^2$	0.647
	cc>2.01	10-60	$1236V^{-0.764}$	0.976
		60-30	$65-0.407V+0.0042V^2$	-
ECE 15-02/03	cc<1.41	10-50	$544V^{-0.63}$	0.929
		50-130	$85-1.108V+0.0077V^2$	0.641
	1.41<cc<2.01	10-50	$879V^{-0.72}$	0.950
		50-130	$71-0.7032V+0.0059V^2$	0.830
	cc>2.01	10-50	$1224V^{-0.756}$	0.961
		50-130	$111-1.333V+0.0093V^2$	0.847
ECE 15-04	cc<1.41	10-17.9	$296.7-80.21\ln(V)$	0.518
		17.9-130	$102.5-1.364V+0.0086V^2$	0.760
	1.41<cc<2.01	10-22.3	$606.1V-0.667$	0.907
		22.3-130	$102.5-1.364V+0.0086V^2$	0.927
	cc>2.01	10-60	$819.9V^{-0.663}$	0.966
		60-130	$41.7+0.122V+0.0016V^2$	0.650
Improved conventional	cc<1.41	10-130	$80.52-1.41V+0.013V^2$	0.954
	1.41<cc<2.01	10-130	$41.7+0.122V+0.0016V^2$	0.994
Open Loop	cc<1.41	10-130	$85.52-1.383V+0.0117V^2$	0.997
	1.41<cc<2.01	10-130	$109.6+1.98V+0.0168V^2$	0.997

Source: EMEP/EEA Guidebook

Table 3.3-16 Pre-Euro passenger car e^{COLD}/e^{HOT} ratio

Matter	e^{COLD}/e^{HOT}, Ta: Air temperature
CO	3.7-0.09Ta
NOx	1.14-0.006Ta
VOC	2.8-0.06Ta
Fuel consumption	1.47-0.009Ta

Source: EMEP/EEA Guidebook

Table 3.3-17 Cold start parameter β

Calculation value	Parameter β
l_{trip}	$0.6474-0.02545\times l_{trip}+(0.00974-0.000383\times l_{trip})\times Ta$

Source: EMEP/EEA Guidebook

- Post Euro-1

Post Euro-1 of gasoline car during hot, the emission factor formula is calculated by using EF= $(a+c\times V+e\times V^2)/(1+b\times V+d\times V^2)$. Coefficient list of EF emission factor formula is shown in Table 3.3-18. PM emission factors for Post Euro-1 gas passenger car are shown in Table 3.3-19.

Table 3.3-18 Post-Euro-1 factor list used in EF emission factors formula

Target matter	Regulation	Engine capacity	Car speed (km/h)	R^2	A	b	c	d	e
CO	Euro1	All	10-130	0.87	1.12E+01	1.29E-01	-1.02E-01	-9.47E-04	6.77E-04
	Euro2	All	10-130	0.97	6.05E+01	3.50E+00	1.52E-01	-2.52E-02	-1.68E-04
	Euro3	All	10-130	0.97	7.17E+01	3.54E+01	1.14E+01	-2.48E-01	
	Euro4	All	10-130	0.93	1.36E-01	-1.41E-02	-8.91E-04	4.99E-05	
HC	Euro1	All	10-130	0.82	1.35E+00	1.78E-01	-6.77E-03	-1.27E-03	
	Euro2	All	10-130	0.95	4.11E+06	1.66E+06	-1.45E+04	-1.03E+04	
	Euro3	All	10-130	0.88	5.57E-02	3.65E-02	-1.10E-03	-1.88E-04	1.25E-05
	Euro4	All	10-130	0.10	1.18E-02		-3.47E-05		8.84E-07
NOx	Euro1	All	10-130	0.86	5.25E-01		-1.00E-02		9.36E-05
	Euro2	All	10-130	0.52	2.84E-01	-2.34E-02	-8.69E-03	4.43E-04	1.14E-04
	Euro3	All	10-130	0.80	9.29E-02	-1.22E-02	-1.49E-03	3.79E-05	6.53E-06
	Euro4	All	10-130	0.71	1.06E-01		-1.58E-03		7.10E-06
FC	Euro1	<1.4	10-130	0.99	1.91E+02	1.29E-01	1.17E+00	-7.23E-04	
		1.4-2.0	10-130	0.98	1.99E+02	8.92E-02	3.46E-01	-5.38E-04	
		>2.0	10-130	0.93	2.30E+02	6.94E-02	-4.26E-02	-4.46E-04	
	Euro2	<1.4	10-130	0.99	2.08E+02	1.07E-01	-5.65E-01	-5.00E-04	1.43E-02
		1.4<2.0	10-130	0.98	3.47E+02	2.17E-01	2.73E+00	-9.11E-04	4.28E-03
		>2.0	10-130	0.98	1.54E+03	8.69E-01	1.91E+01	-3.63E-03	
	Euro3	<1.4	10-130	0.99	1.70E+02	9.28E-02	4.18E-01	-4.52E-04	4.99E-03
		1.4-2.0	10-130	0.99	2.17E+02	9.60E-02	2.53E-01	-4.21E-04	9.65E-03
		>2.0	10-130	0.99	2.53E+02	9.02E-02	5.02E-01	-4.69E-04	
	Euro4	<1.4	10-130	0.95	1.36E+02	2.60E-02	-1.65E+00	2.28E-04	3.12E-02
		1.4-2.0	10-130	0.96	1.74E+02	6.85E-02	3.64E-01	-2.47E-04	8.74E-03
		>2.0	10-130	0.98	2.85E+02	7.28E-02	-1.37E-01	-4.16E-04	

Source: EMEP/EEA Guidebook

Table 3.3-19 Post-Euro-1 gasoline passenger car PM emission factors

Target matter	Regulation	Fuel specification	City(g/km)	Suburbs (g/km)	Highway (g/km)
PM	Euro1and 2	2000-2009	3.22E-03	1.84E-03	1.90E-03
	Euro3and4	2000-2009	1.28E-03	8.36E-04	1.19E-03
	Euro3 GDI	2000-2009	6.60E-03	2.96E-03	6.95E-03

Source: EMEP/EEA Guidebook

Cold start post Euro-1 gasoline car e^{COLD}/e^{HOT} factors are listed in Table 3.3-20, post Euro-1 parameter β (Euro-1 value) is listed in Table 3.3-21.

Table 3.3-20 Post-Euro1 gasoline passenger car eCOLD/eHOT coefficient

Target matter	Engine capacity	Car speed (km/h)	Air temperature (℃)	$e^{COLD}/e^{HOT}=A\times V+B\times t_a+C$		
				A	B	C
CO	cc<1.41	5-25	-20 : 15	0.156	-0.155	3.519
		26-45	-20 : 15	0.538	-0.373	-6.24
		5-45	>15	8.032E-02	-0.444	9.826
	1.41<cc<2.01	5-25	-20 : 15	0.121	-0.146	3.766
		26-45	-20 : 15	0.299	-0.286	-0.58
		5-45	>15	5.03E-02	-0.363	8.604
	cc>2.01	5-25	-20 : 15	7.82E-02	-0.105	3.116
		26-45	-20 : 15	0.193	-0.194	0.305
		5-45	>15	3.21E-02	-0.252	6.332
NOx	cc<1.41	5-25	>-20	4.61E-02	7.37E-03	0.755
		26-45	>-20	5.13E-02	2.34E-02	0.616
	1.41<cc<2.01	5-25	>-20	4.58E-02	7.47E-03	0.764
		26-45	>-20	4.84E-02	2.28E-02	0.685
	cc>2.01	5-25	>-20	3.43E-02	5.66E-03	0.827
		26-45	>-20	3.75E-02	1.72E-02	0.728
VOC	cc<1.41	5-25	-20 : 15	0.154	-0.134	4.937
		26-45	-20 : 15	0.323	-0.240	0.301
		5-45	>15	9.92E-02	-0.355	8.967
	1.41<cc<2.01	5-25	-20 : 15	0.157	-0.207	7.009
		26-45	-20 : 15	0.282	-0.338	4.098
		5-45	>15	4.76E-02	-0.477	13.44
	cc>2.01	5-25	-20 : 15	8.14E-02	-0.165	6.464
		26-45	-20 : 15	0.116	-0.229	5.739
		5-45	>15	1.75E-02	-0.346	10.462
Fuel consumption rate	cc<1.41	-	-10 : 30	0	-0.009	1.47

Source: EMEP/EEA Guidebook

Table 3.3-21 Post-Euro-1 parameter β (against Euro-1 value)

Regulation	CO	NOx	VOC
Euro2	0.72	0.72	0.56
Euro3	0.62	0.32	0.32
Euro4	0.18	0.18	0.18

Source: EMEP/EEA Guidebook

B) Diesel passenger cars

- Pre-Euro

Pre-Euro emission factors and fuel consumption during hot is shown in Table 3.3-22.

Table 3.3-22 Pre-Euro emission factors and fuel consumption (passenger car)

Target matter	Engine capacity	Car speed (km/h)	Emission factor (g/km)	R^2
CO	All emission rate	10-130	$5.4130V^{-0.574}$	0.745
NOx	cc<2.01	10-130	$0.918-0.014V+0.000101V^2$	0.949
	cc>2.01	10-130	$1.331-0.018V+0.000133V^2$	0.927
VOC	All emission rate	10-130	4.61V-0.937	0.794
PM	All emission rate	10-130	$0.45-0.0086V+0.000058V^2$	0.439
Fuel consumption rate	All emission rate	10-130	$118.489-2.084V+0.014V^2$	0.583

Source: EMEP/EEA Guidebook

e^{COLD}/e^{HOT} coefficient of Pre-Euro diesel passenger car during cold start is shown in Table 3.3-23.

Table 3.3-23 eCOLD/eHOT coefficient of Pre-Euro diesel passenger car

Target matter	eCOLD/eHOT Ta: Air temperature
CO	$1.9-0.03t_a$
NOx	$1.3-0.013t_a$
VOC	$3.1-0.09t_a$(1)
PM	$3.1-0.1t_a$(2)
Fuel consumption	$1.34-0.008t_a$

(1)VOC: When t_a>29°C, $e^{COLD}/e^{HOT}>0.5$, (2) PM: When ta>26°C, $e^{COLD}/e^{HOT}>0.5$

Source: EMEP/EEA Guidebook

- Post Euro-1

Post Euro-1 Hot gasoline passenger car during hot, emission factors are calculated using f following emission factor formula.

$$EF=(a+c\times V+e\times V^2)/(1+b\times V+d\times V^2)+f/V \cdots\cdots (3.3\text{-}12)$$

Coefficient list using above EF emission factors is shown in Table 3.3-24, PM emission factors for Euro-3 DPF-equipped cars are shown in Table 3.3-25.

Table 3.3-24 Coefficient list of EF emission factor formula (diesel passenger car)

Target matter	Regulation	Engine capacity	Car speed(km/h)	R^2	a	b	c	D	E	F
CO	Euro1	All	10-130	0.94	9.96E-01		-1.88E-02		1.09E-04	
	Euro2	All	10-130	0.91	9.00E-01		-1.74E-02		8.77E-05	
	Euro3	All	10-130	0.95	1.69E-01		-2.92E-03		1.25E-05	1.1
	Euro4	All	10-130	$17.5E-03+86.42\left[1+e^{-\frac{V+117.67}{-21.99}}\right]^{-1}$						
HC	Euro1	<2.0	10-130	0.93	1.42E-01	1.38E-02	-2.01E-03	-1.90E-05	1.15E-05	
		>2.0	10-130	0.98	1.59E-01		-2.46E-03		1.21E-05	
	Euro2	<2.0	10-130	0.99	1.61E-01	7.46E-02	-1.21E-03	-3.35E-04	3.63E-06	
		>2.0	10-130	0.98	5.01E+04	3.80E+04	8.03E+03	1.15E+03	-2.66E+01	
	Euro3	<2.0	10-130	0.99	9.65E-02	1.03E-01	-2.38E-04	-7.24E-05	1.93E-06	
		>2.0	10-130	0.54	9.12E-02		-1.68E-03		8.94E-06	
	Euro4	All	10-130		3.47E-02	2.69E-02	-6.41E-04	1.59E-03	1.12E-05	
NOx	Euro1	All	10-130	0.96	3.10E+00	1.41E-01	-6.18E-03	-5.03E-04	4.22E-04	
	Euro2	All	10-130	0.94	2.40E+00	7.67E-02	-1.16E-02	-5.00E-04	1.20E-04	
	Euro3	All	10-130	0.92	2.82E+00	1.98E-01	6.69E-02	-1.43E-03	-4.63E-04	
	Euro4	All	10-130		1.1E+00		-2.02E-02		1.48E-04	
PM	Euro1	All	10-130	0.70	1.14E-01		-2.33E-03		2.26E-05	
	Euro2	All	10-130	0.71	8.86E-02		-1.42E-03		1.06E-05	
	Euro3	All	10-130	0.81	5.15E-02		-8.80E-04		8.12E-06	
	Euro4	All	10-130		4.50E-02		-5.39E-04		3.48E-06	
FC	Euro1	<1.4	10-130	0.98	1.45E+02	6.73E-02	-1.88E-01	-3.17E-04	9.47E-03	
		>2.0	10-130	0.96	1.95E+02	7.19E-02	1.87E-01	-3.32E-04	9.99E-03	
	Euro2	<1.4	10-130	0.97	1.42E+02	4.98E-02	-6.51E-01	-1.69E-04	1.32E-02	
		>2.0	10-130	0.96	1.95E+02	7.19E-02	1.87E-01	-3.32E-04	9.99E-03	
	Euro3	<1.4	10-130	0.95	1.62E+02	1.23E-01	2.18E-01	-7.76E-04	-1.28E-02	
		>2.0	10-130	0.96	1.95E+02	7.19E-02	1.87E-01	-3.32E-04	9.99E-03	

Source: EMEP/EEA Guidebook

Table 3.3-25 PM emission factors of Euro-3 DPF-equipped car

Diesel passenger car	City (g/km)	Suburbs (g/km)	Highway (g/km)
Euro3+DPF	0.002	0.002	0.002

Source: EMEP/EEA Guidebook

Diesel car coefficients during cold start use the same values as gasoline cars.

C) Light duty truck (gasoline)

Emission factors for light duty trucks (gasoline) and emission reduction ratio of Post Euro-2 against Euro-1 is shown in Table 3.3-26 and Table 3.3-27.

Table 3.3-26 Emission factors of gasoline light duty vehicle

Target matter	Regulation	Car speed (km/h)	Emission factor (g/km)	R^2
CO	Conventional	10-110	$0.01104V^2-1.5132V+57.789$	0.732
	Euro 1	10-120	$0.0037V^2-0.5215V+19.127$	0.394
NOx	Conventional	10-110	$0.0179V+1.9547$	0.142
	Euro 1	10-120	$7.55E-05V^2-0.009V+0.666$	0.0141
VOC	Conventional	10-110	$67.7E-05V^2-0.117V+5.4734$	0.771
	Euro 1	10-120	$5.77E-05V^2-0.01047V+0.5462$	0.358
Fuel consumption	Conventional	10-110	$0.0167V^2-2.649V+161.51$	0.787
	Euro 1	10-120	$0.0195V^2-3.09V+188.85$	0.723

Source: EMEP/EEA Guidebook

Table 3.3-27 Post-Euro-2 emission reduction ratio against Euro-1

	CO (%)	NOx (%)	VOC (%)
Euro2	39	66	76
Euro3	48	79	86
Euro4	72	90	94

Source: EMEP/EEA Guidebook

D) Light duty truck (diesel)

Emission factors for light duty trucks (diesel) and emission reduction ratio of Post Euro-2 against Euro-1 is shown in Table 3.3-28 and Table 3.3-29.

Table 3.3-28 Emission factors for light duty diesel truck

Target matter	Regulation	Car speed (km/h)	Emission factor (g/km)	R^2
CO	Conventional	10-110	$20E\text{-}05V^2-0.0256V+1.8281$	0.136
	Euro 1	10-110	$22.3E\text{-}05V^2-0.026V+1.076$	0.301
NOx	Conventional	10-110	$81.6E\text{-}05V^2-0.1189V+5.1234$	0.402
	Euro 1	10-110	$24.1E\text{-}05V^2-0.03181V+2.0247$	0.0723
VOC	Conventional	10-110	$1.75E\text{-}05V^2-0.00284V+0.2162$	0.0373
	Euro 1	10-110	$1.75E\text{-}05V^2-0.00284V+0.2162$	0.0373
PM	Conventional	10-110	$1.25E\text{-}05V^2-0.000577V+0.288$	0.0230
	Euro 1	10-110	$4.5E\text{-}05V^2-0.004885V+0.1932$	0.224
Fuel consumption rate	Conventional	10-110	$0.02113V^2-2.65V+148.91$	0.486
	Euro 1	10-110	$0.0198V^2-2.506V+137.42$	0.422

Source: EMEP/EEA Guidebook

Table 3.3-29 Post-Euro-2 emission reduction ratio against Euro-1

	CO (%)	NOx (%)	VOC (%)	PM (%)
Euro2	0	0	0	0
Euro3	18	16	38	33
Euro4	35	32	77	65

Source: EMEP/EEA Guidebook

E) Heavy duty truck (gasoline)

Emission factors for heavy duty truck (gasoline) are shown in Table 3.3-30.

Table 3.3-30 Emission factors for heavy duty (gasoline) vehicle

	CO (g/km)	NOx (g/km)	VOC (g/km)	Fuel consumption (g/km)
City	70	4.5	7.0	225
Suburbs	55	7.5	5.5	150
Highway	55	7.5	3.5	165

Source: EMEP/EEA Guidebook

F) Heavy duty truck and bus (diesel)

Emission factors for heavy duty truck and bus (diesel) is shown in Table 3.3-31 and Table 3.3-32. These emission factors, formula about travel speed is quite complicated, and car types are classified so detailed, it is difficult to calculate them. Therefore, consideration of user friendly, the emission factors are adopted same factors as average emission factor.

Table 3.3-31 Emission factors for light duty truck

Type	Technology	CO	NMVOC	NOx	N_2O	NH_3	$PM_{2.5}$
Units		g/km	g/km	g/km	g/km	g/km	g/km
Notes			Given as $THC-CH_4$	Given as NO_2 equivalent			$PM_{2.5}$=PM_{10} =TSP
Gasoline >3.5t	Conventional	59.5	5.25	6.60	0.006	0.0019	0.000
Rigid <=7.5 t	Conventional	1.85	1.07	4.70	0.029	0.0029	0.333
Rigid <=7.5 t	HD Euro I - 91/542/EEC I	0.657	0.193	3.37	0.005	0.0029	0.129
Rigid <=7.5 t	HD Euro II -91/542/EEC II	0.537	0.123	3.49	0.004	0.0029	0.061
Rigid <=7.5 t	HD Euro III -2000	0.584	0.115	2.63	0.003	0.0029	0.0566
Rigid <=7.5 t	HD Euro IV -2005	0.047	0.005	1.64	0.006	0.0029	0.0106
Rigid <=7.5 t	HD Euro V -2008	0.047	0.005	0.933	0.017	0.0029	0.0106
Rigid <=7.5 t	HD Euro VI	0.047	0.005	0.180	0.017	0.0029	0.0005
Rigid 12 -14 t	Conventional	2.13	0.776	8.92	0.029	0.0029	0.3344
Rigid 12 -14 t	HD Euro I - 91/542/EEC I	1.02	0.326	5.31	0.008	0.0029	0.201
Rigid 12 -14 t	HD Euro II -91/542/EEC II	0.902	0.207	5.50	0.008	0.0029	0.104
Rigid 12 -14 t	HD Euro III -2000	0.972	0.189	4.30	0.004	0.0029	0.0881
Rigid 12 -14 t	HD Euro IV -2005	0.071	0.008	2.65	0.012	0.0029	0.0161
Rigid 12 -14 t	HD Euro V - 2008	0.071	0.008	1.51	0.034	0.0029	0.0161
Rigid 12 -14 t	HD Euro VI	0.071	0.008	0.291	0.033	0.0029	0.0008
Rigid 20 -26 t	Conventional	1.93	0.486	10.7	0.029	0.0029	0.418
Rigid 20 -26 t	HD Euro I - 91/542/EEC I	1.55	0.449	7.52	0.008	0.0029	0.297
Rigid 20 -26 t	HD Euro II -91/542/EEC II	1.38	0.29	7.91	0.007	0.0029	0.155
Rigid 20 -26 t	HD Euro III -2000	1.49	0.278	6.27	0.004	0.0029	0.13
Rigid 20 -26 t	HD Euro IV -2005	0.105	0.010	3.83	0.012	0.0029	0.0239
Rigid 20 -26 t	HD Euro V - 2008	0.105	0.010	2.18	0.034	0.0029	0.0239
Rigid 20 -26 t	HD Euro VI	0.105	0.010	0.422	0.032	0.0029	0.0012
Rigid >32 t	Conventional	2.25	0.534	12.8	0.029	0.0029	0.491
Rigid >32 t	HD Euro I - 91/542/EEC I	1.90	0.510	9.04	0.012	0.0029	0.358
Rigid >32 t	HD Euro II -91/542/EEC II	1.69	0.326	9.36	0.012	0.0029	0.194
Rigid >32 t	HD Euro III -2000	1.79	0.308	7.43	0.007	0.0029	0.151
Rigid >32 t	HD Euro IV -2005	0.121	0.012	4.61	0.018	0.0029	0.0268
Rigid >32 t	HD Euro V - 2008	0.121	0.012	2.63	0.053	0.0029	0.0268
Rigid >32 t	HD Euro VI	0.121	0.012	0.507	0.049	0.0029	0.0013

Source: EMEP/EEA Guidebook

Table 3.3-32 Large bus emission factors

Technology	CO	NMVOC	NOx	N_2O	NH_3	$PM_{2.5}$
	g/km	g/km	g/km	g/km	g/km	g/km
		Given as $THC-CH_4$	Given as NO_2 equivalent			$PM_{2.5}=PM_{10}=TSP$
HD Euro I -91/542/EEC I	8.40	0.371	16.5	n.a.	n.a.	0.02
HD Euro II - 91/542/EEC II	2.70	0.313	15.0	n.a.	n.a.	0.01
HD Euro III - 2000	1.00	0.052	10.0	n.a.	n.a.	0.01
EEV	1.00	0.045	2.50	n.a.	n.a.	0.005
Conventional	5.71	1.99	16.5	0.029	0.0029	0.909
HD Euro I - 91/542/EEC I	2.71	0.706	10.1	0.012	0.0029	0.479
HD Euro II -91/542/EEC II	2.44	0.463	10.7	0.012	0.0029	0.22
HD Euro III -2000	2.67	0.409	9.38	0.001	0.0029	0.207
HD Euro IV -2005	0.223	0.022	5.42	0.012	0.0029	0.0462
HD Euro V -2008	0.223	0.022	3.09	0.032	0.0029	0.0462
HD Euro VI	0.223	0.022	0.597	0.040	0.0029	0.0023
Conventional	2.27	0.661	10.6	0.029	0.0029	0.47
HD Euro I - 91/542/EEC I	1.85	0.624	8.10	0.009	0.0029	0.362
HD Euro II -91/542/EEC II	1.60	0.416	8.95	0.008	0.0029	0.165
HD Euro III -2000	1.91	0.399	7.51	0.004	0.0029	0.178
HD Euro IV -2005	0.150	0.021	4.51	0.012	0.0029	0.0354
HD Euro V -2008	0.150	0.021	2.57	0.034	0.0029	0.0354
HD Euro VI	0.150	0.021	0.496	0.033	0.0029	0.0018

Source: EMEP/EEA Guidebook

G) Motorcycle emission factors

【50cm^3 below】

The emission factor and fuel consumption of motorcycle with engine capacity 50cm^3 below is shown in Table 3.3-33, PM emission factors are in Table 3.3-34.

Table 3.3-33 Emission factor and fuel consumption of motorcycle 50cm^3 below

Regulation	CO (g/km)	NOx (g/km)	VOC (g/km)	Fuel consumption (g/km)
Conventional	13.80	0.02	13.91	25.0
Euro1	5.60	0.02	2.73	15.0
Euro2	1.30	0.26	1.56	12.08
Euro3	1.00	0.26	1.20	10.50

Source: EMEP/EEA Guidebook

Table 3.3-34 PM emission factors for motorcycle 50cm^3 below

Regulation	Car speed (km/h)	PM (g/km)
Conventional	10-110	1.88E-01
Euro1	10-110	7.55E-02
Euro2	10-110	3.76E-02
Euro3	10-110	1.14E-02

Source: EMEP/EEA Guidebook

【50cm^3 and above】

Manufacturing and sales of 2-stroke motorcycles are prohibited in East-Asia countries such as Vietnam, it is described index of emission factors and fuel consumption about 4-stroke engine.

A) Motorcycle CO and NOx emission factors (50cm^3 and above, 4-stroke) until Pre-Euro-1 regulation is shown in Table 3.3-35, and HC emission factors and fuel consumption (50cm^3 and above, 4-stroke) until Pre-Euro-1 regulation is shown in Table 3.3-36. The emission factors are calculated from $EF=1/(((c\times(V^2))+(b\times V))+a)$.

B) Euro-2 and Euro-3 motorcycle emission factor and fuel consumption (50cm^3 and above, 4-stroke) is shown in Table 3.3-37, motorcycle PM emission factors (50cm^3 and above, 4-stroke) are shown in Table 3.3-38.

Table 3.3-35 Motorcycle CO and NOx emission factors until Euro-1 (50cm^3 and above, 4-stroke)

Target matter	Engine capacity	Regulation	Car speed (km/h)	Factors		
				e	c	A
CO	<250cm^3	Conventional	10-60	1.93E-02	-1.92E+00	6.83E+01
			60-110	1.70E-03	1.21E-01	9.50E+00
		Euro1	10-60	-4.68E-04	1.08E-01	9.33E+00
			60-110	-4.68E-04	1.08E-01	9.33E+00
	250-750cm^3	Conventional	10-60	1.39E-02	-1.42E+00	5.50E+01
			60-110	9.00E-04	-9.90E-03	1.78E+01
		Euro1	10-60	1.51E-03	-4.02E-02	8.73E+00
			60-110	1.51E-03	-4.02E-02	8.73E+00
	>750cm^3	Conventional	10-60	1.23E-02	-1.19E+00	4.28E+01
			60-110	5.00E-04	1.24E-01	6.90E+00
		Euro1	10-60	2.79E-03	-3.42E-01	1.71E+01
NOx	<250cm^3	Conventional	10-60	5.00E-05	-1.00E-03	9.00E-02
			60-110	2.00E-05	6.00E-04	1.02E-01
		Euro1	10-60	7.66E-05	-2.73E-03	2.32E-01
			60-110	7.66E-05	-2.73E-03	2.32E-01
	250-750cm^3	Conventional	10-60	5.00E-05	-9.00E-04	9.20E-02
			60-110	2.00E-05	7.0E-04	1.04E-01
		Euro1	10-60	5.23E-05	4.30E-04	1.91E-01
			60-110	5.23E-05	4.30E-04	1.91E-01
	>750cm^3	Conventional	10-60	5.00E-05	-8.00E-04	1.00E-01
			60-110	2.00E-05	8.00E-04	1.12E-01
		Euro1	10-60	1.43E-04	-5.32E-03	1.94E-01
			60-110	1.43E-04	-5.32E-03	1.94E-01

Source: EMEP/EEA Guidebook

Table 3.3-36 Motorcycle HC emission factors and fuel consumptions until Euro-1 regulation (50cm^3 and above, 4-stroke)

Engine capacity	Engine capacity	Regulation	Car speed (km/h)	Factors		
				e	c	A
HC	<250cm^3	Conventional	10-60	1.90E-03	-2.11E-01	6.95E+00
			60-110	9.00E-04	-1.41E-01	6.42E+00
		Euro1	10-60	-1.53E-04	3.44E-03	1.21E+00
			60-110	0.00E+00	0.00E+00	8.70E-01
	250-750cm^3	Conventional	10-60	1.50E-03	-1.64E-01	5.51E+00
			60-110	1.00E-05	5.00E-04	8.60E-01
		Euro1	10-60	1.59E-04	-2.58E-02	1.78E+00
			60-110	1.59E-04	-2.58E-02	1.78E+00
	>750cm^3	Conventional	10-60	2.20E-03	-2.57E-01	9.28E+00
			60-110	1.00E-04	-3.10E-02	3.29E+00
		Euro1	10-60	3.36E-04	-5.12E-02	2.68E+00
			60-110	3.36E-04	-5.12E-02	2.68E+00
Fuel consumption rate	<250cm^3	Conventional	10-60	1.89E-02	-1.87E+00	6.79E+01
			60-110	8.00E-04	1.61E-01	1.15E+01
		Euro1	10-60	8.40E-03	-6.77E-01	2.57E+01
			60-110	8.40E-03	-6.77E-01	3.57E+01
	250-750cm^3	Conventional	10-60	2.73E-02	2.85E+00	9.89E+01
			60-110	2.10E-03	-1.55E-01	2.92E+01
		Euro1	10-60	6.44E-03	-6.96E-01	4.65E+01
			60-110	6.44E-03	-6.96E-01	4.65E+01
	>750cm^3	Conventional	10-60	2.87E-02	-3.11E+00	1.16E+02
			60-110	1.80E-03	-1.64E-01	3.70E+01
		Euro1	10-60	7.22E-03	-1.08E+00	7.66E+01
			60-110	7.22E-03	-1.08E+00	7.66E+01

Source: EMEP/EEA Guidebook

Table 3.3-37 Euro-2 and Euro-3 Motorcycle emission factors and fuel consumption (50cm^3 and above, 4-stroke)

Target matter	Engine capacity	Regulation	Car speed (km/h)	Emission rate (g/km)		
				City	Suburbs	Highway
CO	All emission rate	Euro2	10-110	6.472	5.947	9.309
	All emission rate	Euro3	10-110	4.705	1.581	2.241
NOx	All emission rate	Euro2	10-110	0.195	0.265	0.531
	All emission rate	Euro3	10-110	0.126	0.150	0.329
HC	All emission rate	Euro2	10-110	1.053	0.557	0.612
	All emission rate	Euro3	10-110	0.628	0.193	0.179
Fuel consumption rate	All emission rate	Euro2	10-110	Same as Euro-1		
	All emission rate	Euro3	10-110			

Source: EMEP/EEA Guidebook

Table 3.3-38 Motorcycle PM emission factors (50cm^3 and above, 4-stroke)

Target matter	Engine capacity	Regulation	Car speed (km/h)	Emission rate (g/km)
PM	<250cm^3	Conventional	10-110	2.0E-02
		Euro1	10-110	2.0E-02
		Euro2	10-110	5.0E-03
		Euro3	10-110	5.0E-03
	250<cc<750cm^3	Conventional	10-110	2.0E-02
		Euro1	10-110	2.0E-02
		Euro2	10-110	5.0E-03
		Euro3	10-110	5.0E-03
	<750cm^3	Conventional	10-110	2.0E-02
		Euro1	10-110	2.0E-02
		Euro2	10-110	5.0E-03
		Euro3	10-110	5.0E-03

Source: EMEP/EEA Guidebook

Article 3.3-1 Emission of air pollutants from automobile in Vietnam

As examples of traffic count survey point, Figure 3.3-6 shows traffic count survey points in Hanoi city (only central area), and Figure 3.3-7 shows traffic count survey counts in Ho Chi Minh city.

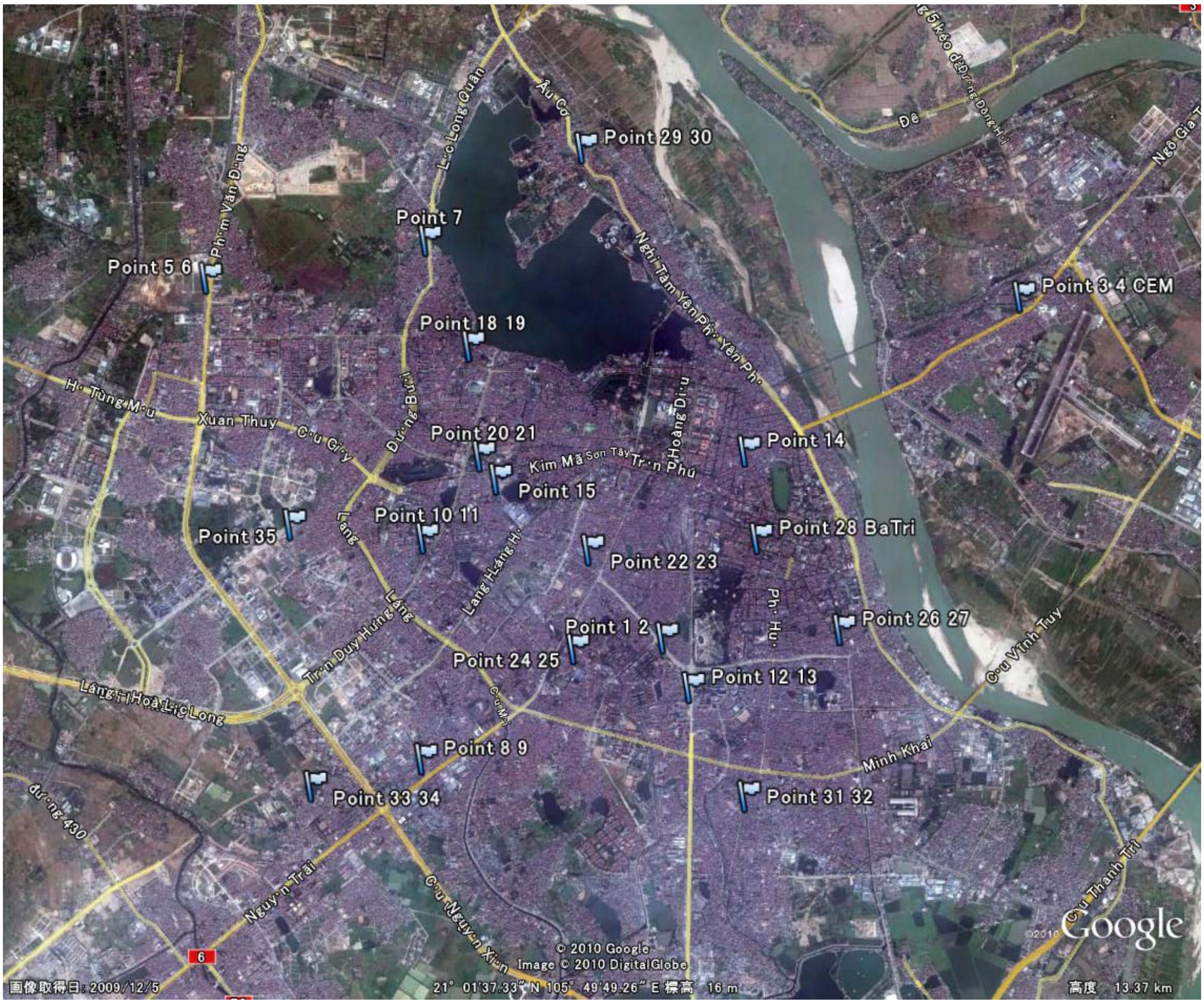

Figure 3.3-6 Traffic count survey points in Hanoi city center

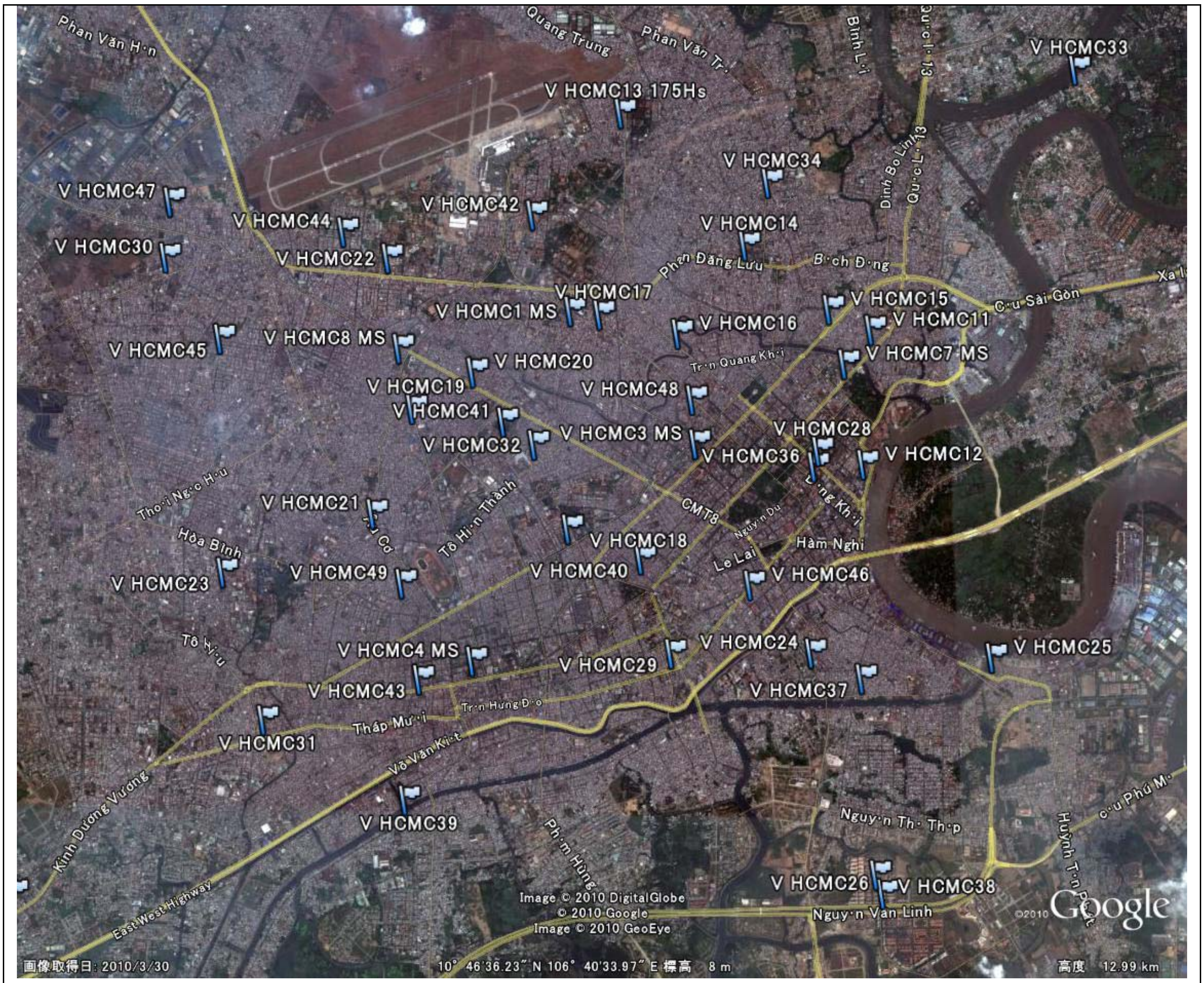

Figure 3.3-7 Traffic count survey points in Ho Chi Minh City

The example is allocated assignment traffic volume for target car types (PCU unit) in Hanoi and Ho Chi Minh City distribution to inventory target car type, which is shown in Table 3.3-39.

Table 3.3-39 Distribution ratio by car type in Hanoi and Ho Chi Minh City

Assignment traffic volume for target car types	Emission inventory target car type of emission inventory	Distribution ratio from assignment traffic volume for target car types (PCU unit) in Hanoi and Ho Chi Minh City distribution to inventory target car type
Motorcycle	Motorcycle	4.0
Passenger car	Passenger car	1.0
Bus	Minibus	0.18051
	Bus	0.36462
Duty vehicle	Light duty vehicle	0.1984
	Medium duty vehicle	0.3072
	Heavy duty vehicle	0.0716

Result of traffic volume survey in Hanoi in May 2010 are classified into road type and four categories: Suburban, Secondary, Primary-1, Primary-2 for arrangement hourly change. The hourly patterns are shown from Figure 3.3-9 to Figure 3.3-11. The traffic volume of motorcycle shows its 10%.

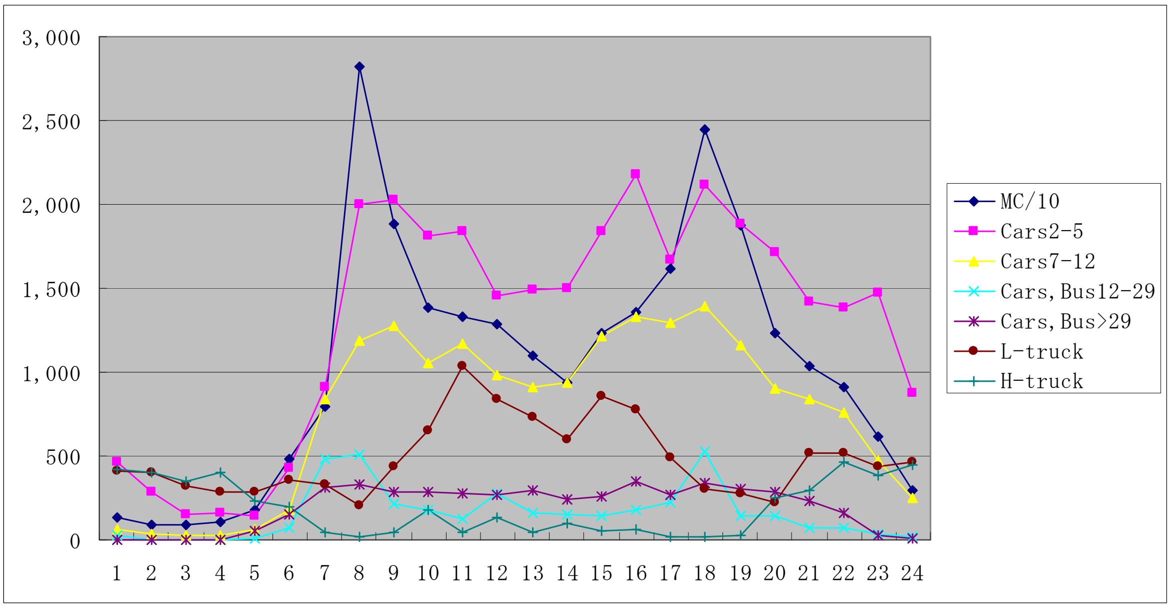

Figure 3.3-8 hourly change of Suburban traffic volume

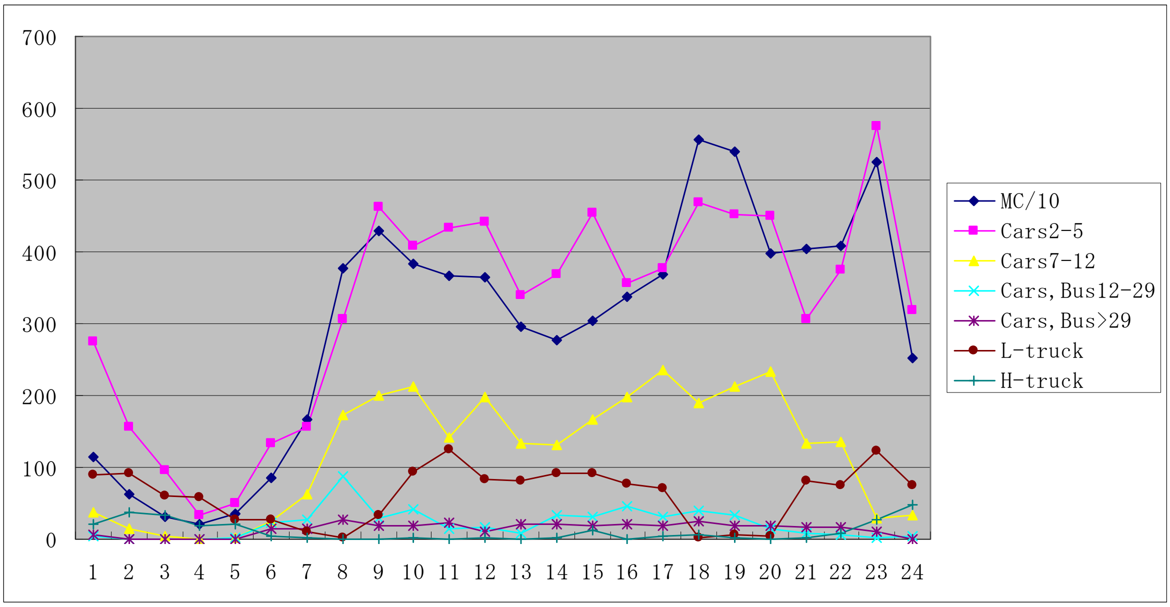

Figure 3.3-9 Hourly change of secondary traffic volume

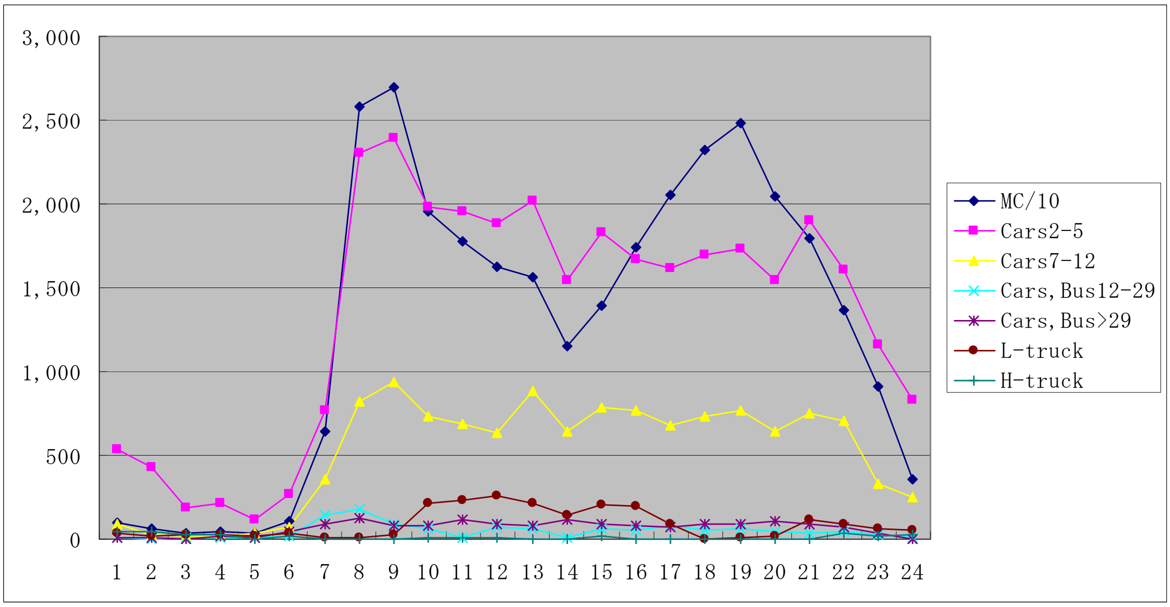

Figure 3.3-10 Hourly change of Primary-1 traffic volume

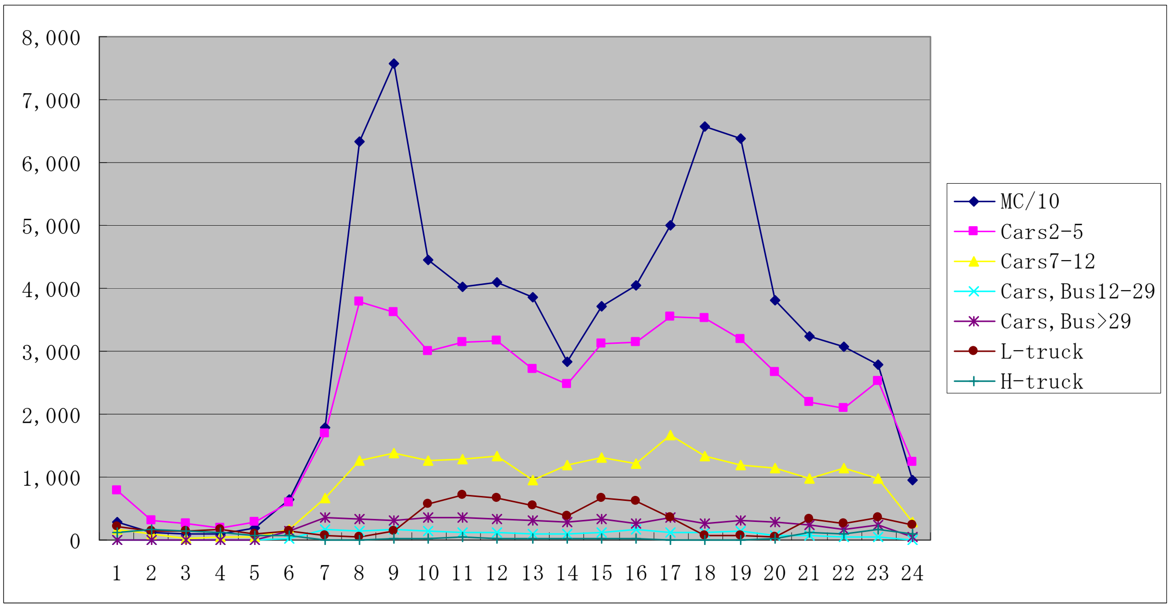

Figure 3.3-11 Hourly change of Primary-2 traffic volume

Exhaust gas regulation by year in Vietnam is shown in Table 3.3-40, however, it is for large cities such as Hanoi, Ho Chi Minh City and Danang, small towns are not applied Euro-2 regulation at this stage.

Fuel consumption rate and emission factor for target air pollutants of automobile in Vietnam is shown in Table 3.3-41.

Table 3.3-40 Exhaust gas regulation by year in Vietnam

Year	Vehicle Age	Regulation
2008	1	EURO2
2007	2	EURO2
2006	3	EURO1
2005	4	EURO1
2004	5	EURO1
2003	6	EURO1
2002	7	EURO1
2001	8	EURO1
2000	9	EURO1
1999	10	EURO1
1998	11	EURO1
1997	12	PRE EURO
1996	13	PRE EURO
1995	14	PRE EURO
1994	15	PRE EURO
1993	16	PRE EURO
1992	17	PRE EURO
1991	18	PRE EURO
1990	19	PRE EURO
1989	20	PRE EURO
1988	21	PRE EURO
1987	22	PRE EURO
1986	23	PRE EURO
1985	24	PRE EURO
1984	25	PRE EURO

Table 3.3-41 Fuel consumption rate and emission factors for target air pollutants

Unit: g/km

Substance	Car Type | Speed (km/h)	10	20	30	40	50	60	70	80	90	100
Ratio of Fuel use	Passenger car	112.239	78.403	64.452	56.541	51.725	48.938	47.843	48.008	49.351	51.896
	Small Truck	123.632	103.320	86.961	74.555	66.103	61.603	61.057	64.464	71.824	83.137
	Middle Truck	204.996	149.776	124.871	112.505	107.058	106.386	109.811	117.556	124.695	124.695
	Heavy Truck	431.116	309.241	248.605	214.092	193.815	182.357	177.079	176.840	179.049	179.049
	Mini Bus	403.261	267.622	208.358	179.185	164.407	157.535	155.817	156.566	156.566	156.566
	Bus	583.884	399.927	308.929	258.337	229.938	213.887	204.756	200.156	197.917	196.571
	Motorbike	32.939	27.543	24.074	22.532	22.918	25.303	29.142	34.462	41.262	49.542
NOx	Passenger car	0.777	0.682	0.637	0.622	0.631	0.659	0.704	0.766	0.844	0.937
	Small Truck	1.580	1.347	1.159	1.018	0.921	0.870	0.864	0.903	0.988	1.118
	Middle Truck	6.696	4.877	4.056	3.738	3.675	3.741	3.874	4.041	4.149	4.149
	Heavy Truck	14.343	10.561	8.639	7.569	6.961	6.608	6.398	6.267	6.213	6.213
	Mini Bus	13.852	9.305	7.169	6.164	5.690	5.468	5.362	5.333	5.333	5.333
	Bus	20.983	13.882	10.770	9.133	8.231	7.714	7.403	7.255	7.210	7.197
	Motorbike	0.213	0.212	0.221	0.240	0.269	0.308	0.355	0.411	0.476	0.551
CO	Passenger car	8.223	4.644	3.301	2.596	2.171	1.830	1.641	1.577	1.600	1.730
	Small Truck	3.400	2.478	1.730	1.157	0.759	0.535	0.486	0.612	0.912	1.388
	Middle Truck	2.032	1.293	0.950	0.773	0.680	0.635	0.618	0.621	0.629	0.629
	Heavy Truck	4.177	2.565	1.903	1.545	1.340	1.221	1.153	1.120	1.112	1.112
	Mini Bus	4.861	2.773	1.914	1.475	1.231	1.089	1.004	0.975	0.975	0.975
	Bus	6.603	3.760	2.648	2.051	1.685	1.445	1.281	1.198	1.169	1.151
	Motorbike	14.047	12.971	12.313	12.072	12.249	12.881	13.592	14.299	15.002	15.703
VOC	Passenger car	0.982	0.604	0.452	0.367	0.313	0.270	0.229	0.207	0.192	0.186
	Small Truck	0.254	0.213	0.180	0.152	0.129	0.112	0.101	0.095	0.095	0.101
	Middle Truck	0.849	0.528	0.380	0.298	0.246	0.213	0.190	0.174	0.167	0.167
	Heavy Truck	1.737	0.981	0.678	0.528	0.441	0.386	0.349	0.322	0.309	0.309
	Mini Bus	1.696	1.042	0.748	0.590	0.504	0.458	0.432	0.425	0.425	0.425
	Bus	2.103	1.249	0.885	0.682	0.558	0.480	0.429	0.399	0.382	0.370
	Motorbike	1.543	1.346	1.178	1.040	0.931	0.861	0.832	0.824	0.838	0.874
NH_3	Passenger car	0.064	0.064	0.029	0.064	0.064	0.064	0.064	0.064	0.064	0.064
	Small Truck	0.021	0.021	0.010	0.021	0.021	0.021	0.021	0.021	0.021	0.021
	Middle Truck	0.003	0.003	0.036	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	Heavy Truck	0.003	0.003	0.077	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	Mini Bus	0.001	0.001	0.047	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	Bus	0.002	0.002	0.071	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	Motorbike	0.002	0.002	0.140	0.002	0.002	0.002	0.002	0.002	0.002	0.002
PM	Passenger car	0.032	0.026	0.022	0.019	0.017	0.016	0.016	0.018	0.020	0.024
	Small Truck	0.125	0.099	0.078	0.065	0.059	0.060	0.068	0.082	0.104	0.133
	Middle Truck	0.337	0.215	0.159	0.129	0.114	0.106	0.103	0.103	0.103	0.103
	Heavy Truck	0.730	0.435	0.313	0.249	0.213	0.194	0.185	0.183	0.184	0.184
	Mini Bus	0.686	0.424	0.302	0.239	0.207	0.191	0.182	0.179	0.179	0.179
	Bus	0.942	0.582	0.426	0.336	0.281	0.245	0.221	0.208	0.203	0.199
	Motorbike	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
CH_4	Passenger car	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
	Small Truck	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
	Middle Truck	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
	Heavy Truck	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077
	Mini Bus	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
	Bus	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
	Motorbike	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
N_2O	Passenger car	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
	Small Truck	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
	Middle Truck	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
	Heavy Truck	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
	Mini Bus	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
	Bus	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
	Motorbike	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002

Estimation result of emission for the current year and the future year from automobile in Vietnam is shown in Table 3.3-42, NOx emission map in Vietnam is shown in Figure 3.3-12.

Table 3.3-42 Estimation result of emission for the current year and future year from automobile in Vietnam

Unit: ton/year

Substance	Current year (2008)			Future year (2015)			Ratio of Future year by Current year
	MajorRoad	MinorRoad	Total	MajorRoad	MinorRoad	Total	
SO_2	4,166	3,352	7,518	9,092	7,314	16,406	2.182
NOx	99,111	79,725	178,836	229,847	184,882	414,729	2.319
NH_3	1,764	1,419	3,184	3,554	2,858	6,412	2.014
CO	696,244	560,056	1,256,301	983,761	791,306	1,775,066	1.413
NMVOC	64,415	51,816	116,231	95,660	76,946	172,605	1.485
BENZENE	3,297	2,652	5,949	4,584	3,687	8,271	1.390
TOLUENE	6,283	5,054	11,337	8,735	7,026	15,761	1.390
ETHYL BENZENE	1,296	1,042	2,338	1,801	1,448	3,249	1.390
XYLENE	4,664	3,752	8,416	6,570	5,284	11,854	1.409
PM	4,273	3,438	7,711	5,781	4,650	10,431	1.353
CO_2	13,156,123	10,582,739	23,738,862	28,700,004	23,085,372	51,785,376	2.181
CH_4	7,966	6,408	14,374	13,093	10,531	23,624	1.643
N_2O	300	242	542	600	483	1,082	1.997

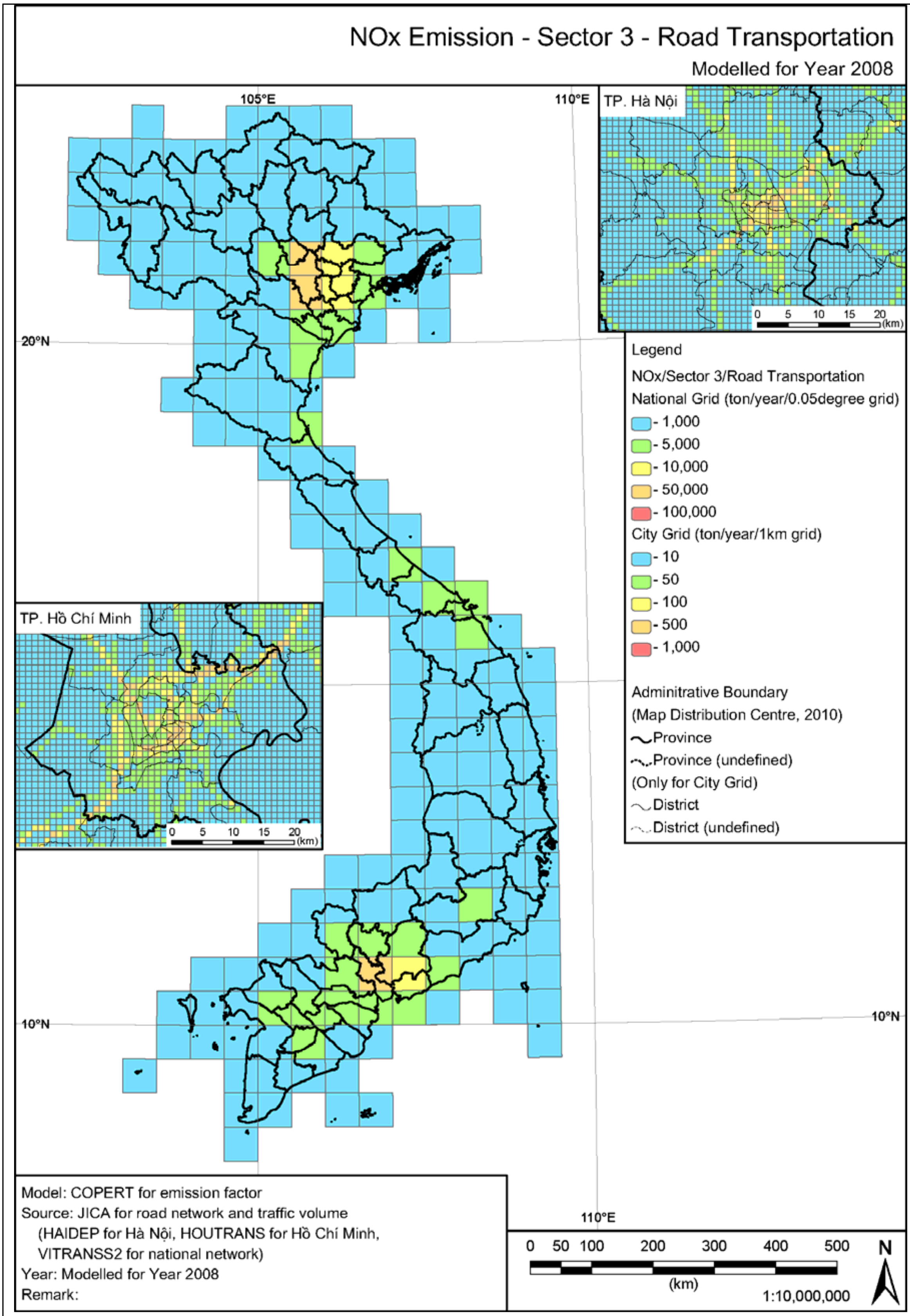

Figure 3.3-12 NOx emission map of mobile source in Vietnam

3.3.2.2 Automobile emission from evaporation gas

1. Simple method

1) Type of evaporation gas

Vehicle gasoline evaporates in fuel tank due to rise in temperature inside the tank by air temperature change or during travel. This evaporation, is shown in the table, and is three types: Diurnal Bridging Loss (DBL), Hot Soak Loss, or Running Loss.

Table 3.3-43 Outline of fuel evaporation gas of automobile[9]

Types of fuel evaporation gas	Outline
Diurnal Bridging Loss (DBL)	Evaporation gas is emitted from canister by breaking through gasoline steam to be generated in gasoline tank due to air temperature change during parking.
Hot Soak Loss	Evaporation gas is emitted from gasoline to be stuck to suction pipe within one hour of engine stop
Running Loss	Evaporation gas is generated from fuel tank beyond canister purge capacity by high temperature as a result of travel

2) Outline of estimation method of emission

Emission by gas evaporation is estimated using below formula in EMEP/EEA Guidebook.

$$E_{VOC} = \sum_{j} N_j \times EF_{VOC,j} \times 365 \quad \cdots\cdots (3.3\text{-}13)$$

E_{VOC}: VOC emission (g/year)

N_j: Number of vehicles by car type (j)

$EF_{VOC,j}$: VOC emission factors by car type (j) (g/unit/day)

3) Emission factors

Temperature range of 24 hours is classified into four types. NMVOC emission factors for four types are shown in Table 3.3-44. The emission factors contain all the 3 types of gas evaporation.

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[9] http://www.meti.go.jp/policy/chemical_management/law/prtr/h21kohyo/todokedegai_haisyutsu/syousai/12_3.pdf

Table 3.3-44 NMVOC emission factor for evaporation gas

Unit: g/vehicle/day

Car type	Air temperature range			
	20 to 35°C	10 to 25°C	0 to 15°C	-10 to 5°C
Gasoline cars	24.9	14.8	10.8	7.7
Gasoline duty vehicle	37.9	22.6	16.6	11.7
Motorcycles	5.0	3.0	2.3	1.6

Source: EMEP/EEA Guidebook

4) Activity data

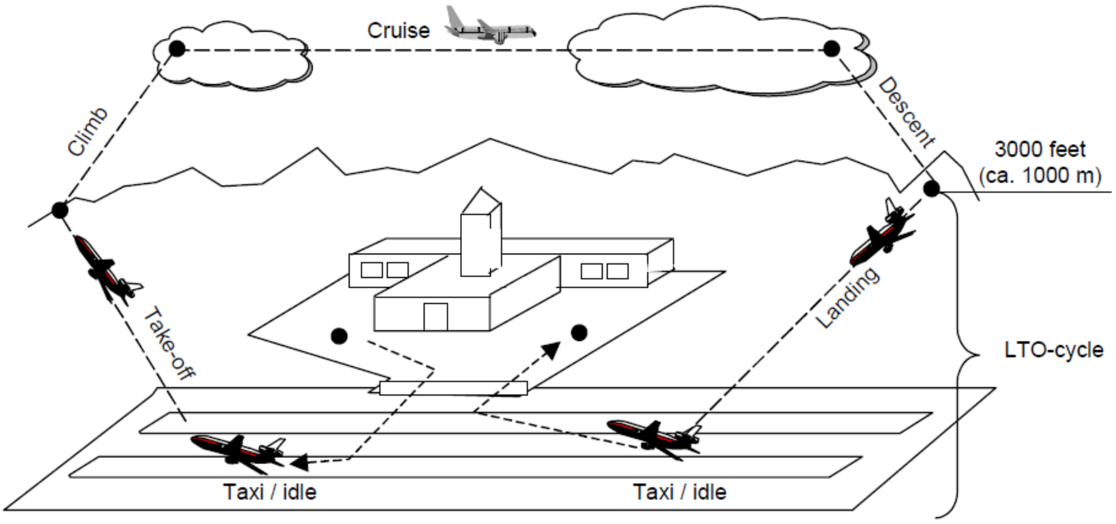
Number of cars using activity is estimated by traffic count survey and traffic assignment simulation data, or using number of retained cars.

3.3.3 Estimation method of air pollutants emission of aircraft

3.3.3.1 Simple method

1. LTO cycle

LTO (Landing and Take-off) cycle for aircraft is estimated for target of air pollutants. LTO cycle, as shown in Figure 3.3-13, means one cycle of aircraft that is from landing to take-off on airport. LTO consists of 4 modes: “Landing”, “Taxi/idle”, “Take-off” and “Climb-out”, LTO less than 3000 feet height is estimation target of emission.



Source: Figure 2-2 of Activities 080501-080504 (AIR TRAFFIC) in EMEP/EEA Guidebook

Figure 3.3-13 General flying cycle

【Aircraft LTO cycle】

・Idle (idling)

Engine warming-up and aircraft move to certain lot at the airport (taxiing idle).

・Take-off

The engine power during take-off and the power is full-throttle. Engine power of full throttle for 2 minutes or more is dangerous, so engine power after take-off can be reduced climb mode.

・Climb

Climbing aircraft has inclination from 8 to 15°, but climb inclination degree of aircraft is from is 3 to 5°. The engine power is high and second of take-off mode, and reaches 85% of engine maximum power.

・Approach

For approach, and aircrafts with approximately 30% of engine power land down runway.

2. Outline of estimation method of emission

Air pollutants emission during aircraft LTO cycle is estimated by following method.

$$E \text{ (emission)} = AR \text{ (fuel consumption rate)} \times EF \text{ (emission factor)} \cdots\cdots (3.3\text{-}14)$$

E: Emission AR: Fuel consumption rate

EF: Emission factor

For emission estimation, number of domestic and international LTO is calculated, and estimated by multiplying the number with typical aircraft emission factor.

3. Fuel consumption, emission factor

If aircraft total fuel consumption data is not existed, total fuel consumption is calculated by multiplying number of LTO and fuel consumption per LTO. Typical aircraft fuel consumption per LTO and emission factors by air pollutant are shown in Table 3.3-45.

Table 3.3-45 Typical aircraft emission factors per LTO (kg/LTO)

Domestic	Fuel	SO_2	CO_2	CO	NOx	NMVOC	CH_4	N_2O	$PM_{2.5}$
B737-400	825	0.8	2600	11.8	8.3	0.5	0.1	0.1	0.07
B737-100	920	0.9	2900	4.8	8.0	0.5	0.1	0.1	0.10
International	**Fuel**	**SO_2**	**CO_2**	**CO**	**NOx**	**NMVOC**	**CH_4**	**N_2O**	**$PM_{2.5}$**
B767	1617	1.6	5094	6.1	26.0	0.2	0.0	0.2	0.15
B737-400 (Short Distance)	825	0.8	2600	11.8	8.3	0.5	0.1	0.1	0.07
B747-400 (Long Distance)	3400	3.4	10717	19.5	56.6	1.7	0.2	0.3	0.32
DC10	2400	2.4	7500	61.6	41.7	20.5	2.3	0.2	0.32
B737-100 (Short Distance)	920	0.9	2900	4.8	8.0	0.5	0.1	0.1	0.10
B747-100 (Long Distance)	3400	3.4	10754	78.2	55.9	33.6	3.7	0.3	0.47

Short Distance: Cruising distance 500 nautical mile (= 926 km), Long Distance: Cruising distance 3,000 nautical mile (= 5556 km)

Source: EMEP/EEA Guidebook

4. *Temporal change and spatial distribution*

Temporal change is set by number of LTO by aircraft type based on flight schedule. Spatial distribution, emission is distributed by number of LTO by airport and aircraft type.

3.3.3.2 Detailed method

1. *Outline of emission estimation method*

Emission of aircraft about movement at the airport, less than 3000 feet of approach, climb, and take-off is estimated. In this guideline, auxiliary Propulsion Unit (APU) emission excluded.

Estimation method of emission by detailed method is shown in Figure 3.3-14. Aircraft emission is estimated from emission per unit fuel consumption by operation mode (ground movement, approach, climb and take-off) and fuel consumption per LTO by operation mode.

Air pollutant emission by mode

= Number of take-off and landing by airport, aircraft type (times)
×LTO cycle time by mode (s) × Emission factor by aircraft type and by mode (g/s)············(3.3-15)

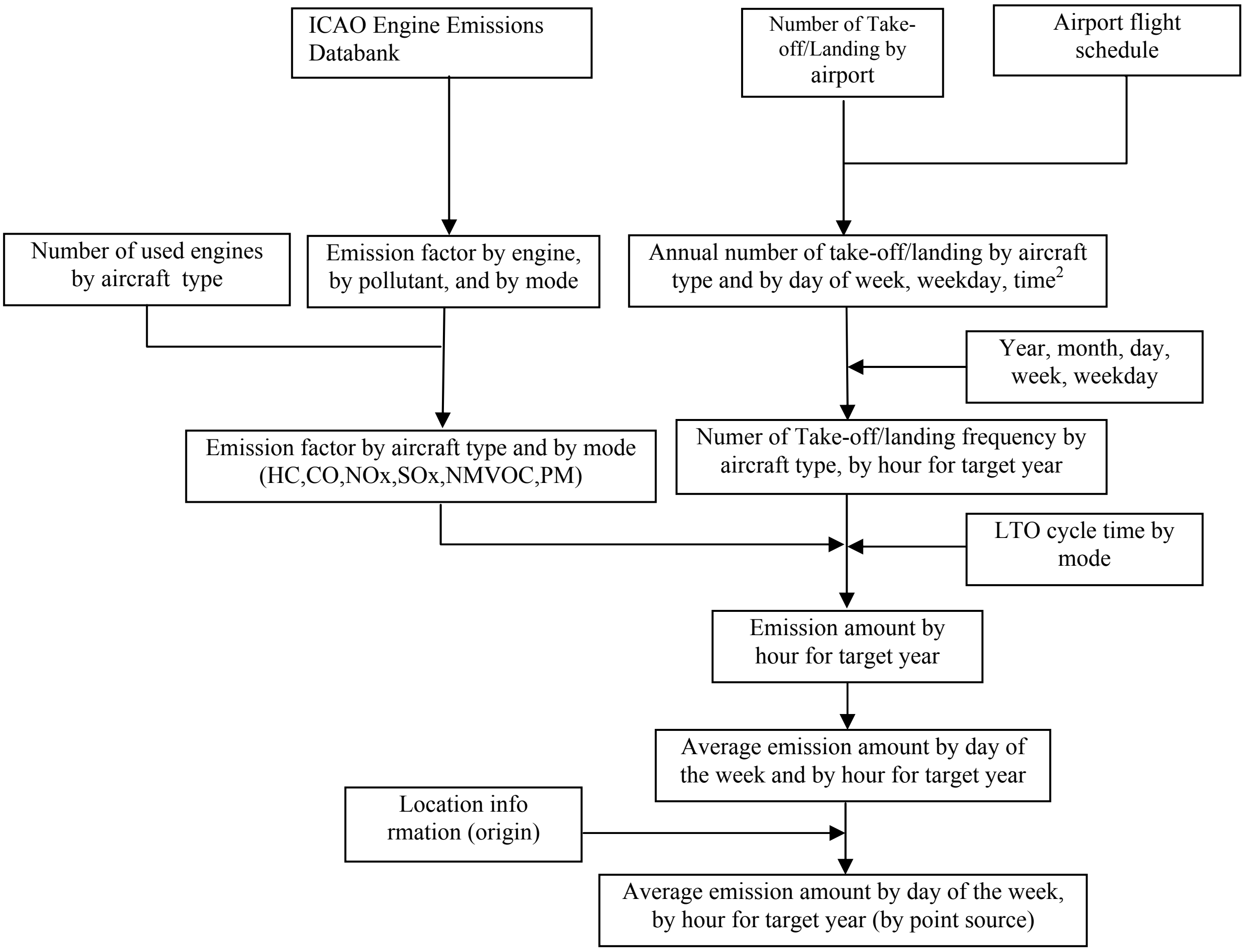


Figure 3.3-14 Outline of detailed estimation method of emission

2. *Estimation of fuel consumption by airport and by aircraft type*

Fuel consumption by airport and by aircraft type (kg/LTO) is estimated by multiplying fuel flow rate of each mode (kg/sec･unit), continuous time of each rating mode (sec/LTO) and number of engines. Number of annual take-off and landing by aircraft type is estimated from total annual landing times and flight schedule (e.g. take-off/landing data by airport and by aircraft type, OAG Official Airline Guide, etc)

As shown in Table 3.3-46, engine load rate by ICAO mode and LTO cycle time is used. However, if LTO cycle mode time had been measured for the main airports in each country, the measurement times are used as a priority.

Table 3.3-46 Engine load rate and mode time for LTO cycle

	Take-off	Climb-out	Landing	Taxi/idle
Engine load rate	100%	85%	30%	7%
LTO cycle time	42 sec	132 sec	240 sec	1,560 sec

Source: Default value; Table 2-2 of Activities 080501-080504 (AIR TRAFFIC) in EMEP/EEA Guidebook

3. Set of emission factors by aircraft type and by mode

Aircraft emission factors depend kind of type of installed engine, and LTO cycle mode (from landing to take-off). Therefore, the emission factors need to be set by engine and by operation mode. However, same types of aircrafts use some types of engines, so currently it is difficult to know accurately number of landing times by airport and by aircraft type. Therefore, same type of aircraft to be installed one typical engine is emitted, the engine type of the aircraft is selected, and emission factors are estimated.

Representative typical engine by aircraft and number of engines to be installed is indicated in Table 3.3-47.

Emission factors are set by ICAO data (Engine Exhaust Emissions Data Bank). SO_2 emission, emission factors by mode are calculated by sulfur content of fuel.

Emission factors by engine, by mode and by fuel consumption are indicated from Table 3.3-48 to Table 3.3-51.

HC, CO, NOx, NMVOC emission factor by engine and by mode (g/s)
= Fuel consumption by engine and by mode (kg/s) × Emission factor by engine and by mode (g/kg)
……………………………………(3.3-16)

SO_x emission factor by engine and by mode (SO_2 conversion, g/s)
= Fuel consumption by engine and by mode (kg/s)
×1000×Sulfur content×SO_2 molecular weight (64) / S atomic weight (32)……………(3.3-17)

PM emission factor by engine and by mode (g/s)
= (Volatile PM emission factor (mg/kg) + Non-volatile PM emission factor (mg/kg))
×Fuel consumption by engine and by mode (kg/s) / 1000 ……………………(3.3-18)

Emission factors by engine and by mode (g/s)
= Number of engines by aircraft type and by engine (unit) × Emission factor by engine and by mode (g/s)……………………………………(3.3-19)

Table 3.3-47 Typical engine and number of engines by aircraft

Air Craft Code	Air Craft Name	Engine Type	Number of Engine
320	Airbus Industrie A320	CFM56-5B1	2
321	Airbus Industrie A321	CFM56-5B1	2
332	Airbus Industrie A330-200	CF6-80E1A1	2
333	Airbus Industrie A330-300	CF6-80E1A1	2
343	Airbus Industrie A340-300	CFM56-5C4	4
737	Boeing 737 Passenger	CFM56-7B18	2
738	Boeing 737-800 Passenger	CFM56-7B18	2
739	Boeing 737-900 Passenger	CFM56-7B18	2
763	Boeing 767-300 Passenger	CF6-80C2A1	2
767	Boeing 767 Passenger	CF6-80C2A1	2
772	Boeing 777-200 Passenger	PW4077	2
777	Boeing 777 Passenger	PW4098	2
AT7	ATR-72	TAY Mk620-15	2
F70	Fokker 70	TAY Mk620-15	2
M90	Boeing (Douglas) MD-90	V2525-D5	2
AB6	Airbus Industrie A300-600(Pax)	CF6-80C2A1	2
T20	Tupolev Tu-204	PS-90A	2
M1F	Boeing (Douglas) MD-11 (Frighter)	CF6-80C2A1	2
74Y	Boeing 747-400F (Freighter)	PW4060	4
31Y	Airbus Industrie A310-300 Freighter	CF6-80C2A1	2
733	Boeing 737-300 Passenger	CFM56-3B-2	2
734	Boeing 737-400 Passenger	CFM56-3C-1	2
E90	Embraer 190	CF34-10E2A1	2
752	Boeing 757-200 Passenger	RB211-535E4	2
77W	Boeing 777-300ER Passenger	GE90-115B	2
340	Airbus Industrie A340	CFM56-5C4	4
319	Airbus Industrie A319	CFM56-5B1/3	2
75F	Boeing 757-200PF Freighter	RB211-535E4B	2
76Y	Boeing 767-300 Freighter	CF6-80C2B1F	2
72F	Boeing 727 (Freighter)	JT8D-9 series	2
330	Airbus Industrie A330	CF6-80E1A1	2
747	Boeing 747 Passenger	PW4060	4
773	Boeing 777-300 Passenger	PW4098	2
762	Boeing 767-200 Passenger	CF6-80C2A1	2

Table 3.3-48 Emission factors and fuel consumption by engine (take-off)

Engine Type	Emission Factor (g/s)							Fuel Consumption (kg/s)
	SOx	NOx	CO	HC	NMVOC	CH_4	PM	
CF34-10E2A1	0.046	13.827	0.315	0.031	0.028	0.003	0.066	0.769
CF6-80C2A1	0.144	77.328	1.344	0.192	0.173	0.019	0.265	2.400
CF6-80C2B1F	0.145	60.405	0.097	0.121	0.109	0.012	0.243	2.422
CF6-80E1A1	0.162	102.325	1.027	0.135	0.122	0.014	0.310	2.702
CFM56-3B-2	0.063	20.486	0.950	0.038	0.034	0.004	0.100	1.056
CFM56-3C-1	0.069	23.888	1.039	0.035	0.031	0.003	0.118	1.154
CFM56-5B1	0.082	47.701	0.680	0.136	0.122	0.014	0.156	1.359
CFM56-5B1/3	0.079	34.505	0.501	0.040	0.036	0.004	0.187	1.318
CFM56-5C4	0.087	54.848	1.456	0.012	0.010	0.001	0.721	1.456
CFM56-7B18	0.051	16.397	0.512	0.085	0.077	0.009	0.107	0.854
GE90-115B	0.281	236.095	0.375	0.188	0.169	0.019	0.404	4.690
JT8D-9 series	0.062	20.072	1.082	0.156	0.140	0.016	0.180	1.040
PS-90A	0.104	64.343	0.609	0.209	0.188	0.021	0.141	1.739
PW4060	0.159	86.822	0.979	0.265	0.238	0.026	0.299	2.647
PW4077	0.181	120.156	0.302	0.302	0.272	0.030	0.328	3.019
PW4098	0.248	212.238	0.662	0.000	0.000	0.000	0.387	4.138
RB211-535E4	0.112	83.477	1.432	0.000	0.000	0.000	0.171	1.860
RB211-535E4B	0.125	113.277	1.955	0.021	0.019	0.002	0.193	2.080
TAY Mk620-15	0.046	16.036	0.532	0.608	0.547	0.061	0.450	0.760
V2525-D5	0.063	27.905	0.558	0.043	0.039	0.004	0.191	1.053

Source: ICAO Engine Exhaust Emissions Data Bank

Table 3.3-49 Emission factors and fuel consumption by engine (climb)

Engine Type	Emission Factor (g/s)							Fuel Consumption (kg/s)
	SOx	NOx	CO	HC	NMVOC	CH_4	PM	
CF34-10E2A1	0.038	9.766	0.243	0.032	0.029	0.003	0.049	0.640
CF6-80C2A1	0.117	48.532	1.055	0.176	0.158	0.018	0.184	1.953
CF6-80C2B1F	0.119	39.105	0.079	0.099	0.089	0.010	0.177	1.983
CF6-80E1A1	0.132	59.615	0.748	0.154	0.139	0.015	0.227	2.199
CFM56-3B-2	0.053	14.663	0.790	0.041	0.037	0.004	0.072	0.878
CFM56-3C-1	0.057	16.981	0.859	0.038	0.034	0.004	0.082	0.954
CFM56-5B1	0.067	30.274	0.557	0.111	0.100	0.011	0.141	1.113
CFM56-5B1/3	0.064	21.016	0.213	0.021	0.019	0.002	0.144	1.063
CFM56-5C4	0.072	34.715	1.016	0.010	0.009	0.001	0.505	1.195
CFM56-7B18	0.043	11.852	0.286	0.071	0.064	0.007	0.073	0.714
GE90-115B	0.220	132.047	0.257	0.110	0.099	0.011	0.288	3.670
JT8D-9 series	0.051	12.257	0.938	0.152	0.137	0.015	0.068	0.845
PS-90A	0.086	45.077	0.572	0.172	0.155	0.017	0.109	1.431
PW4060	0.125	51.500	1.063	0.063	0.056	0.006	0.145	2.085
PW4077	0.147	79.690	0.245	0.245	0.221	0.025	0.211	2.452
PW4098	0.195	118.280	0.681	0.000	0.000	0.000	0.337	3.245
RB211-535E4	0.091	48.411	0.755	0.015	0.014	0.002	0.148	1.510
RB211-535E4B	0.099	60.753	0.990	0.000	0.000	0.000	0.161	1.650
TAY Mk620-15	0.038	10.584	0.504	0.189	0.170	0.019	0.322	0.630
V2525-D5	0.053	19.624	0.546	0.036	0.032	0.004	0.225	0.880

Source: ICAO Engine Exhaust Emissions Data Bank

Table 3.3-50 Emission factors and fuel consumption by engine (approach)

Engine Type	Emission Factor (g/s)							Fuel Consumption (kg/s)
	SOx	NOx	CO	HC	NMVOC	CH_4	PM	
CF34-10E2A1	0.013	1.696	0.990	0.022	0.020	0.002	0.017	0.222
CF6-80C2A1	0.038	6.207	1.393	0.127	0.114	0.013	0.058	0.636
CF6-80C2B1F	0.039	8.106	1.385	0.072	0.064	0.007	0.048	0.650
CF6-80E1A1	0.043	7.026	1.214	0.100	0.090	0.010	0.054	0.714
CFM56-3B-2	0.019	2.732	1.068	0.023	0.021	0.002	0.027	0.314
CFM56-3C-1	0.020	3.058	1.042	0.024	0.021	0.002	0.029	0.336
CFM56-5B1	0.022	3.931	0.571	0.044	0.039	0.004	0.027	0.364
CFM56-5B1/3	0.021	3.220	0.878	0.017	0.016	0.002	0.028	0.347
CFM56-5C4	0.023	4.119	0.540	0.025	0.023	0.003	0.041	0.386
CFM56-7B18	0.016	2.366	0.936	0.026	0.023	0.003	0.019	0.260
GE90-115B	0.068	18.645	2.237	0.068	0.061	0.007	0.088	1.130
JT8D-9 series	0.018	1.786	0.637	0.179	0.161	0.018	0.030	0.298
PS-90A	0.029	5.770	0.440	0.098	0.088	0.010	0.038	0.489
PW4060	0.042	8.436	1.251	0.098	0.089	0.010	0.053	0.703
PW4077	0.049	9.221	0.326	0.163	0.147	0.016	0.066	0.816
PW4098	0.065	16.007	0.753	0.000	0.000	0.000	0.087	1.075
RB211-535E4	0.031	3.526	0.593	0.021	0.019	0.002	0.047	0.520
RB211-535E4B	0.033	4.043	0.578	0.017	0.015	0.002	0.050	0.550
TAY Mk620-15	0.014	1.311	0.897	0.207	0.186	0.021	0.127	0.230
V2525-D5	0.019	2.839	0.778	0.019	0.018	0.002	0.072	0.319

Source: ICAO Engine Exhaust Emissions Data Bank

Table 3.3-51 Emission factors and fuel consumption by engine (idling)

Engine Type	Emission Factor (g/s)							Fuel Consumption (kg/s)
	SOx	NOx	CO	HC	NMVOC	CH_4	PM	
CF34-10E2A1	0.005	0.299	4.268	0.457	0.411	0.046	0.009	0.084
CF6-80C2A1	0.012	0.794	8.406	1.829	1.646	0.183	0.029	0.199
CF6-80C2B1F	0.012	0.941	3.827	0.306	0.276	0.031	0.015	0.199
CF6-80E1A1	0.014	1.010	9.772	2.188	1.969	0.219	0.029	0.226
CFM56-3B-2	0.007	0.488	3.582	0.208	0.187	0.021	0.011	0.119
CFM56-3C-1	0.007	0.533	3.323	0.176	0.158	0.018	0.011	0.124
CFM56-5B1	0.007	0.538	3.323	0.376	0.338	0.038	0.010	0.117
CFM56-5B1/3	0.007	0.485	3.043	0.149	0.134	0.015	0.010	0.109
CFM56-5C4	0.007	0.531	3.835	0.620	0.558	0.062	0.018	0.124
CFM56-7B18	0.006	0.417	2.745	0.340	0.306	0.034	0.009	0.097
GE90-115B	0.023	1.972	14.862	1.611	1.450	0.161	0.037	0.380
JT8D-9 series	0.008	0.384	1.871	0.413	0.371	0.041	0.011	0.132
PS-90A	0.011	1.032	1.228	0.053	0.048	0.005	0.012	0.178
PW4060	0.013	1.044	4.328	0.354	0.318	0.035	0.017	0.213
PW4077	0.014	0.974	4.686	0.696	0.626	0.070	0.020	0.232
PW4098	0.019	2.497	2.080	0.000	0.000	0.000	0.022	0.321
RB211-535E4	0.011	0.623	2.396	0.067	0.060	0.007	0.015	0.180
RB211-535E4B	0.011	0.669	2.234	0.053	0.048	0.005	0.015	0.190
TAY Mk620-15	0.007	0.275	2.651	0.374	0.337	0.037	0.021	0.110
V2525-D5	0.008	0.602	1.591	0.013	0.012	0.001	0.023	0.128

Source: ICAO Engine Exhaust Emissions Data Bank

4. Temporal change and spatial distribution

Temporal change, time by aircraft type by hour and by mode is calculated from airport flight schedule by airport, and emission by airport, by mode and hour is estimated.

Spatial distribution, the emission is assumed to be emitted from aircraft parking lot, access roads, runway and flight path. Emission is estimated on parking lot as point source, access roads and runway as line source, and flight route as pointed line source.

3.3.4 Estimation of air pollutants emission of vessel

3.3.4.1 Simple method

1. Outline of emission estimation method

Estimation method of vessel emission by fuel type by Tier-1 is as follows: -

$$E_i = \sum_m FC_m \times EF_{i,m} \quad \cdots\cdots (3.3\text{-}20)$$

Ei: Emission (air pollutant i, unit: kg or g)

FC_m: Total fuel type (m) consumption total in engine (ton)

EF_i: Emission factors (air pollutant i, kg/ton)

m: Fuel type (C-heavy oil, A-heavy oil, gas oil, gasoline)

2. Estimation of Fuel consumption

Fuel consumption data use fuel consumption statistics data for vessels of the country. In Tier-1, the emission factors of C-heavy oil (bunker heavy oil), A-heavy oil, gas oil and gasoline are difference, annual fuel consumption is estimated by 4 types of fuel.

3. Setting of emission factors

Vessel emission factors by target matter and by fuel type (Simple method) are shown from Table 3.3-52 to Table 3.3-54. CO_2, CH_4, N_2O emission factor is shown in Table 3.3-55 and Table 3.3-56.

Table 3.3-52 Vessel emission factors by target matter (C-heavy oil)

Target matter	Emission factor (kg/ton fuel)	Target matter	Emission factor (kg/ton fuel)
NOx	79.3	TSP	6.2
CO	7.4	PM_{10}	6.2
NMVOC	2.7	$PM_{2.5}$	5.6
SO_2	20×S content (%)		

Source: EMEP/EEA Guidebook

Table 3.3-53 Vessel emission factor by target matter (A-heavy oil and gas oil)

Target matter	Emission factor (kg/ton fuel)	Target matter	Emission factor (kg/ton fuel)
NOx	78.5	TSP	1.5
CO	7.4	PM_{10}	1.5
NMVOC	2.8	$PM_{2.5}$	1.4
SO_2	20×S content (%)		

Source: EMEP/EEA Guidebook

Table 3.3-54 Vessel emission factor by target matter (gasoline)

Target matter	Emission factor (kg/ton fuel)	Target matter	Emission factor (kg/ton fuel)
NOx	9.4	TSP	9.5
CO	573.9	PM_{10}	9.5
NMVOC	181.5	$PM_{2.5}$	9.5
SO_2	20×S content (%)		

Source: EMEP/EEA Guidebook

Table 3.3-55 Vessel CO_2 emission factor

Fuel type	CO_2 Emission factor (kg/TJ)
Gasoline	69,300
Other Kerosene	71,900
Gas/Diesel Oil	74,100
Residual Fuel Oil	77,400

Source: 2006 IPCC Guidelines

Table 3.3-56 Vessel CH_4, N_2O emission factor

	CH_4(kg/TJ)	N_2O(kg/TJ)
All fuels	7	2

Source: 2006 IPCC Guidelines

4. *Temporal change and spatial distribution*

Temporal change, typical passenger boarding time and loading volume is calculated, and is estimated.

Spatial distribution is distributed by ratio between total gross ton by port and national total of gross tone.

3.3.4.2 Detailed method

1. *Outline of emission estimation method*

About air pollutants emission from vessel, estimation target of emission of air pollutants is the vessel in port and voyage route. The estimation methods use the methods of EMEP/CORINAIR Atmospheric Emission Inventory Guidebook ("EMEP/CORINAIR Guidebook").

The emission is estimated from exhaust during sea voyage, during berthing, during loading/unloading and boats in the port.

There are two estimation methods. One is "ship movement mode" and the other is "fuel consumption mode". If each vessel detailed movement data or technical data can be obtained, "ship movement mode" is recommended.. It can be divided into domestic emission and international emission, but it takes time to estimate. And consistency with energy statistics is difficult. The emission during voyage to be estimated is from cruising start to berthing location, transportation, voyage to be reached destination port. The emission is estimated by multiplying the emission ratio (emission rate per hour), which is estimated by multiplying the engine power, engine load rate, engine number and emission factors, and voyage time.

If fuel consumption by vessel category or by each vessel can be obtained, "fuel consumption mode" is recommended. Spatial distribution of emission is rather difficult, but emission is relatively easy to estimate, and also the method is suitable indicator for trend of the annual emission. The emission during voyage is estimated by multiplying fuel consumption (activity data) to be estimated by multiplier, which fuel consumption uses function of gross ton and multiplier by operation mode, and emission factor.

Emission estimation flow is as follows: -

1) Vessel size, engine power, engine type and engine number, port leaving / arrival information, departure / arrival time, voyage route and port-to-port distance etc. of each vessel is obtained from Lloyd's Maritime Information Service or related organization.
2) From engine number and engine power, each vessel the air pollutant emission ratio (kg/hour) can be obtained.
3) From route information and in/out port name of each vessel, the spatial distribution (voyage route) can be determined.
4) From in/out port time of each vessel, temporal change (hourly emission pattern) can be determined.
5) From multiplying the emission ratio and voyage time, emission of air pollutants (CO, NMVOC and NO_x) is obtained, and the emission to be obtained can be distributed along the voyage route. At the same time, based on the temporal change, hourly emission amount can be distributed.
6) From gross ton and operation mode by ship type, fuel consumption can be calculated (Table 3.3-60)

The above data can be obtained by all-in survey for inventory period, or estimation of each vessel type can be used same conditions of sampling survey results.

Emission estimation formula is as follows:

CO, NMVOC and NOx emission estimation by "ship movement mode" is described below.

$$E = e \times t \quad \cdots\cdots (3.3\text{-}21)$$

E: Emission peer vessel for specified region (kg/hour)

e: Emission ratio (kg/hour)

t: Specified region voyage time (d/s) (hour)

d: Specified region voyage distance (km)

s: Vessel speed (km/hour)

Calculation of SO_2 and heavy metal, PM, and other emission by "ship movement mode" multiplies emission factor and fuel consumption by fuel type. Fuel consumption can be estimated from total gross ton and operation mode by ship type (Table 3.3-60). Emission estimation is as follows: -

$$\text{Emissions} = \sum_i \text{Activity}_i \times \text{EF}_i \quad \cdots\cdots (3.3\text{-}22)$$

Activity: Fuel type i fuel consumption

EF_i: Fuel type i emission factor

i: Fuel type

"Fuel consumption mode", emission is estimated by multiplying emission factor and fuel consumption. Estimation of SO_2, heavy metal, PM, and other emission should be divided into distillated fuel type and residue fuel type. This guideline includes indirectly emission of during loading/unloading and berthing. Emission calculation is as follows:

$$\text{Emissions} = \sum_i \text{Activity}_i \times \text{EF}_i \quad \cdots\cdots (3.3\text{-}23)$$

Activity: Fuel type i fuel consumption

EF_i: Fuel type i emission factor

i: Fuel type

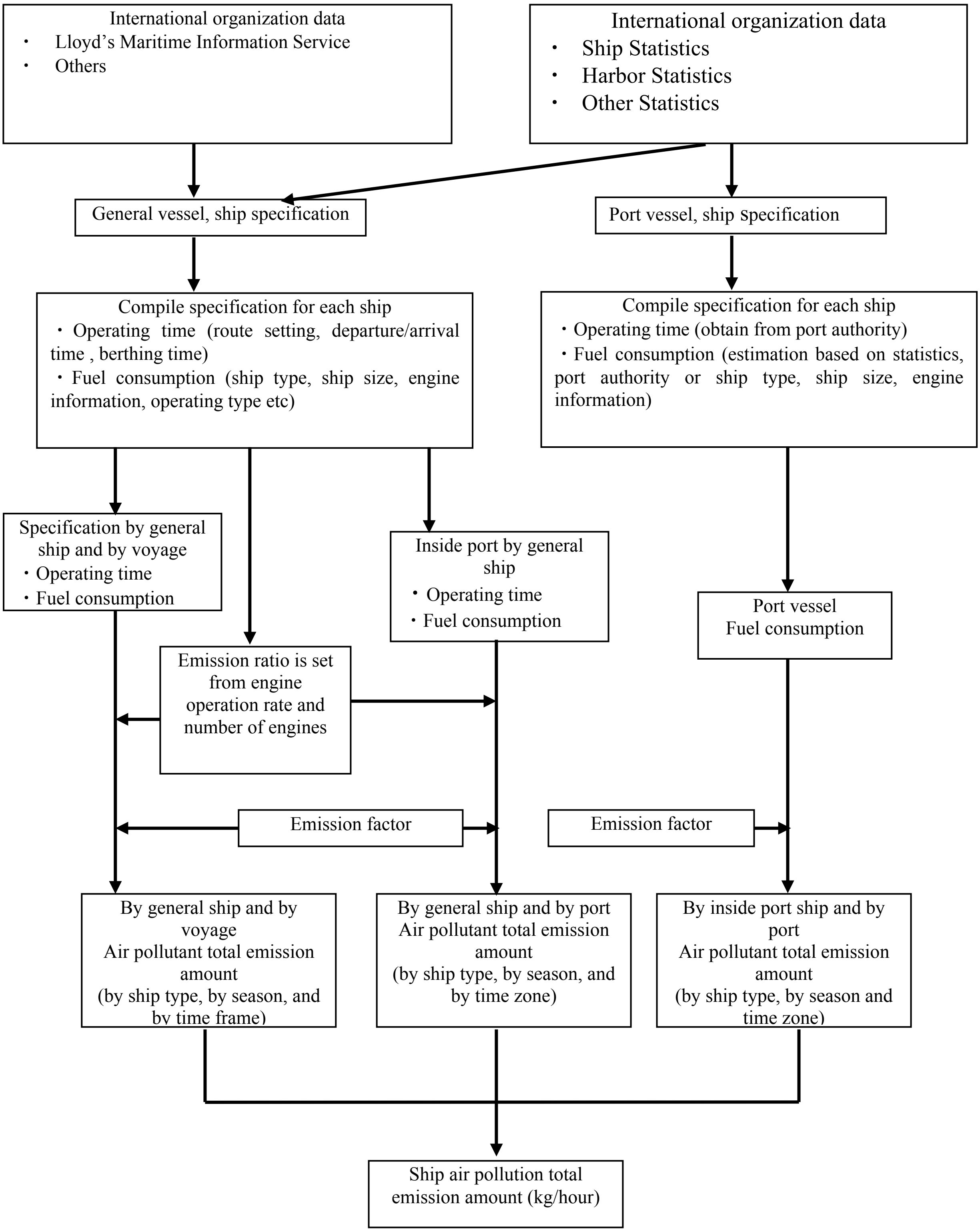


Figure 3.3-15 Estimation flow of emission of air pollutants from vessels

2. Estimation of activity data

1) Ship movement mode

Activity data of ship movement mode is based on time by cruising mode. The cruising mode is arranged as shown in Table 3.3-57. From collection data of each ship, the time for each cruising mode from (a) to (h) is estimated. At the same time, the position information for each cruising mode is arranged. That is, the route and port position, berthing location is determined.

Table 3.3-57 Arrangement of vessel cruising mode

Ship movement mode	Category of ship movement method
(a) Cruising in international waters	“Cruising Phases”
(b) Cruising in national x-miles zones	“Cruising Phases”
(c) Approaching harbor (by a river or a canal)	“Maneuvering Phases”
(d) Docking in the harbor	“Maneuvering Phases”
(e) Berthing in the harbor	“Berthing Phase”
(f) Departing from the harbor (by a river or a canal)	“Maneuvering Phases”
(g) Cruising in x-miles zones	“Cruising Phases”
(h) Cruising in international waters	“Cruising Phases”

In order to obtain these data, statistic data in Table 3.3-58 should be obtained.

Table 3.3-58 Vessel statistic data list

Statistic data	Remarks
Lloyd’s Maritime Information Service (LMIS)	“Ship size”, “Destination”, “Approximately arrival time and departure time”, “Engine type and number of engines” etc
Port calling statistics	Data close to LMIS
Survey of ship owner	Conduced in several countries
Ferry timetable	In/out port time table data, time table data
Fishing deliveries	Operation area (fishing area) and landing fish port information

From these statistic data, cruising time for each ship by cruising mode is estimated.

- Estimation steps in each cruising mode -

1) Determine port area of estimation target port.
2) For international route, determine estimation target range. This Guideline defines the range as half the distance from home port to destination port.
3) For domestic route, if calculating the inventory for whole of country, all routes should be included as estimation target. And if estimation area is limited, calculate the target area.
4) Fishing boat includes coastal and offshore fishing boats. Ocean fishery boats, operation areas are assumed to be far away, fuel consumption in coastal area is relatively assumed to small, and it can be ignored.
5) After determining the route, define cruising mode to be classified by Table 3.3-57.
6) From in/out port time, speed factor (Table 3.3-62: ship speed by ship type) etc., calculate the time pattern for each ship by cruising mode to be defined in 5). From in/out port time, direct cruising time can be estimated, but the time is divided by each cruising mode. From the distance of each cruising mode, the time for each cruising mode is estimated by subtracting distance of each cruising mode from speed factor. However, the speed factor in Table 3.3-62 is constantly for each ship type, the speed factor by each cruising mode needs to be further examined.

Knowing the condition of ship in/out port and berthing, ship information can be easily compiled as shown in data collection sheet in Table 3.3-59 (survey chart).

The main survey items are ship name, ship type, total gross ton (number of G/T), purpose of port visit, arrival time and departure time, berthing time, installed number of engines, engine type, engine power, and fuel consumption.

Table 3.3-59 Collection arragement format sample of vessel information

In/out port time		Loading		Ship name	Gross ton	Cargo type	Domestic/Overseas route	Cruise type	Port of registry	Ship type	Purpose of visit	Mooring		Destination port		Installed engine			
In time	Out time	Start time	Finish time									Location	Time	Incoming port	Outgoing port	Main diesel engine	Aux. diesel engine	Main boiler	Aux. boiler
																Number of engines, model, power		Number of engines, fuel consumption	

2) Fuel consumption mode

As shown in Table 3.3-60, fuel consumption par day for full power is estimated from total gross ton. Based on the defined cruising mode Table 3.3-57, fuel consumption par day by each operation mode is estimated by multiplying the fuel consumption and multiplier by operation mode (“Cruise time”, “Maneuvering time” and “Berthing time” in Table 3.3-60).

Each cruising mode is estimated by “Estimation steps of each operation model” that is calculated by the above “ship movement mode”. Fuel consumption of each mode is estimated by multiplying time by operation mode and fuel consumption per day.

Table 3.3-60 Fuel consumption ratio

Fuel consumption factor	Fuel consumption at max power as function of gross ton (GT) (ton/day)	Average (ton/day)	Cruise time	Maneuvering time	Berthing time
Solid bulk	20.186+0.00049×GT	33.8	0.8	0.4	0.2
Liquid bulk	14.685+0.00079×GT	41.1	0.8	0.4	0.2
General cargo	9.8197+0.00143×GT	21.3	0.8	0.4	0.2
Container	8.0552+0.00235×GT	65.9	0.8	0.4	0.2
Passenger/Ro-Ro/Cargo	12.834+0.00156×GT	32.3	0.8	0.4	0.2
Passenger	16.904+0.00198×GT	70.2	0.8	0.4	0.2
High Speed ferry	39.483+0.00972×GT	80.4	0.8	0.4	0.2
Inland cargo	9.8197+0.00143×GT	21.3	0.8	0.4	0.2
Sail ship	0.4268+0.00100×GT	3.4	0.8	0.4	0.2
Tugs	5.6511+0.001048×GT	14.4	0.8	0.4	0.2
Fishing	1.9387+0.00448×GT	5.5	0.8	0.4	0.2
Other ships	9.7126+0.00091×GT	26.4	0.8	0.4	0.2
All ships	16.263+0.001×GT	32.8	0.8	0.4	0.2

Source: EMEP/CORINAIR Guidebook

The fuel consumption for each mode of each ship to be calculated, which is estimated by fuel type, by domestic demand, and by international bunker oil. These data treat as “Data A”.

From the below mentioned statistics, fuel consumption in the whole country is obtained. These data treat as “Data B”. For ship fuel consumption, the actual fuel consumption or its alternative data source is listed in the order of their reliability.

a) National energy statistics from energy or statistical agencies;

b) International Energy Agency (IEA) statistical information;

c) Surveys of shipping companies (including ferry and freight);

d) Surveys of fuel suppliers (e.g. quantity of fuels delivered to port facilities);

e) Surveys of individual port and marine authorities;

f) Surveys of fishing companies

g) Equipment counts, especially for small gasoline powered fishing and pleasure craft;

h) Import/export records;

i) Ship movement data and standard passenger and freight ferry schedules;

j) Passenger counts and cargo tonnage data;

k) International Maritime Organization (IMO), engine manufacturers, or Jane's Military Ships Database;

l) Ship movement data derived from Lloyds Register data

Data A and Data B is cross-checked to determine fuel consumption for using inventory. At this time, it should be noted that international marine bunkers excluded domestic fuel consumption. Therefore, fuel consumption for international route is not considered domestic fuel consumption.

3. *Setting of emission factors*

Emission factors are arranged as follows.

1) *Ship movement mode*

The emission ratio is shown in Table 3.3-61. Speed factors for various ship categories are provided in Table 3.3-62.

Table 3.3-61 Air pollution matter emission ratio

Unit: (kg/hours)	Medium speed and auxiliary engines	Slow speed
NOx	$4.25\times10^{-3}\times P^{1.15}\times N$	$17.50\times10^{-3}\times P\times N$
CO	$15.32\times10^{-3}\times P^{0.68}\times N$	$17.50\times10^{-3}\times P^{1.08}\times N$
HC	$4.86\times10^{-3}\times P^{0.69}\times N$	$0.28\times10^{-3}\times P\times N$
SO_2 (engines<2000kW)	$2.31\times10^{-3}\times P\times N$	
SO_2 (engines>=2000kW)	$12.47\times10^{-3}\times P\times N$	$11.34\times10^{-3}\times P\times N$

Note: P equals to engine power (kW) multiplied by engine load (85%). N means number of engines

Source: EMEP/CORINAIR Guidebook

For air pollutants not to be listed in Table 3.3-61, the fuel consumption by ship movement mode is treated as activity data and the emission factors of <fuel consumption mode> (Table 3.3-63 to Table 3.3-66) is used.

Table 3.3-62 Vessel speed factors by type and by gross tonnage; main and auxiliary engine work rate

Ship Type	**Speed Factor**	**Estimated Main Engine Power kW (total power of all engines)**							**Estimated Auxiliary Power kW (medium speed)**					
	Knots	<500 GRT	500-999 GRT	1000-4999 GRT	5000-9999 GRT	10000-49999 GRT	>=50000 GRT	All	<500 GRT	500-999 GRT	1000-4999 GRT	5000-9999 GRT	10000-49999 GRT	>=50000 GRT
Liquified Gas Tanker	16	650 (m)	700 (m)	2250 (m)	5350 (#)	11600 (s)	15200 (s)	5900	75	100	125	300	400	1000
Chemical Tanker	15	1000 (m)	-	2000 (m)	5000 (#)	10250 (s)	-	5700	40	50	165	300	435	-
Other Tanker	14	600 (m)	950 (m)	2200 (m)	4300 (#)	9600 (s)	17200 (s)	7900	40	50	165	300	435	530
Bulk Dry Cargo	14	550 (m)	750 (m)	2700 (m)	5000 (#)	8800 (s)	17000 (s)	9100	20	40	175	300	380	500
General Cargo	14	550 (m)	950 (m)	1800 (m)	5500 (#)	8500 (s)	-	3300	20	40	175	300	380	-
Passenger/General Cargo	18	450 (m)	900 (m)	2850 (m)	6450 (#)	12600 (s)	-	4900	20	40	175	300	380	-
Container	20	1000 (m)	1750 (m)	2950 (m)	6000 (#)	17200 (s)	35000 (s)	16300	40	60	160	500	1400	1400
Refrigerated Cargo	20	900 (m)	900 (m)	3100 (m)	8850 (#)	10000 (s)	-	6700	40	140	180	455	580	-
Ro-Ro Cargo	18	1500 (m)	1900 (m)	4300 (m)	7200 (#)	11600 (#)	12550 (s)	7700	100	150	350	1000	2500	4000
Passenger/Ro-Ro	20	600 (m)	-	6500 (m)	12300 (#)	16650 (#)	-	12800	100	150	350	1000	2500	-
Passenger	20	550 (m)	-	3350 (m)	7800 (#)	16800 (#)	50000 (m)	14400	100	150	350	1000	2500	4000
Other Dry Cargo	15	900 (m)	-	2050 (m)	4450 (#)	17600 (#)	-	5900	20	40	175	300	380	500
Fish Catching	11	-	1050 (m)	2500 (m)	-	-	-	2200	-	80	200	-	-	-
Other Fishing	15	650 (m)	800 (m)	2300 (m)	5300 (m)	5400 (s)	-	2600	40	105	180	550	550	-
Offshore	14	1800 (m)	2150 (m)	3800 (m)	7450 (#)	11800 (#)	-	4000	40	60	150	350	450	-
Research	14	900 (m)	1300 (m)	3250 (m)	5300 (#)	8950 (s)	-	2900	40	60	150	400	400	-
Tug	11	3000 (m)	4050 (m)	6450 (m)	-	-	-	4400	40	60	150	-	-	-
Dredger	9	400 (m)	550 (m)	2400 (m)	7350 (#)	9250 (#)	-	4500	40	50	60	130	770	-
Cable	7	1100 (m)	-	3850 (m)	5950 (m)	13400 (s)	-	5300	80	-	200	300	-	-
Other Activities	-	500 (m)	900 (m)	3300 (m)	7650 (#)	8500 (#)	-	3700	40	60	150	300	500	-
Non-propelled	2	-	400 (m)	2750 (m)	-	-	-	2200	-	-	-	-	-	-
All		900 (m)	1200 (m)	2400 (m)	6200 (#)	9900 (#)	18700 (s)		50	80	200	450	900	1750

m = predominantly medium speed
s = predominantly slow speed
# = both medium and slow speed

Source: EMEP/CORINAIR Guidebook

2) *Fuel consumption mode*

If air pollutants emission is calculated from fuel consumption of vessel, emission ratio of air pollutants per fuel consumption, in other words, emission factors are used (from Table 3.3-63 to Table 3.3-65).

Table 3.3-63 Air pollutant emission factors (Part 1: Depending on fuel composition)

	(kg/ton fuel)	Distillate Fuel (g/ton fuel)	Residual Fuel Oil (g/ton fuel)
CO_2	3,170	-	-
SO_2	20 * S (%)	-	-
TSP	-	1,100	6,700
PM_{10}	-	1,100	6,700
$PM_{2.5}$	-	1,100	6,700

Note: S (%) = Sulfur content of fuel (% by wt)

Default Value of S (%): 2.7% (by wt) - residual fuel oil

Default Value of S (%): 0.5% (by wt) - distillate fuel

Source: EMEP/CORINAIR Guidebook

Table 3.3-64 Air pollutants matter emission factor (Part 2: engine-based)

	(kg/ton fuel)
NOx	87* / 72+ / 57++
CO	7.4
NMVOC	2.4
CH_4	0.05
N_2O	0.08

Note: * Slow speed, + Composite factor, ++ Medium speed

Source: EMEP/CORINAIR Guidebook

Table 3.3-65 Air pollutant emission factors (Part 3: Steam turbine, gas turbine etc.)

Unit: (kg/ton fuel)	NO_x	CO	VOC	TSP	PM_{10}	$PM_{2.5}$
Steam turbine propulsion - distillate fuel	3.3	0.6	0.5	1.0	1.0	1.0
Steam turbine propulsion - residual fuel	7.4	0.4	0.1	2.6	2.6	2.6
Gas turbines	16	0.5	0.2	0.2	0.2	0.2

Source: EMEP/CORINAIR Guidebook

CO_2 emission factor by simple method and detailed method has same values. CH_4 and N_2O emission factor comes from Table 3.5.3 of "Chapter 3: Mobile Combustion" of "Volume 2: Energy" in 2006 IPCC Guidelines, and is set as in Table 3.3-66.

Table 3.3-66 Air pollutant emission factor (CH_4 and N_2O)

	CH_4 (kg/TJ)	N_2O (kg/TJ)
Ocean-going Ships	7 (±50%)	2 (-40% to +140%)

Source: 2006 IPCC Guidelines

4. *Temporal change and spatial distribution*

Ship emission by detailed method is estimated as line source. Line source has position information, namely, spatial distribution can be obtained.

Temporal change of emission from ship route is set by using method in Table 3.3-67.

Table 3.3-67 Temporal change and spatial distribution setting method for emission from vessel route

	Application condition	Application method
Level-1	If departure time and arrival time is not be obtained.	Distribute constantly emission for each route for 24-hours
Level-2	If ship information is received by sample survey.	Arrange sample survey by ship type. Calculate average emission per ship type. Emission rate of ships not to be targeted by sample survey is assumed to be equal for each ship type. Ship voyage pattern for each ship type to be obtained from sample survey is also applied to non-target ships of sample survey. Based on the above assumption, the emission for each route in each time period (e.g. 7:00 - 7:59) is calculated.
Level-3	If ship information of overall survey is	Calculate each ship emission from engine information by each ship. Then emission by each voyage and by each time zone (e.g.

	received.	7:00 - 7:59) is estimated.

However, air pollutant emission should be allocated to any of country. Therefore, in case of international route, it should be allocated evenly among the related countries, and calculate the emission for half of the distance from departure port of own country to destination port of its country.

3.3.5 Estimation of air pollutants emission of railway

3.3.5.1 Simple method

1. Outline of emission estimation method

Estimation amount of Tier-1 fuel-based railroad emission is as follows: -

$$E_i = \sum_m FC_m \times EF_{i,m} \quad \cdots\cdots (3.3\text{-}24)$$

Ei: Emission (pollutant i,unit: kg or g)

FC_m: Fuel consumption by fuel type m of target engine (ton)

EF_i: Emission factor (pollutant i, kg/ton)

m: Fuel type (diesel oil, heavy oil)

2. Estimation of fuel consumption

Fuel consumption data use fuel consumption statistics data for national railroad. Tier-1, SO_2 emission factor varies fuel type, so the annual consumption to be divided diesel oil and heavy oil is estimated. Emission factors for other air pollutants use the same factor for the two types of fuel.

3. Setting of emission factors

Railroad emission factors by target pollutant (Simple method) are shown in Table 3.3-68 and Table 3.3-69.

Table 3.3-68 Railroad emission factors by target matter

Unit: kg/ton fuel

Target matter	Emission factor	Target matter	Emission factor
NOx	52.4	TSP	1.52
CO	10.7	PM_{10}	1.44
NMVOC	4.65	$PM_{2.5}$	1.37
NH_3	0.007	CO_2	3140
SO_2	20×S content (%)		

Source: EMEP/EEA Guidebook

Table 3.3-69 Railroad CH_4, N_2O emission factor

Fuel type	CH_4(kg/TJ)	N_2O(kg/TJ)
Diesel oil	4.15	28.6

Source: 2006 IPCC Guidelines

4. Temporal change and spatial distribution

Temporal change is estimated by setting hourly change of typical passenger embarkation and hourly change of loading capacity.

Space distribution is assigned by national transportation statistics by route etc.

3.3.5.2 Detailed method

1. Outline of emission estimation method

Detailed estimation method of air pollutant emission for railroad is bottom-up method that is total of air pollutant emission to be estimated by each railway and by railroad route. The pre-conditions are due to obtain the annual average use time of each engine by railroad route, average horse power, typical load ratio.

More detailed estimation method based on US-EPA off-road emission is described below. To estimate emission, the following basic formula is used.

$$\text{Emissions} = \sum_{i}\left(N_i \times HRS_i \times HP_i \times LF_i \times EF_i\right) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (3.3\text{-}25)$$

Emissions = Air pollutant emission of pollutant source i for inventory calculation period

N_i = Number of pollutant sources i unit (number of engines)

HRS_i = Pollutant source i annual use hours

HP_i = Pollutant source i average horse power

LF_i = Pollutant source i typical load ratio

EF_i = Pollutant source i average emission per engine use (e.g. [g/kWh])

i = Pollutant source i (locomotives) and itinery type

This is the same method as "Tier-3" that is CH_4 and N_2O emission of "3.4 RAILWAYS" locomotives of "Chapter 3: Mobile Combustion" in 2006 IPCC Guidelines.

2. Estimation of activity data

Following data is obtained and then activity data is calculated. Locomotives and railroad vehicles except electric-power type treats as locomotives. Locomotives are composed of diesel engine car, diesel railcar, and steam locomotive.

Table 3.3-70 Parameters for estimation of activity data

Activity data parameter	Received data contents	Assumed source etc.
N = Pollutant source number (number of locomotives)	Number of locomotives and railroad vehicles (except electric-power type)	Railway company, related organizations, Web etc.
HRS = Annual use hours	Time table (if possible, each train locomotives information)	Railway company, related organization, Web, library, stations, bookstores etc.
HP = Average horse power	Locomotives rated horse power	Railway company, related organization, engine car manufacturer etc.
LF = Typical load ratio	Locomotives load ratio and average value of each route and national average is assumed	Interview with railway companies etc.

From these data, activity data is shown as follows:

$$AD = N \times HRS \times HP \times LF \quad \cdots\cdots (3.3\text{-}26)$$

AD = Activity data of pollutant source i for inventory calculation period

N = Number of pollutant sources (number of locomotives)

HRS = Annual use hours

HP = Average horse power

LF = Typical load ratio

3. *Setting of emission factors*

Emission factor is set as shown in Table 3.3-71.

Table 3.3-71 Emission factor list

	Category				
Pollutant		**Locomotives**			**Railcars**
	Outside the quoted ranges	**130 - 560**	**> 560**	**> 2000 and SV > 5.0 l/cylinder**	**< 130**
Implementation data		**N/A**	**1/7/2005**	**1/1/2007**	**1/1/2008**
NO_x [g/kWh]	14.4	3.50	6.00	7.40	3.50
N_2O [g/kWh]	0.35	0.35	0.35	0.35	0.35
CH_4 [g/kWh]	0.05	0.05	0.05	0.05	0.05
CO [g/kWh]	8.38	3.50	3.50	3.50	3.50
NMVOC [g/kWh]	3.82	0.50	0.50	0.50	0.50
PM [g/kWh]	2.22	0.20	0.20	0.20	0.20
$PM_{2.5}$ [g/kWh]	2.09	0.19	0.19	0.19	0.19
NH_3 [g/kWh]	0.002	0.002	0.002	0.002	0.002

Source: EMEP/CORINAIR Guidebook “OTHER MOBILE SOURCES and MACHINERY” “Table 8-5f”

Furthermore, based on “Box 3.4.1” of “Volume 2: Energy” in 2006 IPCC Guidelines, the emission factor can be used in Table 3.3-72.

Table 3.3-72 2006 IPCC Guidelines emission factors

Model	Engine	Power		Brake specific diesel fuel consumption (kg/kWh)	Reported emission levels (g/kWh)			
		HP	kW		NOx	CO	HC	CO_2
EMD SD-40	645E3B	3000	2237	0.246	15.82	2.01	0.36	440
EMD SD-60	710G3	3800	2834	0.219	13.81	2.68	0.35	391
EMD SD-70	710G3C	4000	2983	0.213	17.43	0.80	0.38	380
EMD SD-75	710G3EC	4300	3207	0.206	17.84	1.34	0.40	367
GE Dash 8	7FDL	3800	2834	0.219	16.63	6.44	0.64	391
GE Dash 9	7FDL	4400	3281	0.215	15.15	1.88	0.28	383
GE Dash 9	7FDL(Tier0)	4400	3281	0.215	12.74	1.88	0.28	383
Evolution	GEVO12	4400	3281	NA	10.86	1.21	0.40	NA
2TE116	1A-5Д49	6035	2・2250	0.214	16.05	10.70	4.07	382
2TE10M	10Д100	5900	2・2250	0.226	15.82	10.62	4.07	403
TEII60	11Д45	2950	2200	0.236	16.05	10.62	3.84	421
TEII70	2A-5Д49	3420	2550	0.211	15.83	10.55	4.01	377
2M62	14Д40	3943	2・1470	0.231	13.40	9.01	3.23	412

Source: 2006 IPCC Guidelines

4. Temporal change and spatial distribution

Railway emission by detailed method treats as line source for each line, and since line source has position information, namely spatial distribution is identified.

If locomotives information not available, simple method is used to estimate. Locomotives information can be sample survey, but overall survey is desirable.

If time table is not available, simple method is used to estimate. Number of operated train’s information by each line can be used, but detailed time table can be desirable.

Temporal change of railway emission is estimated as follows. If cargo ratio is unclear, the emission during travel by each railway is assumed to be evenly same.

Table 3.3-73 Setting method of temporal change and spatial distribution about emission from railroad

	Application condition	Application method
Level-1	Obtain number of operated trains by route. Obtain locomotives information by sample survey.	Emission from locomotives to be estimated by sample survey appropriately apply to trains emission. If information is not available, the average can be used, but trains are classified if possible, and average emission of each classification is estimated, and emission to be allocated should be necessary. For temporal change, emission of 24-hours is assigned constantly.
Level-2	Obtain time table by route. Obtain locomotives information by sample survey.	Emission from locomotives to be estimated by sample survey appropriately applies to trains emission. If information is not available, the average can be used, but trains are classified if possible, and average emission of each classification is estimated, and emission to be allocated should be necessary. Based on time table, emission of each time zone (e.g. 7:00 - 7:59) by train is calculated.
Level-3	Obtain number of operated trains by route. Obtain all locomotives information.	Calculate emission of each train, and total emission is calculated. Based on number of operated trains, above total emission is distributed each route. For temporal change, emission of 24-hours is assigned constantly.
Level-4	Obtain time table by route. Obtain all locomotives information.	Emission of each train is respectively estimated. Based on time table, emission of each time zone (e.g. 7:00 - 7:59) by train is calculated.

In case of international train, emission amount up to the border is estimated.

4 Estimation of air pollutant amount of fugitive emission from fossil fuel

4.1 Target for estimation

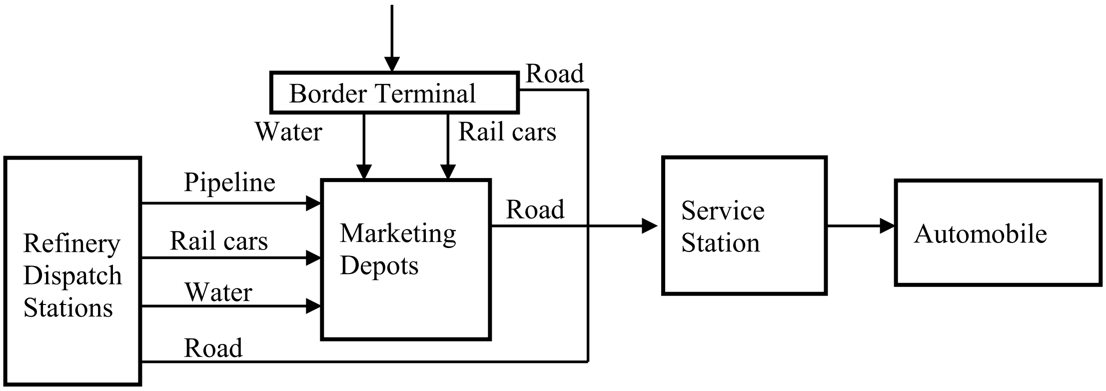
Targets for estimation in this chapter follows ones in 2006 IPCC Guidelines. This chapter treats include intentional and unintentional emissions of air pollutants and GHG during mining, production, treatment, refining, transport, storage and delivery of fossil fuels like coal, oil, and natural gas.

The targets are classified into category and sub-category, as shown in Table 4.1-1 in this guideline, which means "Fugitive emission from fossil fuel" sector is classified into "Fugitive emission from solid fuels like coal etc.", and "Fugitive emission from petroleum and natural gas" category.

Fugitive emissions from solid fuels like coal etc are emissions from mining and handling of coal and from solid fuels. CH_4 is mainly emitted from "mining and handling of coal" and NMVOC, PM and CO_2 are also emitted. Peat and other solid fuels are not included. The processes like coal combustion, cokes production and gasification after handling of coal are not included. Fugitive emissions from coke ovens are cokes oven door leaks and coal dry quenching. Fugitive emissions from fuel combustion for heating coke ovens are estimated in the part for stationary sources in the fuel combustion sector.

Crude oil and natural gas are supplied through similar processes, and are extracted, refined, loaded and delivered. Therefore, crude oil and natural gas are classified into one category. On the other hand, crude oil is separated and processed into various petroleum products at oil refinery and various air pollutants are emitted during the processes. So, oil refinery is treated as independent emission source(sub category).

Gasoline and diesel oil are transported to dispersed gas stations in the country as fuels for automobiles. Gas station is one of major emission sources of NMVOC. Therefore, gas station is treated as independent emission source because different consideration is necessary for estimation of spatial distribution of gas station than one for natural gas etc. Fugitive emission from gasoline and diesel oil are estimated within the range stated in Figure 4.1-1, based on EMEP/EEA Guidebook.



Source: EMEP/EEA Guidebook, "1.B.2.a.v Distribution of oil products" Figure 2-1

Figure 4.1-1 Scope of estimation of air pollutant amount of fugitive emission from gasoline

And emissions from refining, transport and delivery of petroleum products are major emission sources for NMVOC in many countries. On the other hand, CH_4 is mainly emitted from fugitive emission of natural gas and NMVOC emission from this is not so much.

Table 4.1-1 Emission source categories and target pollutant of fugitive emission from fossil fuel

Category	Sub Category	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Fugitive emission from solid fuels like coal etc	Mining and handling (Shipping or transport) of coal	NE	NA	NA	○	NA	○	○	○	NE	NE	○	○	NE
	Fugitive emission from solid fuels like coal etc. (production of cokes, non-smoke fuels)	○	○	○	○	○	○	○	○	○	○	○	○	NE
Fugitive emission from oil and natural gas	Investigation for extraction, production, and loading of oil	NA	NA	NA	○	NA	NA	NA	NA	NA	NA	○	○	○
	Refining and storage of oil	○	○	○	○	○	○	○	○	NE	NE	○	○	○
	Delivery of petroleum products	NE	NA	NA	○	NA	NA	NA	NA	NA	NA	○	○	○
	Extraction, production, loading, refining, storage and transport of natural gas	NE	NA	NA	○	NA	NA	NA	NA	NA	NA	○	○	○

Note: “NE” means ”Not Estimated”, ”NA” means ”Not Applicable”

Emission source categories as in Table 4.1-1 are classified into categories as in Table 4.1-2.

Table 4.1-2 Emission source categories of fugitive emission from fossil fuel leak

Category (Emission source)	Detailed emission source and borderline
Mining and handling (shipping or transport) of coal	Coal mine access and mining preparation Surface coal mining and transportation During the process of coal treatment, waste treatment, transportation, coal crushing before end use Emission from methane drainage in underground coal mine during the process of pre and post mining Waste treatment from coal extraction
Fugitive emissions from solid fuels like coal etc. (production of cokes, non-smoke fuels)	Emission from cokes oven (Oven door leaks, cokes making extrusion machine, cokes furnace fire extinguishing equipment) Emission from production of non-smoke fuels production (coal carbonization process)
Investigation for extraction, production, and loading of oil	Fugitive emissions from oil well (including test well, mining mud) leak Fugitive emissions from facilities and platforms Fugitive emissions from transit in marine tankers Fugitive emissions from pipeline transport and tankers transport
Refining and storage of oil	Fugitive emissions from petroleum products processing (vacuum distillation, contact dispersion, catalytic cracking, thermal cracking, sweetening, blow down system processes) Sulfur recovery Storage and handling
Delivery of petroleum products	From refinery to automobile (refer to Figure 4.1-1), including fugitive emission from refueling automobile.
Extraction, production, loading, refining, storage and transport of natural gas	Fugitive emissions from gas well (including test well, mining mud) leak Fugitive emissions from facilities and platforms Fugitive emissions from transit in gas marine tankers Fugitive emissions from gas pipeline transport, compressing facilities and gas delivery network

4.2 Fugitive emission from solid fuels like coal etc

4.2.1 Simple method

4.2.1.1 Outline of emission estimation method

Air pollutant emission amount is estimated by multiplying activity data and emission factors. Activity data are coal production etc. and statistics data of country or province are used for estimation. The emission factor is the emission amount per unit of production amount. "Simple method" is compared to "4.2.2 Detailed method", it is much simpler, rough and average. These emission factors are treated as default values in this guideline.

$$\mathrm{Emissions} = \mathrm{AD} \times \mathrm{EF} \quad \cdots\cdots (4.2\text{-}1)$$

Whereas,

Emissions: Air pollutant and greenhouse gas emission amount

AD: Activity data (fossil fuel production amount etc.)

EF: Emission factor

However, in the total national activity data of fugitive emission from fossil fuel, activity data is not estimated from "4.2.2 Detailed method" is treated as area source, and estimated using "4.2.1 Simple method"

4.2.1.2 Estimation of activity data

Activity data is basically set as production volume of solid fuels like a coal etc. of the country, and the activity data of each emission source is listed in Table 4.2-1. However, the proper unit can also be converted to calorific value unit, if required, in which case, basically the conversion factor uses the proper value of the coal mine, factory. If suitable conversion factor is not available, the standard calorific value published by the country can be used, and if the appropriate calorific value in the country is not available, use the default calorific value stated in 2006 IPCC Guidelines.

Table 4.2-1 Simple method – Activity data of fugitive emission from solid fuels like coal etc.

Category	Activity data	Source/remarks
Mining and handling (shipping or transport) of coal	Coal production volume	Underground mining and open cast mining etc. to be identified preferably Coal statistics data of the country and various energy statistics data(country, IEA,UN statistics) etc.
Fugitive emissions from solid fuels like coal etc. (production of cokes, non-smoke fuels)	Cokes production volume	Various energy statistics data (country, IEA,UN statistics),"International Iron and Steel Institute",etc.

4.2.1.3 Setting of emission factors

Emission factors are basically set as default values of GAP Forum Manual. These values are based on ones in Europe. Fugitive emissions from fuels seem to depend on climate, technology and quality of fuel etc. Actual emission factors of NMVOC may become larger values in tropical and sub tropical countries with higher temperature than one in Europe.

Table 4.2-2 Emission factors for air pollutant from cokes production

Category	Air pollutant	Emission factor	Unit
Coking process	NMVOC	29-400	(kg/ tons coke)
Cokes oven gas purification	NMVOC	210	(kg/ tons coke)
Coal crushing	PM_{10}	0.055	(kg/ tons coke)
Coal preheating	PM_{10}	1.7	(kg/ tons coke)
	$PM_{2.5}$	1.0	(kg/ tons coke)
Cokes oven charging	PM_{10}	0.24	(kg/ tons coke)
Cokes oven door leaks	PM_{10}	0.27	(kg/ tons coke)
Cokes oven pushing	PM_{10}	0.25	(kg/ tons coke)
	$PM_{2.5}$	0.1	(kg/ tons coke)
Cole dry quenching facility	PM_{10}	0.6	(kg/ tons coke)
	$PM_{2.5}$	0.51	(kg/ tons coke)

Source: All from GAP Forum Manual

If default values of emission factor of Table 4.2-2 cannot be used, use default values of Tier 1 method in EMEP/EEA Air Pollutant Emission Inventory Guidebook – 2009. These values are based on ones in Europe. Fugitive emissions from fuels seem to depend on climate, technology and quality of fuel etc. Actual emission factors of NMVOC may become larger values in tropical and sub tropical countries with higher temperature than one in Europe. And greenhouse gas emission factors are basically set as default values of 2006 IPCC Guidelines. These emission factors are set as in Table 4.2-3.

Table 4.2-3 Emission factors of fugitive emission from solid fuels like coal etc.

Category	Air pollutant	Emission factor	Unit/source
Mining and handling (shipping or transport) of coal	NMVOC	0.8	(kg/Mg coal) EMEP/EEA Guidebook
	PM_{10}	3	(kg/Mg coal) EMEP/EEA Guidebook
Open cast mining Mining	CH_4	1.2	(m^3/ton) 2006 IPCC Guidelines
Open cast mining Post mining process	CH_4	0.1	(m^3/ton) 2006 IPCC Guidelines
Underground mining Mining	CH_4	18	(m^3/ton) 2006 IPCC Guidelines
Underground mining After mining process	CH_4	2.5	(m^3/ton) 2006 IPCC Guidelines
Flaring CH_4 to CO_2 in mine gas	CO_2	1.8×10^{-6}	(Gg/m^3 volume of CH_4 flared) 2006 IPCC Guidelines
Flaring CH_4 to CO_2 in mine gas	CH_4	1.34×10^{-6}	(Gg/m^3 volume of CH_4 flared) 2006 IPCC Guidelines
Fugitive emissions from solid fuels like coal etc. (production of cokes, non-smoke fuels)	NMVOC	17	(kg/Mg coke produced) EMEP/EEA Guidebook
	NH_3	5	(kg/Mg coke produced) EMEP/EEA Guidebook
	TSP	110	(kg/Mg coke produced) EMEP/EEA Guidebook
	PM_{10}	100	(kg/Mg coke produced) EMEP/EEA Guidebook
	$PM_{2.5}$	90	(kg/Mg coke produced) EMEP/EEA Guidebook

Black Carbon (BC) and Organic Carbon (OC) emission factors set as values of "A technology-based global inventory of black and organic carbon emission from combustion" (Tami C. Bond, etc 2004), and set as follows: -

$$EF_{BC} = EF_{PM} \times F_{1.0} \times F_{BC} \times F_{cont} \quad \cdots\cdots (4.2\text{-}2)$$

$$EF_{OC} = EF_{PM} \times F_{1.0} \times F_{OC} \times F_{cont} \quad \cdots\cdots (4.2\text{-}3)$$

Whereas,

EF_{PM}: PM emission factor (g/kg)

$F_{1.0}$: Fraction of the emissions with diameters smaller than one micrometer

F_{BC}: Fraction of the fine particulate matter that is black carbon Ratio of black carbon

F_{OC}: Fraction of the fine particulate matter that is organic carbon

F_{cont}: Fraction of the fine PM that penetrates the control device

However, Organic matter and Organic Carbon ratio R_{org} are not considered here.

Table 4.2-4 BC and OC emission factors for cokes production

Fuel	Technology	EF_{PM} (g/kg)	$F_{1.0}$	F_{BC}	F_{OC}	F_{cont}
Coking coal	Coke oven	5.8	0.35	0.48	0.34	0.33
Coking coal	Coke oven (uncaptured)	20	0.5	0.48	0.34	1.0

Source: "A technology-based global inventory of black and organic carbon emission from combustion" (Tami C. Bond, etc 2004)

4.2.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

And in "4.2.2 Detailed method" if hourly operational patterns are obtained, the patterns should be applied to estimation of emission amount of "4.2.1 Simple method"

2. Spatial distribution

Spatial distribution is as set in Table 4.2-5. However, the "spatial distributions indications" in table 4.2-5 are set in priority sequence with spatial distribution of emission amount.

Table 4.2-5 Spatial distribution indications in air pollutants of fugitive emissions from fossil fuel

Category	Activity data	Spatial distribution indications
Mining and handling (shipping or transport) of coal	Coal production mount (underground mining, open cast mining)	1) If the production volume of each coal mine can be identified, create spatial distribution based on that location. 2) Identify the coal production volume by province or detailed administrative region, and emission amount is evenly divided in the area. 3) If you can only identify the national activity data, and if the coal mine location is evenly divided in the country with a certain degree, it can be evenly divided across the country.
Fugitive emissions from solid fuels like coal etc. (production of cokes, non-smoke fuels)	Cokes production volume	1) If each cokes plant can be identified, create spatial distribution based on that location. 2) Identify the cokes production volume by province or detailed administrative region, and emission amount is evenly divided the area 3) Emission amount is divided with the most detailed numbers of factories and business establishments by jurisdictions as allocations indications.. Allocation indicators are numbers of factories establishment by cokes production, or industrial categories. If unavailable, agriculture forestry and fisheries or service business can also be used. 4) Assume the facility that uses cokes (furnace, metal, casting), and emission amount is divided neighborhood.

4.2.2 Detailed method

4.2.2.1 Outline of emission estimation method

The basic formula in emission amount estimation is the same as “4.2.1 Simple method”, but the detailed method classifies the category into more detail technically to estimate the air pollutant of emission amount. And identifying the emission amount from each coal mine and cokes production facility is included in this method.

Activity data is the production volume of solid fuels like coal etc. , or the production volume at each coal mine or cokes production facility. The emission factor is the emission amount per unit of production volume, but compared to “4.2.1 Simple method”, it is more detailed technically. The national, provincial, regional total emission amount is estimated based on the accumulation of each emission amount.

$$\text{Emissions} = \text{AD} \times \text{EF} \quad \cdots\cdots \quad 4.2\text{-}4$$

Where,

Emissions: Air pollutant and greenhouse gas emission amount

AD: Activity data (fossil fuel production volume etc.)

EF: Emission factor

The contents that have to be identified in detailed method are the production volume, processing amount of solid fuels like coal etc. treatment process in the country (from mining, refining, transportation, to storage).

The contents that have to be identified by questionnaire survey or interview survey or the mine, cokes production facility are as shown in Table 4.2-6. However, for cokes production facility, the survey is expected to be the same as the survey carried out in large point source in “3 Estimation of air pollutant emission amount from fuel combustion”.

Table 4.2-6 Information material to collect for estimation of emission amount

Survey type	Survey item	Survey content
By statistics data etc	Information of coal production	Coal production volume of underground mining and open cast mining, handling coal amount etc
	Cokes production volume	Cokes production volume by emission reduction measures
Plant/ workplace by questionnaire, interview	Coal mine basic information	Name of product mined, number of employers, coal mine location, area drawing
	Information of coal production	Coal production volume over the past few years, including current one, monthly production volume, coal condition (calorific value, sulfur content, ash content, nitrogen content)
	Pollutant control measure	Condition of pollution control measure introduction
	Shipping information	Shipment destination, condition of shipment (vessel, railways, truck, pipeline)
	Others	Air pollutant of emission amount actual survey result, emission factor condition (if any), other info as required

However, in the total national activity data of fugitive emission from fossil fuel, activity data is not estimated by "4.2.2 Detailed method", is treated as area source, and estimated using "4.2.1 Simple method".

4.2.2.2 Estimation of activity data

Emission factors are basically set as default values of "4.2.1 Simple method", in other words, activity data is basically the national solid fuels like coal etc and production volume etc. The activity data for each emission source is shown in Table 4.2-7.

Table 4.2-7 Technical detailed method - activity data of fugitive emission from solid fuels

Category	Activity data	Source/remarks
Mining and handling (shipping or transport) of coals	Coal production volume	It is necessary to identify by underground mining or opencast mining. Storage and handling of coal production volume is necessary too. Statistics data of the country’s coal, various energy statistics data(country, IEA,UN statistics) etc
Fugitive emissions from solid fuels like coal etc. (production of cokes, non-smoke fuels)	Cokes production volume, Cokes oven charging, etc.	Various energy statistics dates (country, IEA,UN statistics),”International Iron and Steel Institute”,etc

4.2.2.3 Setting of emission factors

The emission factor of “Coal mining and handling (shipping or transport) works “which belong to fugitive emission from solid category is shown in Table 4.2-8 to Table 4.2-18. For $CH_{4,}$ emission factor is basically set as default values of 2006 IPCC Guidelines Tier-1 procedure is used. For other emission factors, are basically set as default values of EMEP/EEA Guidebook Tier-2 procedure emission factors are used.

Except cokes production etc, coal mining, coal handling and other coal treatment process emission factors are shown in Table 4.2-8.

Table 4.2-8 Emission factors for air pollutants etc from coal mining and coal handling

Category	Air pollutant	Emission factor	Unit/source
Open cast mining Mining	NMVOC	0.2	(kg/Mg coal produced) EMEP/EEA Guidebook
Open cast mining Mining	CH_4	1.2	(m^3/ton) 2006 IPCC Guidelines
Open cast mining Post mining process	CH_4	0.1	(m^3/ton) 2006 IPCC Guidelines
Underground mining Mining	NMVOC	3	(kg/Mg coal produced) EMEP/EEA Guidebook
Underground mining Mining	CH_4	18	(m^3/ton) 2006 IPCC Guidelines
Underground mining post mining process	CH_4	2.5	(m^3/ton) 2006 IPCC Guidelines
Storage	PM_{10}	4.1	(kg/Mg coal produced) EMEP/EEA Guidebook
Handling	PM_{10}	3	(kg/Mg coal produced) EMEP/EEA Guidebook
Reducing measures (use of sprinkler or compound material)	PM_{10}	90%	(%) EMEP/EEA Guidebook

The emission factor of cokes, non-smoke fuels productions from solid fuels like coal etc is shown in Table 4.2-9. These sources are EMEP/EEA Guidebook and the emission factor is considered cokes or non-smoke fuels cokes productions process.

Table 4.2-9 Emission factors for air pollutants of fugitive emission from solid fuel (cokes production etc)

Category	Air pollutant	Emission factor	Unit/source
Fugitive emission from solid fuels like coal (cokes production)	NMVOC	17	(kg/Mg coke produced) EMEP/EEA Guidebook
	NH_3	5	(kg/Mg coke produced) EMEP/EEA Guidebook
	TSP	110	(kg/Mg coke produced) EMEP/EEA Guidebook
	PM_{10}	100	(kg/Mg coke produced) EMEP/EEA Guidebook
	$PM_{2.5}$	90	(kg/Mg coke produced) EMEP/EEA Guidebook
Fugitive emission from solid fuels like coal (non-smoke fuels production)	SO_x	2.5	(kg/Mg coal carbonized) EMEP/EEA Guidebook

Emission from each process of cokes production is classified in detail and the categorized emission factors are shown in Table 4.2-10 to Table 4.2-18Table 4.2-18. Source of these emission factor are mainly AP-42.

Table 4.2-10 Emission factors for air pollutants of emission from cokes production

Category	PM	SO_2	CO	TOC (as propane)	NO_x	Unit
Charging						(kg/Mg of coal charged)
Uncontrolled	0.60					
Scrubber	0.0070					
Pre-NESHAP controls	0.0058					
Post-NESHAP controls	0.00053					
Oven door leaks						
Uncontrolled	0.26					
Pre-NESHAP controls	0.020	0.020	0.011	0.0028	0.0007	
Post-NESHAP controls	0.0079					
Lid leaks						
Uncontrolled	0.047					
Pre-NESHAP controls	0.0065					
Post-NESHAP controls	0.000086					
Off-take leaks						
Uncontrolled	0.047					
Pre-NESHAP controls	0.0059					
Post-NESHAP controls	0.00029					

Source: All from AP-42

Note: NESHAP stands for “National Emission Standard for Hazardous Air Pollutants”.
“Uncontrolled” refers to cokes oven up to 1980. The source of ”Pre-NESHAP” SO2, CO, TOC, NOx emission factor is 1990 announced thesis. This can be used as a guide to study the emission factor.

Table 4.2-11 Emission factors for air pollutants from bypassed coke oven gas

Category	Air pollutant	Emission factor	Unit/source
Bypassed coke oven gas			(kg/ tons of coal charged)
Filterable PM	PM	40	
Condensable PM	PM	40	
	CO	48	
	CO_2	21	
	NH_3	6.5	
	SO_2	0	
	CH_4	120	

Source: All from AP-42

Table 4.2-12 Emission factors for air pollutants (PM) from cokes oven pushing

Category	Air pollutant	Emission factor	Unit/source
Filterable PM			
Uncontrolled	PM	0.695	(kg/ tons of coal charged)
With Hood and EF control	PM	0.19	(kg/ tons of coal charged)
With Hood and scrubber	PM	0.19	(kg/ tons of coal charged)
With Shed and EF	PM	0.20	(kg/ tons of coal charged)
Condensable PM			
With Hood and EF control	PM	0.036	(kg/ tons of coal charged)
With Hood and scrubber	PM	0.0094	(kg/ tons of coal charged)
Extractable Organic Particulate (EOM)			
Uncontrolled		0.0043	(kg/ tons of coal charged)
With Hood and EF		0.00421	(kg/ tons of coal charged)

Source: All from AP-42

Table 4.2-13 Emission factors for air pollutants from cokes oven pushing

Category	Substance	Emission factor	Unit/source
Cokes oven pushing			(kg/ tons of coal charged)
	CO	0.032	
	CO_2	8.00	
	NH_3	0.006	
	SO_2	0.049	
	NO_x	0.0097	

Source: All from AP-42

Table 4.2-14 Emission factors for air pollutants from coal dry quenching facility

Category	Air pollutant	Emission factor	Unit/source
Cole dry quenching facility			(kg/ tons of coal)
Uncontrolled, clean water	PM	0.57	
Uncontrolled, dirty water	PM	2.6	
Clean water, tall tower and/or poor maintenance	PM	0.73	
Clean water, normal tower height and/or proper maintenance	PM	0.15	
Dirty water, tall tower and/or poor maintenance	PM	1.37	
Dirty water, normal tower height and/or proper maintenance	PM	0.27	

Source: All from AP-42

Table 4.2-15 Emission factors for air pollutants from combustion stack emission

Category	Air pollutant	Emission factor	Unit/source
Combustion stack emission (Filterable PM)			(kg/tons of coal charged)
Uncontrolled (Raw COG)	PM	0.20	
Uncontrolled (BFG)	PM	0.10	
Uncontrolled (Desulfurized COG)	PM	0.034	
With EF (Raw COG)	PM	0.11	
With EF or ESP (BFG)	PM	0.031	
Chimney exhaust gas burning(condensable PM)			(kg/tons of coal charged)
With COG	PM	0.11	
With BFG	PM	0.014	

Source: All from AP-42

Note: ”COG: Coke Oven Gas”, ”BFG: Blast Furnace Gas”

Table 4.2-16 Emission factors for air pollutants from combustion stack emission

Category	Air pollutant	Emission factor	Unit/source
Combustion stack emission			(kg/ tons of coal charged)
	CO	0.34	
CO_2 emission (BFG)	CO_2	482	
CO_2 emission (COG)	CO_2	143	
	NO_x	0.82	
SO_2 emission (Raw COG)	SO_2	1.47	
SO_2 emission (DCOG)	SO_2	0.12	
	CH_4	0.10	

Source: All from AP-42

Note: ”COG: Coke Oven Gas”, ”BFG: Blast Furnace Gas”

Table 4.2-17 Emission factors for miscellaneous coke production source

Category	Air pollutant	Emission factor	Unit/source
Coal crushing, with cyclone (filterable PM)	PM	0.055	(kg/ tons of coal charged)
Coal crushing, with rotoclone (filterable PM)	PM	0.027	
Primary coal pulverizer with builing enclosure (filterable PM)	PM_{10}	0.00009	
Secondary coal pulverizer with builing enclosure (filterable PM)	PM_{10}	0.000044	
Preheater (filterable PM)	PM	1.8	
Preheater, with scrubber (filterable PM)	PM	0.13	
Preheater, with wet ESP (filterable PM)	PM	0.0060	
Coke handling, with cyclone (filterable PM)	PM	0.0030	
Coke screening (filterable PM)	PM	0.011	
De-carbonization	CO	15	(kg/ tons of coal charged)
Soaking	TSP	0.008	(kg/ tons of coal charged)
	SO_2	0.050	
	NO_x	0.0005	
	CO	0.001	

Source: All from AP-42

Note: "COG: Coke Oven Gas", "BFG: Blast Furnace Gas"

Table 4.2-18 Emission factor for air pollutants from stackgas burning of coke production

Category	Name of matters	Emission factor	Unit/source
Stack gas burning			(kg/ tons of coal charged)
	CO	0.34	
CO_2 emission (BFG)	CO_2	482	
CO_2 emission (COG)	CO_2	143	
	NO_x	0.82	
SO_2 emission (Raw COG)	SO_2	1.47	
SO_2 emission (DCOG)	SO_2	0.12	
	CH_4	0.10	

Source: All from AP-42

Note: ”COG: Coke Oven Gas”, ”BFG: Blast Furnace Gas”

4.2.2.4 Temporal change and spatial distribution

1. Temporal change

If the hourly operational patterns of each coal mine or cokes production facility are obtained, and if emission is assumed during operation time only, the time pattern can be used.

If the hourly operational patterns cannot be obtained, set them the same as in “4.2.1 Simple method”.

2. Spatial distribution

In detailed method, if each coals mine or cokes production facilities are obtained, each emission amount can be divided. And if each one of them cannot be obtained separately, active data (or the emission amount), is divided the same as in “4.2.1 Simple method”.

4.3 Fugitive emission from crude oil and natural gas

4.3.1 Simple method

4.3.1.1 Outline of emission estimation method

Air pollutant emission amount is estimated by multiplying activity data and emission factors. Activity data are crude oil and natural gas production etc. and statistics data of country or province are used for estimation. The emission factor is the emission amount per unit of production volume. "Simple method" is compared to "4.3.2 Detailed method" , it is much simpler, rough and average. These emission factors are treated as default values in this guideline.

$$\text{Emissions} = \text{AD} \times \text{EF} \qquad (4.3\text{-}1)$$

Where,

Emissions: Air pollutant and greenhouse gas emission amount

AD: Activity data (fossil fuel production volume)

EF: Emission Factor

However, in the total national activity data of fugitive emission from fossil fuel, activity data is not estimated from "4.3.2 Detailed method" is treated as area source, and estimated using "4.3.1 Simple method".

4.3.1.2 Estimation of activity data

Activity data is basically set as total production volume of crude oil and natural gas of the country, and the activity data of each emission source is listed in Table 4.3-1. However, the proper unit can also be converted to calorific value unit, if required, in which case, basically the conversion factor uses the proper value of the coal mine, factory. If suitable conversion factor is not available, the standard calorific value published by the country can be used, and if the appropriate calorific value in the country is not available, use the default calorific value stated in 2006 IPCC Guidelines.

Table 4.3-1 Simple method – Activity data of air pollutants amount of fugitive emission from fossil fuel

Category	Activity Data	Source/remarks
Well drilling, well testing, production and transport of oil	Marine oil production volume (Mg oil) Land oil production volume (Mg oil)	Oil statistics data of the country, other international organization data etc.
Refining and storage of oil	Crude oil refining amount (Mg crude oil)	Oil statistics data of the country and energy statistics data of the country
Oil refined product distribution	Gasoline total sales amount (Mg oil)	Oil (consumption) statistics data of the country, and energy statistics data
Well drilling, production, transportation, refining, storage, and distribution of natural gas	Gas production volume (m^3 gas)	Natural gas statistics data of the country, other international organization data

4.3.1.3 Setting of emission factors

Emission factors are basically set as default values of GAP Forum Manual. These values are based on ones in Europe. Fugitive emissions from fuels seem to depend on climate, technology and quality of fuel etc. Actual emission factors of NMVOC may become larger values in tropical and sub tropical countries with higher temperature than one in Europe.

Table 4.3-2 Emission factors of air pollutants from crude oil and oil well drilling, refining, transportation

Category	Air pollutant	Emission factor	Unit/remarks
Oil well drilling	NMVOC	0.7	(kg/number of wells drilled)
Fugitive emission from facility and platform	NMVOC	600	(kg/kt-crude oil production)
Crude oil loading onto tanker	NMVOC	71	(kg/ kt-crude oil loaded)
Crude oil loading onto rail tank cars and tank trucks	NMVOC	564	(kg/ kt-crude oil loaded)
Pipeline transport	NMVOC	72	(kg/ kt-mass oil transported)
Transit in marine tankers	NMVOC	146	(kg/ kt-weeks-mass transported)
Oil refining			All units are in kg/ throughput of crude oil tones
	SO_2	0.8	Sources: Vacuum tower, catalytic cracker, fluid coking, sulfur plant, SWS, incinerator, caustic regeneration, vents, off gases, others
	NO_x	0.05	Sources: Catalytic cracking
	CO	0.08	Sources: Fluid catalytic cracker only
	NMVOC	0.53	Sources: Fugitive and process emissions
Gasoline refinery dispatch station	NMVOC	310	(kg/ kt-gasoline handled)
Gasoline transport and depots	NMVOC	740	(kg/ kt-gasoline handled)
Gasoline service station	NMVOC	2880	(kg/ kt-gasoline handled)

Source: All from GAP Forum Manual

Table 4.3-3 Emission factors of air pollutants for fugitive emissions from natural gas

Category	Air pollutant	Emission factor	Unit
Natural gas production	NMVOC	9	(kg/ TJ gas production)
Natural gas distribution	NMVOC	109	(kg/ TJ gas production)

Source: All from GAP Forum Manual

If default emission factor in Table 4.3-2 and Table 4.3-3 cannot be used, use default values of Tier 1 method in 'EMEP/EEA Air Pollutant Emission Inventory Guidebook – 2009'. These values are based on ones in Europe. Fugitive emissions from fuels seem to depend on climate, technology and quality of fuel etc. Actual emission factors of NMVOC may become larger values in tropical and sub tropical countries with higher temperature than one in Europe. And greenhouse gas emission factors are basically set as default values of 2006 IPCC Guidelines which are listed in Table 4.3-4.

Table 4.3-4 Emission factors of air pollutants of fugitive emission from fossil fuel

Category	Air pollutant	Emission factor	Unit/source
Well drilling, well testing, production and transport of oil	NMVOC	0.2	(kg/Mg oil) EMEP/EEA Guidebook
Refining and storage of oil	NMVOC	0.2	(kg/Mg oil) EMEP/EEA Guidebook
Oil refined product distribution	NMVOC	2	(kg/Mg oil) EMEP/EEA Guidebook
Well drilling, production, transportation, refining, storage, and distribution of natural gas	NMVOC	0.1	(kg/m^3 gas) EMEP/EEA Guidebook

Black Carbon (BC) and Organic Carbon (OC) are divided from "A technology-based global inventory of black and organic carbon emission from combustion" (Tami C. Bond, etc 2004), and set as follows: -

$$EF_{BC} = EF_{PM} \times F_{1.0} \times F_{BC} \times F_{cont} \quad \text{(4.3-2)}$$

$$EF_{OC} = EF_{PM} \times F_{1.0} \times F_{OC} \times F_{cont} \quad \text{(4.3-3)}$$

Where,

EF_{PM}: PM emission factor (g/kg)

$F_{1.0}$: Fraction of the emissions with diameters smaller than one micrometer

F_{BC}: Fraction of the fine particulate matter that is black carbon Ratio of black carbon

F_{OC}: Fraction of the fine particulate matter that is organic carbon

F_{cont}: Fraction of the fine PM that penetrates the control device

However, Organic matter and Organic Carbon ratio R_{org} are not considered here.

Table 4.3-5 BC and OC emission factor from cokes production

Fuel	Technology	EF_{PM} (g/kg)	$F_{1.0}$	F_{BC}	F_{OC}	F_{cont}
Coking coal	Coke oven	5.8	0.35	0.48	0.34	0.33
Coking coal	Coke oven (uncaptured)	20	0.5	0.48	0.34	1.0

Source: "A technology-based global inventory of black and organic carbon emission from combustion" (Tami C. Bond, etc 2004)

4.3.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

And in "4.3.2 Detailed method" if work time pattern can be identified, the time pattern should be used in the emission amount calculated using this "4.3.1 Simple method"

2. Spatial distribution

Spatial distribution is as set in Table 4.3-6. However, the "spatial distribution indications" in Table 4.3-6 are set in priority sequence with spatial distribution of emission amount.

Table 4.3-6 Spatial distribution indicator in air pollutants of fugitive emissions from fossil fuel

Category	Activity Data	Spatial distribution indicator
Well drilling, well testing, production and transport of oil	Oil production volume	1) If the production volume of each oil well can be identified, create spatial distribution based on that location. 2) Identify the oil production volume by province or detailed administrative region, and emission amount is evenly divided in the area. 3) If you can only identify the national activity data, and if the oil well location is evenly divided in the country with a certain degree, it can be evenly divided across the country.
Refining and storage of oil	Crude oil refining volume	1) If each refinery can be identified, create spatial distribution based on that location 2) Identify the crude oil refining volume by province or detailed administrative region, and emission amount is evenly divided in the area.
Oil refined product distribution	Gasoline total sales volume	1) Spatial distribution is based on estimation of air pollutant emission amount from automobile (Simple method) 2) Identify the gasoline total sales by province or detailed administrative region, and emission amount is evenly divided in the area.
Well drilling, production, transportation, refining, storage, and distribution of natural gas	Gas production volume	1) If the production volume of each gas well can be identified, create spatial distribution based on that location. 2) Identify the gas production volume by province or detailed administrative region, and emission amount is evenly divided in the area. 3) If you can only identify the national activity data, and if the gas well location is evenly divided in the country with a certain degree, it can be evenly divided across the country.

4.3.2 Detailed method

4.3.2.1 Outline of emission estimation method

The basic formula in emission amount estimation is the same as "4.3.1 Simple method", but the detailed method classifies the category into more detail technically to estimate the air pollutant of emission amount. And identifying the emission mount from each oil field, oil well, and gas field ("oil field etc."), oil refining is included in this method.

Active data is the production volume of crude oil and natural gas, or the production mount at each oil field, or refining volume at refinery. The emission factor is the emission amount per unit of production volume, but compared to "4.3.1 Simple method", it is more detailed technically. The national, provincial, regional total emission amount is estimated based on the accumulation of each emission amount.

$$\text{Emissions} = \text{AD} \times \text{EF} \quad \cdots\cdots (4.3\text{-}4)$$

Where,

Emissions: Air pollutant and greenhouse gas emission amount

AD: Activity data (fossil fuel production volume etc)

EF: Emission factor

The contents that have to be identified in detailed method are the production volume of each fossil fuel like a crude oil natural gas, processing amount of fossil fuel treatment process in the country (from well drilling refining, transportation, to storage).

The contents that have to be identified by questionnaire survey or interview survey or the oil field, gas field are as shown in Table 4.3-7. However, for refinery, the survey is expected to be the same as the survey carried out in large point source in "3 Estimation of air pollutant emission amount from fuel combustion".

Table 4.3-7 Information material to collect for estimation of emission amount

Survey type	Survey item	Survey content
By statistics data etc	Information of crude oil and natural gas	Production volume of crude oil, natural gas , handling amount of crude oil and natural gas , number of oil well
	Oil refining volume	Refining volume according to emission reduction measures
Plant/ workplace by questionnaire, interview	Oil well basic information	Name of product drilling, number of employers, oil well location, area drawing
	Information of crude oil and natural gas l	Crude oil and natural gas production volume over the past few years, including current one, monthly production volume condition (calorific value, sulfur content, ash content, nitrogen content)
	Pollutant control measure	Condition of pollution control measure introduction
	Shipping information	Shipment destination, condition of shipment (tanker, railways, truck, pipeline)
	Others	Air pollutant of emission amount actual survey result, emission factor condition (if any), other info as required

However, in the total national activity data of fugitive emission from fossil fuel, activity data is not estimated by "4.3.2 Detailed method", is treated as area source, and estimated using "4.3.1 Simple method".

4.3.2.2 Estimation of activity data

Emission factors are basically set as default values of "4.3.1 Simple method", in other words, activity data is basically the national fossil fuel (crude oil, natural gas) production volume. The activity data for each emission source is shown in Table 4.3-8.

Table 4.3-8 Technical detailed method – Activity data of air pollutants of fugitive emission from fossil fuel

Category	Activity data	Source/remarks
Well drilling, well testing, production and transport of oil	Marine oil production volume (Mg oil) Land oil production volume (Mg oil)	Oil statistics data of the country, other international organization data etc.
Refining and storage of oil	Crude oil refining volume (Mg crude oil)	Oil statistics data of the country and energy statistics data of the country
Oil refined product distribution	Gasoline total sales volume(Mg oil)	Oil (consumption) statistics data of the country, and energy statistics data
Well drilling, production, transportation, refining, storage, and distribution of natural gas	Gas production volume (m^3 gas)	Natural gas statistics data of the country, other international organization data
Number of oil well drilling and natural gas well drilling	Number of wells drilled	Statistics data of oil and gas field and survey report of the country, questionnaire survey, interview surrey etc.

Active data is basically production volume of fossil fuel in each field that produces crude oil and natural, and the activity data is listed in Table 4.3-9.

And the same as refinery, gas station and other source, at the same time as human activity, air pollutant of fugitive emission from fossil fuel is assumed to occur, so it is necessary to identify the time of human activity, whereas, oil and gas field that operates continuously, as well as distribution, is not required to be considered. However, the same as storage, it is assumed that there is a big difference between day time and night time, so it is preferably to split them.

The above should preferably be acquired through questionnaire survey or interview survey basically. Especially for well drilling, refinery, fossil fuel production volume, product amount, the air pollutant emission amount of each plant, workplace should be identified through these survey.

However, the proper unit can also be converted to calorific value unit, if required, in which case, basically the conversion factor uses the proper value of the oil well gas well, factory and refinery. If suitable conversion factor is not available, the standard calorific value published by the country can be used, and if the appropriate calorific value in the country is not available, use the default calorific value stated in 2006 IPCC Guidelines.

Table 4.3-9 Detailed method – Activity data of air pollutants of fugitive emission from fossil fuel

Category	Activity data	Source/remarks
Well drilling, well testing, production and transport of oil	Marine oil production volume (Mg oil) Land oil production volume (Mg oil)	Oil statistics data of the country, other international organization data etc.
Refining and storage of oil	Crude oil refining volume (Mg crude oil)	Oil statistics data of the country and energy statistics data of the country
Oil refined product distribution	Gasoline total sales volume (Mg oil)	Oil (consumption) statistics data of the country, and energy statistics data
Well drilling, production, transportation, refining, storage, and distribution of natural gas	Gas production volume (m^3 gas)	Natural gas statistics data of the country, other international organization data
Number of oil well drilling and natural gas well drilling	Number of wells drilled	Statistics data of oil and gas field and survey report of the country, questionnaire survey, interview surrey etc.

4.3.2.3 Setting of emission factors

Emission factors of fugitive emission from oil and natural gas production are shown in Table 4.3-10. The emission factors from refinery, natural gas processing plant is not stated in this table, but these are shown in Table 4.3-15 to Table 4.3-20.

Table 4.3-10 Emission factors of air pollutants of fugitive emission from fossil fuel

Category	Air pollutant	Emission factor	Unit
Well drilling well testing, production, transport of oil (land-based)	NMVOC	0.1	(kg/Mg oil)
Well drilling well testing well, production, transport of oil (offshore)	NMVOC	0.4	(kg/Mg oil)
Oil refinery distribution process (Road tanker, bottom loading)	NMVOC	9	(g/m^3 throughput/kPa TVP)
Oil refinery distribution process (Road tanker, top loading)	NMVOC	9	(g/m^3 throughput/kPa TVP)
Oil refinery distribution process (Road tanker, bottom or top loading)	NMVOC	23	(g/m^3 throughput/kPa TVP)
Oil refinery distribution process (Rail tanker)	NMVOC	11	(g/m^3 throughput/kPa TVP)
Oil refinery distribution process (Marine tanker)	NMVOC	4	(g/m^3 throughput/kPa TVP)
Oil refinery distribution process (uncontrolled)	NMVOC	7	(g/m^3 throughput/kPa TVP)
Oil storage tank filling (uncontrolled)	NMVOC	24	(g/m^3 throughput/kPa TVP)
Oil storage tank breathing (uncontrolled)	NMVOC	3	(g/m^3 throughput/kPa TVP)
Automobile refueling (uncontrolled)	NMVOC	37	(g/m^3 throughput/kPa TVP)
Automobile refueling ;drips and spills (uncontrolled)	NMVOC	2	(g/m^3 throughput/kPa TVP)
Well drilling, production, loading, depots, transport of natural gas (land -based)	NMVOC	0.1	(kg/m^3 gas)
Well drilling, production, loading, depots, transport of natural gas (offshore)	NMVOC	0.1	(kg/m^3 gas)

Source: All from EMEP/EEA Guidebook

Note: TVP stands for “True vapor pressure” and which is defined as follows: -

$$\mathrm{TVP} = \mathrm{RVP} \times 10^{\mathrm{AT+B}} \quad \cdots\cdots (4.3\text{-}5)$$

Where,

$$\mathrm{A} = 0.000007047 \times \mathrm{RVP} + 0.0132$$

$$\mathrm{B} = 0.0002311 \times \mathrm{RVP} - 0.5236$$

T means Temperature (°C)

RVP stands for Reid Vapor Pressure (in kPa)

In 2006 IPCC Guidelines, emission factor of CH_4, CO_2, NMVOC, N_2O are as follows in Table 4.3-11 to Table 4.3-14. However, in 2006 IPCC Guidelines, there is “in developed countries” default emission factors and “in developing countries and countries in economic transition” default emission factors. Here it indicates “in developing countries and countries in economic transition” default emission factors. If the country is assumed to be suitable for “in developed countries” default emission factors, 2006 IPCC Guidelines” Volume 2: Energy” Table 4.2.4 should preferably be used.

Table 4.3-11 Emission factors of air pollutants of fugitive emission from oil and gas operation

Category	CH_4	CO_2	NMVOC	N_2O	Unit
Oil well drilling (Flaring and Venting)	33 – 560	100 - 1700	0.87 – 15	ND	(kg/number of wells drilled)
Oil well testing (Flaring and Venting)	51 – 850	9000 - 150000	0.87 – 15	0.068 - 1.1	(kg/number of wells drilled)
Oil well servicing (Flaring and Venting)	110 – 1800	1.9 - 32	17 – 280	ND	(kg/number of wells drilled)
Gas production (Fugitives)	380 - 24000	14 - 1800	91 - 1200	NA	(kg/10^6 m^3 raw gas feed)
Gas production (Flaring)	0.76 - 1.0	1.2 - 1.6	0.62 - 0.85	0.021 - 0.029	(kg/10^6 m^3 raw gas feed)
Gas processing (sweet gas plant) (Fugitives)	480 – 1100	150 - 350	220 - 510	NA	(kg/10^6 m^3 raw gas feed)
Gas processing (sweet gas plant) (Flaring)	1.2 – 1.6	1800 - 2500	0.96 - 1.3	0.025 - 0.034	(kg/10^6 m^3 raw gas feed)
Gas processing (sour gas) (Fugitives)	0.97 – 220	7.9 - 18	68 – 160	NA	(kg/10^6 m^3 raw gas feed)
Gas processing (sour gas) (Flaring)	2.4 – 3.3	3600 - 4900	1.9 - 2.6	0.054 - 0.074	(kg/10^6 m^3 raw gas feed)
Gas processing (sour gas) (Raw CO_2 Venting)	NA	63000 - 150000	NA	NA	(kg/10^6 m^3 raw gas feed)

Source: All from 2006 IPCC Guidelines

Note: “NA” stands for “Not Applicable”, and “ND” ”Not Determined”

Table 4.3-12 Emission factors of air pollutants of fugitive emission from oil and gas operation

Category	CH_4	CO_2	NMVOC	N_2O	Unit
Gas processing (Deep-cut Extraction Plants) (Straddle Plants) (Fugitives)	11 – 25	1.6 - 3.7	27 – 62	NA	(kg/10^6 m^3 raw gas feed)
Gas processing (Deep-cut Extraction Plants) (Straddle Plants) (Flaring)	0.072 - 0.099	0.011 - 0.015	0.059 - 0.081	0.012 - 0.081	(kg/10^6 m^3 raw gas feed)
Gas processing (Default Weighted Total) (Fugitives)	150 – 350	12 - 28	140 - 320	NA	(kg/10^6 m^3 gas production)
Gas processing (Default Weighted Total) (Flaring)	200 – 280	3000 - 4100	1.6 - 2.2	0.033 - 0.045	(kg/10^6 m^3 gas production)
Gas processing (Default Weighted Total) (Raw CO_2 Venting)	NA	40000 - 95000	NA	NA	(kg/10^6 m^3 gas production)
Gas transmission and storage (Transmission) (Fugitives)	166 - 1100	0.88 - 2	7.0 – 16	NA	(kg/10^6 m^3 of marketable gas)
Gas transmission and storage (Transmission) (Venting)	44 – 740	3.1 - 7.3	4.6 – 11	NA	(kg/10^6 m^3 of marketable gas)
Gas transmission and storage (Storage) (All)	25 – 58	0.11 - 0.26	0.36 - 0.83	ND	(kg/10^6 m^3 of marketable gas)
Gas delivery (All)	1100 - 2500	51 - 140	16 – 36	ND	(kg/10^6 m^3 of utility sales)
LNG gas transport (Condensate) (All)	110	7.2	1100	ND	(kg/10^6 m^3 Condensate and Pentanes Plus)
LNG gas transport (Liqurefield Petroleum Gas) (All)	NA	430	ND	0.0022	(kg/10^6 m^3 LPG)

Source: All from 2006 IPCC Guidelines

Note: “NA” stands for “Not Applicable”, and “ND” ”Not Determined”

Table 4.3-13 Emission factors of air pollutants of fugitive emission from oil and gas operation

Category	CH_4	CO_2	NMVOC	N_2O	Unit
Oil production (Conventional Oil) (Liquefied Natural Gas)	ND	ND	ND	ND	(kg/10^6 m^3 of marketable gas)
Oil production (Conventional Oil)(Fugitives (Onshore))	15 – 60000	0.11 - 4300	1.8 - 75000	NA	(kg/10^6 m^3 conventional oil production)
Oil production (Conventional Oil)(Fugitives (Offshore))	0.59	0.043	0.74	NA	(kg/10^6 m^3 conventional oil production)
Oil production (Conventional Oil)(Venting)	720 – 990	95 - 130	430 - 590	NA	(kg/10^6 m^3 conventional oil production)
Oil production (Conventional Oil) (Flaring)	25 – 34	41000 - 56000	21 - 29	0.64 - 0.88	(kg/10^6 m^3 conventional oil production)
Oil production (Heavy Oil/Cold Bitumen)(Fugitives)	7900 - 130000	540 - 9000	2900 - 48000	NA	(kg/10^6 m^3 heavy oil production)
Oil production (Heavy Oil/Cold Bitumen) (Venting)	17000 - 23000	5300 - 7300	2700 - 3700	NA	(kg/10^6 m^3 heavy oil production)
Oil production (Heavy Oil/Cold Bitumen) (Flaring)	140 – 190	22000 - 30000	11 - 15	0.46 - 0.63	(kg/10^6 m^3 heavy oil production)
Oil production (Thermal Oil Production) (Fugitives)	180 – 3000	29 - 480	230 - 3800	NA	(kg/10^6 m^3 thermal bitumen production)
Oil production (Thermal Oil Production) (Venting)	3500 - 4800	220 - 300	870 - 1200	NA	(kg/10^6 m^3 thermal bitumen production)
Oil production (Thermal Oil Production) (Flaring)	16 – 22	270 - 370	13 - 18	0.24 - 0.33	(kg/10^6 m^3 thermal bitumen production)

Source: All from 2006 IPCC Guidelines

Note: “NA” stands for “Not Applicable”, and “ND” ”Not Determined”

Table 4.3-14 Emission factors of air pollutants of fugitive emission from oil and gas operation

Category	CH_4	CO_2	NMVOC	N_2O	Unit
Oil production (Crude from Oil sands) (All)	2300 - 38000	ND	900 – 15000	ND	(kg/10^6 m^3 synthetic crude production from oil sands)
Oil production (Synthetic Crude from Oil Shale) (All)	ND	ND	ND	ND	(kg/10^6 m^3 synthetic crude production from oil shale)
Oil production (Default Weighted Total (Fugitives)	2200 - 37000	280 - 4700	3100 – 52000	NA	(kg/10^6 m^3 total oil production)
Oil production Default Weighted Total) (Venting)	8700 - 12000	1800 - 2500	1600 – 2200	NA	(kg/10^6 m^3 total oil production)
Oil production (Default Weighted Total) (Flaring)	21 – 29	340 - 470	17 – 2300000	54 - 74	(kg/10^6 m^3 total oil production)
Oil Upgrading (All)	ND	ND	ND	ND	(kg/10^6 m^3 total oil upgraded)
Oil transportation (Pipeline)	5.4	0.49	54	NA	(kg/10^6 m^3 total oil transported by pipeline)
Oil transportation (Tanker Trucks and Rail Cars)(Venting)	25	2.3	250	NA	(kg/10^6 m^3 total oil transported by Tanker Truck)
Oil transportation (Loading of Off-shore Production on Tanker Ships) (Venting)	ND	ND	ND	NA	(kg/10^6 m^3 total oil transported by Tanker Truck)
Oil refining(All)	ND	ND	ND	ND	(kg/10^6 m^3 total oil refined)
Oil refined product distribution (Gasoline)	NA	NA	ND	NA	(kg/10^6 m^3 product transported)
Oil refined product distribution (Diesel)	NA	NA	ND	NA	(kg/10^6 m^3 product transported)
Oil refined product distribution (Aviation Fuel)	NA	NA	ND	NA	(kg/10^6 m^3 product transported)
Oil refined product distribution (Jet Kerosene)	NA	NA	ND	NA	(kg/10^6 m^3 product transported)

Source: All from 2006 IPCC Guidelines

Note: “NA” stands for “Not Applicable”, and “ND” ”Not Determined”

From various emission sources of oil refinery and natural gas treatment plant, not only NMVOC, but many pollutants characteristics are emitted. Therefore, the emission factor from various emission sources of this facility is compiled in Table 4.3-15 to Table 4.3-20 by sources, which sources are AP-42 and EMEP/EEA Guidebook.

Table 4.3-15 Emission factors of air pollutants for oil refineries

Category	PM	SO_2	CO	THC[a)]	NO_2	NH_3	Unit
Oil refinery							
FCC (Fluid catalytic cracking units): Uncontrolled	0.695	1.413	39.2	0.630	0.204	0.155	(kg/10^3 Liter Fresh feed)
FCC: Electrostatic precipitator and CO boiler	0.128	1.413	Neg	Neg	0.204	Neg	(kg/10^3 Liter Fresh feed)
Moving-bed catalytic cracking units	0.049	0.171	10.8	0.250	0.014	0.017	(kg/10^3 Liter Fresh feed)
Fluid coking units: Uncontrolled	1.50	ND	ND	ND	ND	ND	(kg/10^3 Liter Fresh feed)
Fluid coking units: Electrostatic precipitator	0.0196	ND	Neg	Neg	ND	Neg	(kg/10^3 Liter Fresh feed)
Delayed coking units	ND	ND	ND	ND	ND	ND	(kg/10^3 Liter Fresh feed)
Compressor engines: Reciprocating engines	Neg	2×s	7.02	21.8	55.4	3.2	(kg/10^3 m^3 gas burned)
Compressor engines: Gas turbines	Neg	2×s	1.94	0.28	4.7	ND	(kg/10^3 m^3 gas burned)
Blow down systems: Uncontrolled	Neg	Neg	Neg	1662	Neg	Neg	(kg/10^3 L refinery feed)
Blow down systems: Vapor recovery system and flaring	Neg	0.077	0.012	0.002	0.054	Neg	(kg/10^3 L refinery feed)
Vacuum distillation column condensers: Uncontrolled	Neg	Neg	Neg	0.14	Neg	Neg	(kg/10^3 L vacuum feed)
Vacuum distillation column condensers: Controlled	Neg	Neg	Neg	Neg	Neg	Neg	(kg/10^3 L vacuum feed)

Source: All from AP-42

Note: a) Overall, less than 1 weight % of total hydrocarbon emission is methane

Note: “Neg” means “Negligible”, “ND”: “No Data”

Table 4.3-16 Emission factors of air pollutants for oil refineries and natural gas processing facility

Category	PM	SO_2	CO	THC[a)]	NO_2	NH_3	Unit
Oil Refinery							
FCC (Fluid catalytic cracking units): Uncontrolled	0.695	1.413	39.2	0.630	0.204	0.155	(kg/10^3 Liter Fresh feed)
FCC: Electrostatic precipitator and CO boiler	0.128	1.413	Neg	Neg	0.204	Neg	(kg/10^3 Liter Fresh feed)
Moving-bed catalytic cracking units	0.049	0.171	10.8	0.250	0.014	0.017	(kg/10^3 Liter Fresh feed)
Vacuum distillation column condensers: Uncontrolled	Neg	Neg	Neg	0.14	Neg	Neg	(kg/10^3 L vacuum feed)
Vacuum distillation column condensers: Controlled	Neg	Neg	Neg	Neg	Neg	Neg	(kg/10^3 L vacuum feed)
Natural gas treatment plant							
	Neg	26.98×S	Neg		Neg		(kg/10^3 m^3 gas processed)

Source: All from AP-42

Note: a) Overall, less than 1 weight % of total hydrocarbon emission is methane

Note: “Neg” means “Negligible”, “ND” means “No Data”

Note: S means Sulfur content (%) in the form of H_2S

Table 4.3-17 Emission factors of air pollutants of fugitive emission for oil refineries

Category	SO_x	NO_x	CO	NMVOC	Unit
Flaring	77	54	12	2	(g/m^3 refinery feed)
Well testing (flaring)		3.7	18		(kg/Mg oil burned)

Source: All from EMEP/EEA Guidebook

Table 4.3-18 Emission factors of air pollutants of fugitive emission for oil refineries

Category	PM_{10}	SO_2	CO	NMVOC	NO_x	NH_3	Unit
Fluid catalytic cracking - CO boiler (Cyclone systems installed internally within the regenerator)	0.55	1.4	39	0.63	0.2	0.16	(kg/m^3 fresh feed)
Fluid catalytic cracking - CO boiler (uncontrolled)		0.004	0.04				(kg/m^3 feed)
Fluid coking units (primary cyclone installed to abate particulates)	0.8			0.05			(kg/m^3 fresh feed)
Sulphur recovery plants (no control technology for tail-gas operations)		140					(kg/Mg sulphur produced)
Processes in petroleum industries (Diffuse emissions)				0.2			(kg/Mg crude oil throughput)

Source: All from EMEP/EEA Guidebook

Table 4.3-19 Emission factors of air pollutants of fugitive emission for oil refineries

Category	SO_x	NO_x	CO	NMVOC
Elevated flaring in oil refinery	2	32.2	177	0.005
Unit	(g/g of S in gas flared)	(g/GJ)	(g/GJ)	(g/g of NMVOC in gas)

Source: All from EMEP/EEA Guidebook

Table 4.3-20 Emission factor list of air pollutants of fugitive emission for oil refineries

Category	SO_x	NO_x	CO	NMVOC	PM_{10}
Enclosed flaring in oil refinery	2	30	40	2.6	0.89
Unit	(g/g of S in gas flared)	(g/GJ)	(g/GJ)	(g/GJ)	(g/GJ)

Source: All from EMEP/EEA Guidebook

In processes like fuel storage, distribution and transport, a portion of the fuel will leak out. Therefore, fuel that are used tanker, rail cars aircraft to transport, Emission factors of NMVOC are as shown in Table 4.3-21 to Table 4.3-25, which main source is AP-42.

Table 4.3-21 Emission factors of NMVOC of fugitive emission from tankers

Category	Air pollutant	Ships/Ocean Barges emission factors	Barges emission factors	Unit
Uncleaned (Volatile)	NMVOC	315	465	(mg/litter Transferred)
Ballasted (Volatile)	NMVOC	205	-[a)]	
Cleaned (Volatile)	NMVOC	180	ND	
Gas-freed (Volatile)	NMVOC	85	ND	
Any condition (Nonvolatile)	NMVOC	85	ND	
Gas-freed (Any cargo)	NMVOC	ND	245410	
Typical overall situation (Any cargo)	NMVOC	215		

Source: All from AP-42

Note: In AP-42, these contain in VOC and is noted that methane and ethane, does not contain. So these are treated as NMVOC.

Note: a) Barges is not stabilized with ballast.

Table 4.3-22 Emission factors of NMVOC of fugitive emission from crude oil ballast of tanker

Category	Air pollutant	Emission factor by category	Typical comprehensive emission factor	Unit
Fully loaded	NMVOC	94.35	109.65	(mg/litter Ballast Water)
Lightered or previously shore loaded	NMVOC	145.35		

Source: All from AP-42

Note: In AP-42, these are published as total organic emission factors and for crude oil, considering methane and ethane amount, the conversion to VOC is multiplied by 0.85. This VOC is treated as NMVOC.

Table 4.3-23 Emission factors of NMVOC of fugitive emission for rail cars

Category	Gasoline	Crude Oil	Jet Naphtha	Jet Kerosene	Distillate Oil	Residual Oil	Unit
Loading operation							(mg/litter transferred)
Submerged loading - Dedicated normal service	590	240	180	1.9	1.7	0.01	
Submerged loading - Vapor balance service	980	400	300	Not normally used	Not normally used	Not normally used	
Splash loading - Dedicated normal service	1430	580	430	5	4	0.03	
Splash loading - Vapor balance service	980	400	300	Not normally used	Not normally used	Not normally used	
Transit losses							
Loaded with product							
Typical	0 - 1.0	ND	ND	ND	ND	ND	
Extreme	0 - 9.0	ND	ND	ND	ND	ND	
Return with vapor							
Typical	0 - 13.0	ND	ND	ND	ND	ND	
Extreme	0 - 44.0	ND	ND	ND	ND	ND	

Source: All from AP-42

Note: In AP-42, these are published as total organic emission factors. And for crude oil, considering methane and ethane amount, conversion to VOC is by multiplying with 0.85. This VOC is treated as NMVOC, whereas for other fuels, the amount of methane and ethane is ignored. So it is treated as NMVOC.

Note: “ND: No data”

Table 4.3-24 Emission factors of NMVOC of fugitive emission from vessel fuel supply facility

Category	Gasoline	Crude Oil	Jet Naphtha	Jet Kerosene	Distillate Oil	Residual Oil	Unit
Loading operation							
Ships/ocean barges	-	62	60	0.63	0.55	0.004	(mg/litter transferred)
Barges	-	102	150	1.60	1.40	0.011	
Tanker ballasting	100	-	ND	ND	ND	ND	(mg/litter ballast water)
Transit	320	128	84	0.60	0.54	0.003	(mg/week-Litter transported)

Source: All from AP-42

Note: In AP-42, these are published as total organic emission factors. And for crude oil, considering methane and ethane amount, conversion to VOC is by multiplying with 0.85. This VOC is treated as NMVOC, whereas for other fuels, the amount of methane and ethane is ignored. So it is treated as NMVOC.

Table 4.3-25 Emission factor of NMVOC of fugitive emission from gasoline stations

Category	Air pollutant	Emission factor	Unit
Filling underground tank			(mg/liter Throughput)
Submerged filling	NMVOC	880	
Splash filling	NMVOC	1380	
Balanced submerged filling	NMVOC	40	
Underground tank breathing and emptying	NMVOC	120	
Vehicle refueling operations			
Displacement losses (uncontrolled)	NMVOC	1320	
Displacement losses (controlled)	NMVOC	132	
Spillage	NMVOC	80	

Source: All from AP-42

Note: In AP-42, VOC and total organic emissions are the same, and the amount of methane and ethane is ignored. So it is treated as NMVOC.

4.3.2.4 Temporal change and spatial distribution

1. Temporal change

If the hourly operational patterns of each oil well and natural gas well or refinery facility are obtained, and if the emission is assumed during operation time only, the time pattern can be used.

If the these hourly operational patterns time pattern cannot be obtained, set them the same as “4.3.1 Simple method”, and the temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

In detailed method, the oil well, natural gas well, refinery, gasoline station are separately obtained, and the spatial distributed accordingly. The details of spatial distribution indicators are shown as in Table 4.3-26.

Table 4.3-26 Emission spatial distribution indicator of air pollutants amount of fugitive emission from fossil fuel

Category	Activity Data	Spatial distribution indicator
Well drilling, well testing, production and transport of oil	Oil production volume	Create spatial distribution based on each location of oil fielded and oil well
Refining and storage of oil	Crude oil refining volume	Create spatial distribution based on each location of refinery.
Oil refined product distribution	Gasoline total sales volume	Create spatial distribution based on each location of gasoline station.
Well drilling, production, transportation, refining, storage, and distribution of natural gas	Gas production volume	Create spatial distribution based on each location of gas field and gas well

Active data that cannot be obtained separately (emission amount) should have its spatial distribution defined using “4.3.1 Simple method”

Article 4.3-1 Estimate of air pollutant amount of fugitive emission from fossil fuel in Vietnam

About the air pollutant amount of fugitive emission from fossil fuel production and fossil fuel transportation in Vietnam, NMVOC emission amount from crude oil and natural gas are estimated.

First, identify the production volume of crude oil and natural gas in Vietnam is shown as in Table 4.3-27.

Table 4.3-27 Production volume of crude oil and natural gas in Vietnam

	2004	2005	2006	2007	2008
Crude oil production volume (Thousand ton)	20,051	17,519	16,800	15,290	14,904
Natural gas production volume (Million m^3)	6,269	6,440	7,000	7,080	7,944

Source: Annual Statistical Year book of Vietnam

Next, set the emission factors of crude oil and natural gas production and fossil fuel transportation in Vietnam are shown as in Table 4.3-28.

Table 4.3-28 Emission factor setting condition for leaks of crude oil and natural gas

Activities	Unit	NMVOC
Crude oil		
Oil well drilling	No. of wells drilled yr^{-1}	0.7
Leaks from equipment and platform	Crude oil production (kt yr^{-1})	600
Loading to oil tanker (vessel)	Crude loaded (kt yr^{-1})	71
Pipelines	Mass oil Transported	72
Ocean tanker transportation	Mass transported (kt-week yr^{-1})	146
Natural gas		
Production	Kg TJ^{-1} yr^{-1}	9
Distribution	Kg TJ^{-1} yr^{-1}	109

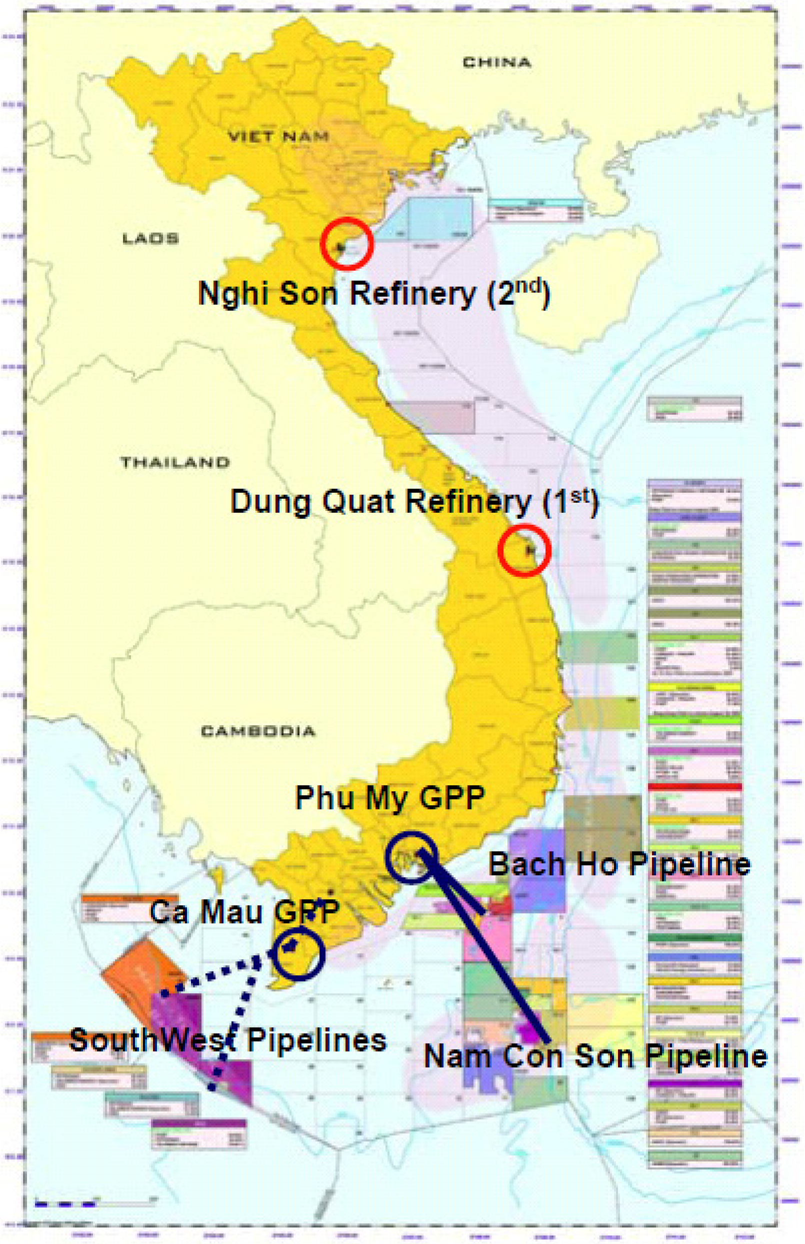
According to the emission factors above, emission amount of fugitive emission from crude oil and natural gas leaks in Vietnam are shown as in Table 4.3-29.

Table 4.3-29 NMVOC fugitive emission from crude oil and natural gas in Vietnam

	2004	2005	2006	2007	2008
NMVOC generation volume (ton yr^{-1})	32,576	33,465	36,375	36,790	41,280

Locations of wells of oil and natural gas in Vietnam are identified with information of provincial production volume of oil and natural gas in statistical books and one by internet as in Figure 4.3-1. The geographical information is referred for making of spatial distribution of emission amounts.

No oil refinery is under operation in 2008.



Source: http://www.ccop.or.th/ppm/document/CHWS4/CHWS4DOC11_PETROVIETNAM.pdf

Figure 4.3-1 Example of locations of oil wells in Vietnam

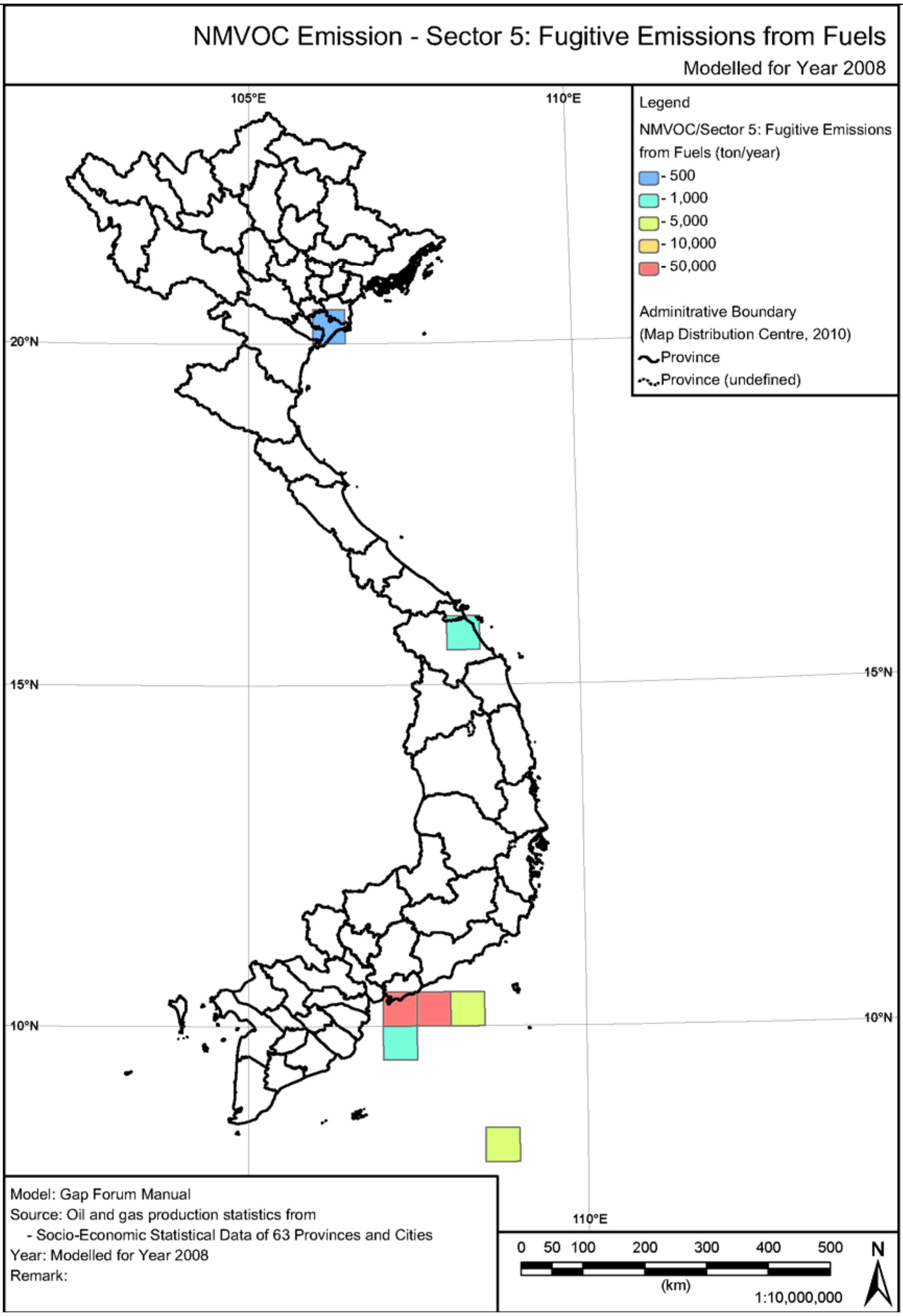


Figure 4.3-2 Example of NMVOC fugitive emission distribution from fossil fuel

5 Emission estimation of air pollutants from industrial processes

5.1 Targets of Estimation

Air pollutants and greenhouse gas not associated with fuel combustion are also emitted from various industrial activities. The main emission sources are the releases from industrial processes that chemically or physically transform materials, and they are classified into the followings, based on 2006 IPCC Guidelines.

1) Mineral products
2) Chemical industry
3) Metal production
4) Other production industry

And each category is further classified into sub-categories as shown in Table 5.1-2 to Table 5.1-4.

Industrial process has many industrial activities, and industrial process often has complicated relation with fuel combustion. Therefore, it is necessary to define industrial process and fuel combustion, and to have clear classification. This guideline follows the 2006 IPCC Guidelines classifications (reference)

Table 5.1-1 Definition of industrial process and fuel burning

Sector	Definition
Fuel combustion	The intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus.
Industrial process	Combustion emissions from fuels obtained directly or indirectly from the feedstock for an industrial process will normally be allocated to the part of the source category in which the process occurs. These source categories are normally industrial process sector source categories. However, if the derived fuels are transferred for combustion in another source category, the emissions should be reported in the appropriate part of energy sector source categories.

Source: 2006 IPCC Guidelines, Volume 3: Industrial Processes and Product Use Box 1.1

In this chapter, greenhouse gas such as HFCs or PFCs, SF_6 are not included. To measure these emission, refer to 2006 IPCC Guidelines.

The air pollutants targeted in the sub-category of industrial process are listed in Table 5.1-2 to Table 5.1-4.

Table 5.1-2 Target of estimation and air pollutants in industrial process (mineral products)

Category	Sub-category	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Mineral industry	Cement industry	IE	IE	IE	IE	NA	○	○	○	IE	IE	○	NE	NE
	Lime industry	IE	IE	IE	IE	IE	○	○	○	IE	IE	○	NE	NE
	Soda ash manufacturing and usage	IE	IE	○	NA	○	○	○	○	IE	IE	○	NE	NE
	Asphalt roofing material manufacturing	IE	IE	○	○	NA	○	○	○	IE	IE	NA	NE	NE
	Asphalt road paving	IE	IE	IE	○	NA	○	○	○	IE	IE	NA	NE	NE
	Non-coal mineral exploration and mining	NA	NA	NA	NA	NA	○	○	○	NA	NA	NA	NE	NE
	Bricks industry	IE	IE	IE	IE	IE	○	○	○	IE	IE	NA	NE	NE
	Construction and demolition	NA	NA	NA	NE	NA	○	○	○	NA	NA	NA	NE	NE
	Mineral product storage, processing, transportation	NA	NA	NA	NA	NA	○	○	○	NA	NA	NA	NE	NE
	Other inorganic product manufacturing	IE	IE	IE	IE	IE	○	○	○	IE	IE	NA	NE	NE

Note: “NE” means “Not Estimated”, “NA” means “Not Applicable”, “IE” means “Included Elsewhere”

Table 5.1-3 Target of estimation and air pollutants in industrial process (chemical industries)

Category	Sub-category	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Chemical industry	Ammonia manufacturing	NE	○	○	○	○	NA	NA	NE	NE	NE	○	NE	NA
	Nitric acid manufacturing	NE	○	NA	NA	NE	NA	NA	NE	NE	NE	NA	NA	○
	Adipic acid manufacturing	NA	○	○	○	NA	○	NA	NE	NE	NE	NA	NA	○
	Carbon-black manufacturing	○	○	○	○	NE	○	NE	NE	○	NE	○	○	NA
	Urea	NE	NE	NE	NE	○	○	○	○	NE	NE	NA	NA	NA
	Nitric acid ammonia	NE	NE	NE	NE	○	○	NE	NE	NE	NE	NA	NA	NA
	Phosphoric acid ammonia	○	NE	NE	NE	○	○	○	○	NE	NE	NA	NA	NA
	Sulfuric acid	○	NE	NE	NE	NE	NE	NE	NE	NE	NE	NA	NA	NA
	Titan dioxide	○	○	○	NE	NE	○	NE	NE	NE	NE	NA	NA	NA
	Other chemical industries	○	○	○	○	NE	○	○	○	NE	NE	○	NA	NA
	Chemical product storage, processing, transportation	Included in the above chemical industry process												

Note: “NE” means “Not Estimated”, “NA” means “Not Applicable”, “IE” means “Included Elsewhere”

Table 5.1-4 Target of estimation and air pollutants in industrial process (metal production and other production industry)

Category	Sub-category	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Metal industry	Steel industry	○	○	○	○	NE	○	○	○	○	○	○	○	NA
	Ferro-alloy manufacturing	IE	IE	IE	IE	NE	○	NE	NE	NE	NE	○	○	NA
	Aluminum manufacturing	○	○	○	○	NE	○	○	○	NE	NE	○	NA	NA
	Copper manufacturing	○	○	○	○	NE	○	○	○	NE	NE	NA	NA	NA
	Lead manufacturing	○	○	○	○	NE	○	○	○	NE	NE	○	NA	NA
	Nickel manufacturing	○	NE	NE	NA	NA	○	NE	NE	NE	NE	NA	NA	NA
	Zinc manufacturing	○	○	○	NE	NE	○	○	○	NE	NE	○	NA	NA
	Other metal manufacturing	NE	NE	NE	NE	NE	○	NE	NE	NE	NE	NA	NA	NA
	Storage, processing, transportation in metal manufacturing	NE	NE	NE	NE	NE	○	NE	NE	NE	NE	NA	NA	NA
Other production industry	Paper and pulp manufacturing	○	○	○	○	NE	○	○	○	NE	NE	NA	NA	NA
	Foods, drinks manufacturing	NA	NA	NA	○	NA	NE	○	NE	NE	NE	NA	NA	NA
	Wood processing industry	NE	NE	NE	NE	NE	○	NE	NE	NE	NE	NA	NA	NA

Note: “NE” means “Not Estimated”, “NA” means “Not Applicable”

5.2 Mineral products

5.2.1 Simple method

5.2.1.1 Outline of emission estimation method

Emission is estimated basically by multiplying the activity data with emission factor. Activity data generally means production volume by each industrial process, such as national or provincial level statistics. Emission factor is the emission rate per production unit. It is relatively simpler, more exhaustive and more average than emission factor of "5.2.2 Detailed method". These emission factors in this guideline are shown as default values, which should be replaced with local values measured if available.

$$\text{Emissions} = \text{AD} \times \text{EF} \quad \cdots\cdots (5.2\text{-}1)$$

Where,

Emissions: Air pollutants and greenhouse gas emission rate

AD: Industrial process activity data (i.e. industrial production volume)

EF: Emission factor for industrial process

Among the activity data of industrial process of country, any activity data which is not counted in "5.2.2 Detailed method", is to be treated as area source, and to be calculated in "5.2.1 Simple method".

5.2.1.2 Estimation of activity data

Activity data is basically the production volume of each industrial product, and is assumed to be available in the statistics of each country, which is to be the priority data to be used. Any activity data which is not available in statistics of the country is to be obtained from international statistics data as follows.

1) Industrial Commodity Statistics Yearbook
2) International Steel Institute (IISI: http://www.worldsteel.org/pictures/publicationfiles/SSY%202010.pdf
3) USA Geological Survey (USGS) Minerals Yearbook (http://minerals.usgs.gov/minerals/pubs/country)

In many countries, there is a large amount of air pollutant emission and greenhouse gas emission from cement industry. To calculate the emission from cement industry, generally clinker production volume is required. However, in many countries, statistics has cement production data instead of clinker production data. Therefore, clinker production is defined as follows, in accordance with 2006 IPCC Guidelines. Nonetheless, if clinker production data is available, the following definition is to be ignored.

Article 5.2-1 Clinker production rate

Clinker production is calculated as follows: -

$$\text{Clinker Production} = \sum_i \left(M_{ci} \times C_{cli}\right) - \text{Im} + \text{Ex}$$

Where,

M_{ci}: Weight (mass) of cement produced of type i

C_{cli}: Clinker fraction of cement of type i

Im: Imports for consumption of clinker, tons

Ex: Experts of clinker, tons

C_{cli} should be based on the value in each country. However, since it may not be available in some country, default value is available as follows.

Table 5.2-1 Clinker ratio default value by cement type

Cement type	Clinker ratio Default value
Portland cement (the most widely used cement)	95%
Masonry-type cement (Portland cement added with lime adhesives)	75%

Alternatively, in 2006 IPCC Guidelines – “Volume 3: Industrial Process and Product Use”, Table 2.2, examples of clinker ratio are shown, which can be used.

For example, in Vietnam, cement production volume was 40,047 (thousand metric tons: 2008), and data for clinker production, import, export were not available. Assuming that all the cement is manufactured domestically, and all is Portland cement, clinker production was calculate as follows: -

Clinker production rate = Cement production rate×95% = 40,047×0.95 = **38,045** (thousand metric tons)

The activity data to calculate air pollutant emission from mineral product is shown in Table 5.2-2.

Table 5.2-2 Industrial process (mineral products) activity data

Sub-category	Active volume	Active volume source	Remarks
Cement industry	Clinker production volume	Statistics in each country, and relevant organization questionnaire survey, etc	2006 IPCC Guidelines and AP-42 In 2006 IPCC Guidelines, activity data validation procedure is described in detail, which is applied in this guideline.
Lime industry	Lime production volume	Statistics in each country, UN statistics	
Bricks manufacturing	Bricks production volume	Statistics in each country, etc	Although statistics unit required for emission calculation is weight, unit of some statistics is in pieces, in which case unit conversion factor is necessary to be developed.
Asphalt roofing material manufacturing	Asphalt roofing material production volume	Questionnaire survey for factories and relevant organization, etc.	It is necessary to avoid double count in sub-categories
Asphalt plastering	Asphalt plastering volume	Questionnaire survey for relevant organization, etc.	
Road paving	Road paving asphalt volume	Questionnaire survey for factories and relevant organization, etc.	

5.2.1.3 Setting of emission factors

Emission factor is classified into mineral product, chemical product, metal product, and other products, and compiled based on GAP Forum Manual values, as shown in Table 5.2-3 and Table 5.2-4. It is necessary to note that these emission factors are defined as single value for each industrial process that contains a wide range of values technically. If emission factor can be set in accordance with the characteristics of the country, it should be used instead of default values shown here. In “5.2.2.3 Setting of emission factors” technically more detailed emission factor is shown, or any emission factor based on the country’s data may available, which should be used instead of default values shown here.

In GAP Forum Manual, cement industry SO_2 emission factor is shown in, and is to be calculated as industrial process, nonetheless, in this guideline, it is to be calculated in fuel consumption sector as same as EMEP/EEA Guidebook.

Table 5.2-3 Industrial process (mineral products, Part 1) emission factor (GAP Forum Manual-based value)

Sub-category	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Cement industry														
Wet process kiln (uncontrolled)	SOx: kg/Mg cement produced Others: kg/Mg clinker produced	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	65[c]	16[b]	4.64[b]			520[a]		
Wet process kiln with ESP		NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	0.38[c]	0.33[b]	0.25[b]			520[a]		
Dry process kiln with fabric filter		NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	0.10[c]	0.084[b]	0.045[b]			520[a]		
Lime industry														
Coal-fired rotary kiln (uncontrolled)	kg/Mg lime produced	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	180[c]	22[b]	2.57[b]			750[a]		
Coal-fired rotary kiln (with ESP)		NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	4.3[c]	2.2[b]	0.62[b]			750[a]		
Bricks manufacturing														
Grinding and screening (dry material: uncontrolled)	kg/Mg fired brick produced	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]		0.26[b]						
Coal-fired kiln (uncontrolled)		NA[b]	NA[b]	NA[b]	NA[b]	NA[b]		0.68[b]	0.44[b]					

Source: [a] 2006 IPCC Guidelines, [b] GAP Forum Manual, [c] AP-42

Note: NA: “Not applicable”, -: “Not available”, ESP: “Electro-static Precipitator”

Table 5.2-4 Industrial process (mineral products, Part 2) emission factor (GAP Forum Manual-based value)

Sub-category	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Asphalt roofing material production	kg/Mg product output	NA[b]	NA[b]	0.0095[b]	0.046[b]	NA[b]		0.6[b]	-[b]			neg.[a]	neg.[a]	neg.[a]
Asphalt plastering		NA[b]	NA[b]	0.014[b]	0.66[b]	NA[b]		0.33[b]	-[b]			neg.[a]	neg.[a]	neg.[a]
Road pavement														
Asphalt plant - Batch Mix Hot Mix (uncontrolled)	kg/Mg product output	NA[b]	NA[b]	NA[b]	0.018[b]	NA[b]	16[c]	2.25[b]	0.14[b]			neg.[a]	neg.[a]	neg.[a]
Asphalt plant - Batch Mix Hot Mix (fabric filter PM controlled)	kg/Mg product output	NA[b]	NA[b]	NA[b]	0.018[b]	NA[b]	0.021[c]	0.0135[b]	0.0042[b]			neg.[a]	neg.[a]	neg.[a]
Asphalt plant - Drum Mix Hot Mix (uncontrolled)	kg/Mg product output	NA[b]	NA[b]	NA[b]	0.016[b]	NA[b]	14[c]	3.25[b]	0.75[b]			neg.[a]	neg.[a]	neg.[a]
Asphalt plant - Drum Mix Hot Mix (fabric filter PM controlled)	kg/Mg product output	NA[b]	NA[b]	NA[b]	0.016[b]	NA[b]	0.0165[c]	0.0115[b]	0.0015[b]			neg.[a]	neg.[a]	neg.[a]
Liquefied asphalt - rapid cure (RC)	kg/Mg product output	NA[b]	NA[b]	NA[b]	170[b]	NA[b]		NA[b]	NA[b]			neg.[a]	neg.[a]	neg.[a]
Liquefied asphalt - medium cure (MC)	kg/Mg product output	NA[b]	NA[b]	NA[b]	140[b]	NA[b]		NA[b]	NA[b]			neg.[a]	neg.[a]	neg.[a]
Liquefied asphalt - slow cure (SC)	kg/Mg product output	NA[b]	NA[b]	NA[b]	50[b]	NA[b]		NA[b]	NA[b]			neg.[a]	neg.[a]	neg.[a]

Source: [a] 2006 IPCC Guidelines, [b] GAP Forum Manual, [c] AP-42
Note: NA: “Not applicable”, -: “Not available”, ESP: “Electro-static Precipitator”

5.2.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

Article 5.2-2 Air pollutant emission estimation example: industrial process in Vietnam

As an example, air pollutant emission estimation for industrial process in Vietnam is shown below.

From Vietnam statistics or UN statistics, industrial process activity data is obtained as shown in Table 5.2-5. This table shows major activity data as examples, selected from the activity data obtained.

Table 5.2-5 Activity data of major industrial process in Vietnam

Sub-category	Name of active volume / statistics year	Activity data	Unit
Cement industry	Clinker production volume / 2008	38,045	Thousand metric tons
Lime industry	Lime production volume / 2008	1,679.40	Thousand metric tons
Bricks industry	Bricks production volume / 2008	18,278	Million pieces
Urea	Urea production volume / 2007	975,400	Ton
Sulfuric acid	Sulfuric acid production volume / 2008	64,966	Ton
Steel industry	Steel production volume / 2007	170	Thousand metric tons
Copper refining	Copper primary refining volume / 2007	11,000	Ton
Zinc refining	Zinc primary refining volume / 2007	23,000	Ton
Pulp industry	Kraft pulp production volume / 2007	622,800	Ton
	Sulfuric acid pulp production volume / 2007	82,000	Ton

Industrial process emission factors for Vietnam are set as shown in Table 5.2-6 and Table 5.2-7. Since SO_x,NO_x,CO and NMVOC emission factors for cement industry are include emissions by fuel combustion, it is necessary to note not to double count. In other words, it is necessary not to count the emission from fuel combustion.

Table 5.2-6 Industrial process emission factor set in Vietnam (Part 1)

Emission factor (g/ton)	SO_2	NO_x	CO	NMVOC
Clinker production 〖Wet process kiln (uncontrolled)〗				

Lime production 『Coal-fired rotary kiln (uncontrolled)』				
Bricks production “Grinding and screening operations (processing dry material)”				
Urea production ” Fluidize bed prilling (Agricultural grade; uncontrolled)”				
Sulfuric acid production “single absorption”	9,050			
Steel production volume “Pig iron production (Blast furnace charging)”				
Copper primary refining “Multiple health roaster followed by reverberatory furnace and converter “	530,000			
Zinc primary refining “Roasting; Suspension (Uncontrolled)”				
Kraft paper production “IPCC default value”	7,000	1,500	5,600	3,700
Sulfuric acid pulp production “IPCC default value”	30,000			

Table 5.2-7 Industrial process emission factor set in Vietnam (Part 2)

Emission factor (g/ton)	TSP	PM_{10}	$PM_{2.5}$	NH_3
Clinker production “Wet process kiln (uncontrolled)”	65,000	16,000	4,640	
Lime production “Coal-fired rotary kiln (uncontrolled)”	180,000	22,000	2,570	
Bricks production “Grinding and screening operations (processing dry material)”	4,250	265	ND	
Urea production “Fluidize bed prilling (Agricultural grade; uncontrolled)”	3,100	1,860	1,333	1,460
Sulfuric acid production “single absorption”				
Steel production volume ”Pig iron production (Blast furnace charging)”	50	40	25	
Copper primary refining ”Multiple health roaster followed by reverberatory furnace	65,000			

and converter"				
Zinc primary refining "Roasting; Suspension (Uncontrolled)"	1,000,000			
Kraft paper production "IPCC default value"	90,000			
Sulfuric acid pulp production "IPCC default value"	2,000			

Air pollutant emission by industrial process in Vietnam is calculated as shown in Table 5.2-8. However, SO_x, NOx, CO and NMVOC emission for cement industry, it is necessary to note that the emission factor includes fuel. In other words, it is necessary not to double count the emission from fuel combustion.

Table 5.2-8 Air pollutant emissions by industrial process in Vietnam

Emissions (ton/year)	Year	**SO_2**	**NO_x**	**CO**	**NMVOC**
Clinker production	2008				
Lime production	2008				
Bricks production	Unknown				
Urea production	2007				
Sulfuric acid production	2008	588			
Steel production rate	2007				
Copper primary refining	2007	5,830			
Zinc primary refining	2007				
Kraft pulp production	2007	4,360	934	3,488	2,304
Sulfuric acid pulp production	2007	2,460			
Total (yearly difference is ignored)		13,238	934	3,488	2,304
Emission rate (ton/year)	**Year**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**NH_3**
Clinker production	2008	2,472,925	608,720	176,529	
Lime production	2008	302,292	36,947	4,316	
Bricks production	Unknown				
Urea production	2007	3,024	1,814	1,300	1,424

Sulfuric acid production	2008				
Steel production rate	200	9	7	4	
Copper primary refining	2007	715			
Zinc primary refining	2007	23,000			
Kraft pulp production	2007	56,052			
Sulfuric acid pulp production	2007	164			
Total (yearly difference is ignored)		2,858,181	647,488	182,149	1,424

5.2.2 Detailed method

5.2.2.1 Outline of emission estimation method

The emission estimation method is basically the same as “5.2.1 Simple method”, that is by multiplying the activity data with the emission factor. Activity data generally means the amounts of production in each industrial process, and it is assumed that statistics at national or provincial level are available. The emission factor is the emission rate per unit of production rate, and compared to the emission factor of “5.2.1 Simple method”.

$$\text{Emissions} = \text{AD} \times \text{EF} \quad \cdots\cdots (5.2\text{-}2)$$

Where,

Emissions: Air pollutant and greenhouse gas emission rate

AD: Industrial process activity data (industrial product production rate)

EF: Industrial process emission factor

The detailed information on the emission rate can be obtained through plant/workplace questionnaire survey/interview (hereinafter referred to as “questionnaire survey”). The questionnaire survey is basically assumed to be the same as the survey of large scale factory, from which, the factory position, amounts of production, pollution prevention policy can be obtained. Further, the emission factor or amounts of air pollutant emission should be preferably obtainable too.

The contents that have to identify by questionnaire or interview of the plant are as shown in Table 5.2-9. Basically it is the same as the survey carried out in large scale plant in “3 Estimating emissions of air pollutants from fuel consumption”.

Table 5.2-9 Information material to collect for emission estimation

Survey item	Survey content
Plant basic information	Product items, number of employee, plant address, plant plan drawing, chimney position and height
Product information	Annual fuel consumption volume, annual raw material consumption volume, annual production volume Monthly production volume of the year, Fuel specification (calorific value, sulfur content, ash content, nitrogen content, etc)
Pollution mitigation technology	Applied pollution mitigation technologies
Others	Measurement data on air pollutant emission, emission factor information (if any), other information as required

However, out of the active volume in industrial process of the country, for activity data not comprehended in this “5.2.2 Detailed method”, it is treated as area source, and calculated with “5.2.1 Simple method”

5.2.2.2 Estimation of activity data

Estimation of activity data is basically the same as “5.2.1 Simple method”, but it is more detailed technically, and activity data like Table 5.2-10 is required.

Table 5.2-10 Industrial process (mineral products) activity data

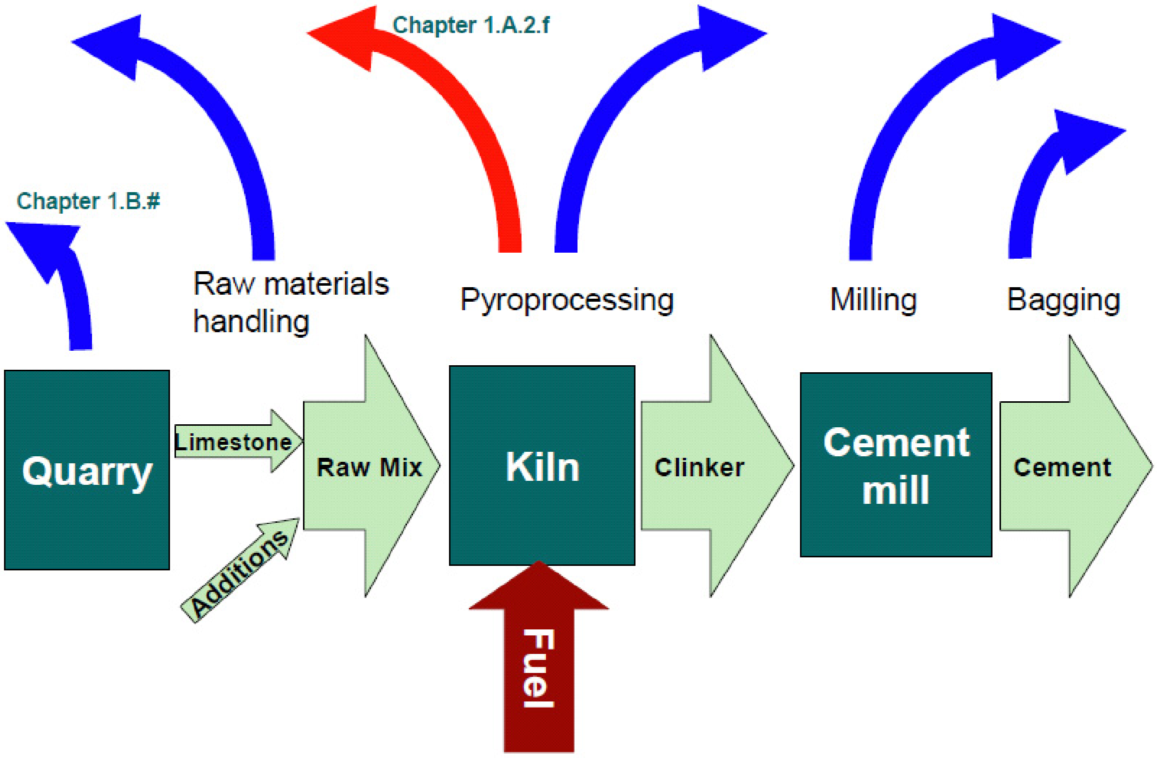
Sub-category	Activity data	Active volume source	Remarks
Cement industry	Cement production volume	Statistics of the country, UN statistics	EMEP/EEA Guidebook
	Clinker production volume	Statistics of the country, relevant organization questionnaire survey	2006 IPCC Guidelines and AP-42 In 2006 IPCC Guidelines, active volume searching method is described in details, and this guideline also use the same method
Lime industry	Lime production volume	Statistics of the country, UN statistics	
Soda ash manufacturing and usage	Soda ash production volume	Statistics of the country, UN statistics	
Asphalt roofing material manufacturing	Asphalt roofing material production volume	Plant and relevant organization questionnaire survey	It is necessary to note not to do double-counting
Asphalt road pavement	Road pavement asphalt volume	Relevant organization questionnaire survey	
Asphalt plant	Asphalt production volume	Plant and relevant organization questionnaire survey	
Bricks industry	Bricks production volume	Statistics of the country, UN statistics	The unit is in weight, but in statistics, some are expressed in piece.
Non-coal mining stone drilling and exploration	Various mining product production volume	Statistics of countries, UN statistics	Except coal, collect from all kinds of statistics
Construction and demolition	Construction, demolition building floor area	Statistics of the country, relevant provincial office, organization questionnaire survey	
Mining product storage, processing, transportation	Mining product production volume	Statistics of the country, UN statistics	Collect from all kinds of statistics
Other inorganic item manufacturing	Other (mainly glass) inorganic item manufacturing	Statistics of the country, UN statistics	

Activity data which should be collected through questionnaire survey is generally sama as the activity data shown in Table 5.2-10.

5.2.2.3 Setting of emission factors

Mineral products are classified into cement industry, lime industry, soda ash industry and usage, asphalt roofing material manufacturing, asphalt road paving, non-coal stone quarrying and mining, construction and demolition, mineral product storage, processing and transportation, and other inorganic item manufacturing. Default values of emission factors here are the normal values in European, that is, emission volume estimated may have some error.

Cement manufacturing process outline is shown in Figure 5.2-1. The fuel used in cement manufacturing is mainly for the cement burning process in the kiln. Therefore, fuel burning air pollutant emission is mainly generated from the kiln. On the other hand, PM is produced not only in cement burning process, but also in the process before and after burning. PM is calculated in industrial process. Air pollutants except PM are calculated in fuel combustion.



Source: EMEP/EEA Guidebook, Figure 2-1 of “2.A.1.Cement production”

Figure 5.2-1 Cement manufacturing process outline

Based on the above, cement industry emission factor is compiled as in Table 5.2-11 to Table 5.2-13.

Table 5.2-11 Emission factor for industrial process (mineral products: cement industry) (EMEP/EEA Guidebook)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Cement industry	Default value	TSP	220	g/Mg cement produced
		PM_{10}	200	g/Mg cement produced
		$PM_{2.5}$	110	g/Mg cement produced
	Wet kiln (removal rate 98.9%)	TSP	0.6	kg/Mg cement produced
		PM_{10}	0.51	kg/Mg cement produced
		$PM_{2.5}$	0.18	kg/Mg cement produced
	Dry kiln (removal rate 99.5%)	TSP	2.5	kg/Mg cement produced
		PM_{10}	1.3	kg/Mg cement produced
		$PM_{2.5}$	0.94	kg/Mg cement produced
Removal rate Environment protection technology	ESP: particle > 10μm		93	%
	ESP: 10μm > particle > 2.5μm		34	%
	ESP: 2.5μm > particle		40	%
	Fabric filter: particle > 10μm		98	%
	Fabric filter: 10μm > particle > 2.5μm		80	%
	Fabric filter: 2.5μm > particle		73	%

Note: ESP: Electro-static Precipitator

Source: EMEP/EEA Guidebook

AP-42 cement industry emission factor of AP-42 is shown in Table 5.2-12.

Table 5.2-12 Emission factor for industrial process (mineral products: cement industry) (AP-42, Part 1)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Cement industry	Wet process kiln (uncontrolled)	TSP	65	kg/Mg clinker produced
		PM_{10}	16	kg/Mg clinker produced
		$PM_{2.5}$	4.64	kg/Mg clinker produced
	Wet process kiln with ESP	TSP	0.38	kg/Mg clinker produced
		PM_{10}	0.33	kg/Mg clinker produced
		$PM_{2.5}$	0.25	kg/Mg clinker produced
	Wet process kiln with fabric filter	TSP	0.23	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced
	Wet process kiln with cooling tower, multiclone, and ESP	TSP	0.10	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced
	Dry Process kiln with ESP	TSP	0.50	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced
	Dry Process kiln with fabric filter	TSP	0.10	kg/Mg clinker produced
		PM_{10}	0.084	kg/Mg clinker produced
		$PM_{2.5}$	0.045	kg/Mg clinker produced
	Pre-heater kiln	TSP	130	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced
	Pre-heater kiln with ESP	TSP	0.13	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced

Note: ESP: Electro-static Precipitator

Source: AP-42

Table 5.2-13 Emission factor for industrial process (mineral products: cement industry) (AP-42, Part 2)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Cement industry	Pre-heater kiln with fabric filter	TSP	0.13	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced
	Pre-heater/precalciner kiln with ESP	TSP	0.024	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced
	Pre-heater/precalciner process kiln with fabric filter	TSP	0.10	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced
	Pre-heater/precalciner process kiln with PM controls	TSP	ND	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced
	Clinker cooler with ESP	TSP	0.048	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced
	Clinker cooler with fabric filter	TSP	0.068	kg/Mg clinker produced
		PM_{10}	ND	kg/Mg clinker produced
		$PM_{2.5}$	ND	kg/Mg clinker produced
	Clinker cooler with gravel bed filter	TSP	0.11	kg/Mg clinker produced
		PM_{10}	0.084	kg/Mg clinker produced
		$PM_{2.5}$	0.044	kg/Mg clinker produced

Note: ESP: Electrostatic Precipitator

Source: AP-42

Emission factors for lime industry of EMEP/EEA Guidebook are shown in Table 5.2-14. More technically detailed emission factors shown in Table 3.4 of "2.A.2 Lime stone production" in EMEP/EEA Guidebook should be used as reference. Air pollutant emission volume by fuel used in kiln need to be calculated in "fuel combustion" sector.

Table 5.2-14 Emission factor for industrial process (mineral products: lime industry)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Lime industry	Default value	TSP	0.59	kg/Mg lime produced
		PM_{10}	0.24	kg/Mg lime produced
		$PM_{2.5}$	0.05	kg/Mg lime produced
	Uncontrolled emission factor	TSP	9	kg/Mg cement produced
		PM_{10}	3.5	kg/Mg cement produced
		$PM_{2.5}$	0.7	kg/Mg cement produced
	Controlled emission factor	TSP	0.4	kg/Mg cement produced
		PM_{10}	0.2	kg/Mg cement produced
		$PM_{2.5}$	0.03	kg/Mg cement produced

Source: EMEP/EEA Guidebook

Emission factors for lime industry of AP-42 are shown in Table 5.2-15. TSP emission factors for some mitigation technology which is not described in Table 5.2-15 are necessary to refer to AP-42 Table 11.17-1. All PM_{10} are stated in Table 5.2-15.

Table 5.2-15 Emission factor for industrial process (mineral products: lime industry) (AP-42)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Lime industry	Coal-fired rotary kiln (uncontrolled)	TSP	180	kg/Mg lime produced
		PM_{10}	22	kg/Mg lime produced
		$PM_{2.5}$	2.57	kg/Mg lime produced
	Coal-fired rotary kiln with large diameter	TSP	60	kg/Mg lime produced
		PM_{10}	ND	kg/Mg lime produced
		$PM_{2.5}$	ND	kg/Mg lime produced
	Coal-fired rotary kiln with fabric filter	TSP	0.14	kg/Mg lime produced
		PM_{10}	0.077	kg/Mg lime produced
		$PM_{2.5}$	0.038	kg/Mg lime produced
	Coal-fired rotary kiln with ESP	TSP	4.3	kg/Mg lime produced
		PM_{10}	2.2	kg/Mg lime produced
		$PM_{2.5}$	0.62	kg/Mg lime produced
	Coal- and gas fired rotary kiln	TSP	40	kg/Mg lime produced
		PM_{10}	ND	kg/Mg lime produced
		$PM_{2.5}$	ND	kg/Mg lime produced
	Coal-fired rotary pre-heater kiln with multi-clone	TSP	42	kg/Mg lime produced
		PM_{10}	ND	kg/Mg lime produced
		$PM_{2.5}$	ND	kg/Mg lime produced
	Coal-fired calcimatic kiln	TSP	48	kg/Mg lime produced
		PM_{10}	ND	kg/Mg lime produced
		$PM_{2.5}$	ND	kg/Mg lime produced

Note: ESP: Electro-static Precipitator

Source: AP-42

Emission factor for Soda ash industry is shown in Table 5.2-16.

Table 5.2-16 Industrial process (mineral products: soda ash) emission factor

Sub-category	Technology	Air pollutant	Emission factor	Unit
Soda ash manufacturing and usage	Default value	CO	9	kg/Mg soda ash produced
		NH_3	0.9	kg/Mg soda ash produced
		TSP	0.1	kg/Mg soda ash produced

Source: EMEP/EEA Guidebook

Emission factor for asphalt roofing material manufacturing is shown in Table 5.2-17.

Table 5.2-17 Emission factor for industrial process (mineral products: asphalt roofing material manufacturing)

Sub-category	Technogy	Air pollutant	Emission factor	Unit
Asphalt roofing material manufacturing	Default value	CO	0.01	kg/Mg Shingle
		NMVOC	0.005	kg/Mg Shingle
		TSP	0.6	kg/Mg Shingle
	Dip saturator (uncontrolled)	CO	0.01	kg/Mg Shingle
		NMVOC	0.005	kg/Mg Shingle
		TSP	0.6	kg/Mg Shingle
	Spray/ dip saturator (uncontrolled)	NMVOC	0.13	kg/Mg Shingle produced
		TSP	1.6	kg/Mg Shingle produced
Removal rate Environmental protection technology	ESP(Dip saturator): TSP		97	%
	ESP(Dip saturator): NMVOC		0	%
	HEAF(Dip saturator): TSP		94	%
	HEAF(Dip saturator): NMVOC		0	%
	HEAF(Spray/ dip saturator): TSP		98	%
	HEAF(Spray/ dip saturator): NMVOC		0	%

Note: ESP: Electro-static Precipitator
: HEAF: High Energy Air Filter
Source: EMEP/EEA Guidebook

Emission factor for asphalt road paving is shown in Table 5.2-18 and Table 5.2-19.

Table 5.2-18 Emission factor for industrial process (mineral products: asphalt road-paving)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Asphalt road paving	Default value	NMVOC	16	g/Mg asphalt
		TSP	14	kg/Mg asphalt
		PM_{10}	3	kg/Mg asphalt
		$PM_{2.5}$	0.4	kg/Mg asphalt
	Batch Mix Hot Mix Plant (uncontrolled)	NMVOC	16	g/Mg asphalt
		TSP	15	kg/Mg asphalt
		PM_{10}	2	kg/Mg asphalt
		$PM_{2.5}$	0.1	kg/Mg asphalt
	Drum Mix Hot Mix Plant (uncontrolled)	NMVOC	15	g/Mg asphalt
		TSP	13	kg/Mg asphalt
		PM_{10}	3	kg/Mg asphalt
		$PM_{2.5}$	0.7	kg/Mg asphalt
	Liquefied asphalt, Cutback asphalt (uncontrolled)	NMVOC	30	kg/Mg asphalt

Source: EMEP/EEA Guidebook

Table 5.2-19 Reduction rate of industrial process (mineral products: asphalt road-paving)

Sub-category	Technology	Reduction ratio	Remarks
Batch Mix Hot Mix plant	Venturi / wet scrubber: TSP	99.6 %	
	Venturi / wet scrubber: PM_{10}	98 %	
	Venturi / wet scrubber: $PM_{2.5}$	98 %	
	Fabric filter: TSP	99.9 %	
	Fabric filter: PM_{10}	99.8 %	
	Fabric filter: $PM_{2.5}$	99.7 %	
Drum Mix Hot Mix plant	Venturi / wet scrubber: TSP	99.7 %	
	Venturi / wet scrubber: PM_{10}	99.7 %	
	Venturi / wet scrubber: $PM_{2.5}$	99.7 %	
	Fabric filter: TSP	99.9 %	
	Fabric filter: PM_{10}	99.9 %	
	Fabric filter: $PM_{2.5}$	99.9 %	

Source: EMEP/EEA Guidebook

Emission factors for asphalt mixing plant of AP-42 are shown in Table 5.2-20 to Table 5.2-22. These emission factors are the combined values of emission from fuel consumption and emission from industrial process. Therefore, when using these emission factors, either use zero for emission factor from asphalt mixing plant fuel consumption, or use zero in fuel consumption sector for asphalt mixing plant fuel consumption.

Table 5.2-20 Emission factor for industrial process (mineral products: asphalt plant) (PM)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Asphalt plant - Batch Mix Hot Mix	Uncontrolled	TSP	16	kg/Mg of product
		PM_{10}	2.25	kg/Mg of product
		$PM_{2.5}$	0.135	kg/Mg of product
	Venturi or wet scrubber	TSP	0.07	kg/Mg of product
		PM_{10}	ND	kg/Mg of product
		$PM_{2.5}$		kg/Mg of product
	Fabric filter	TSP	0.021	kg/Mg of product
		PM_{10}	0.0135	kg/Mg of product
		$PM_{2.5}$	0.00415	kg/Mg of product
Asphalt plant - Drum Mix Hot Mix	Uncontrolled	TSP	14	kg/Mg of product
		PM_{10}	3.25	kg/Mg of product
		$PM_{2.5}$	0.75	kg/Mg of product
	Venturi or wet scrubber	TSP	0.0225	kg/Mg of product
		PM_{10}	ND	kg/Mg of product
		$PM_{2.5}$		kg/Mg of product
	Fabric filter	TSP	0.0165	kg/Mg of product
		PM_{10}	0.0115	kg/Mg of product
		$PM_{2.5}$	0.00145	kg/Mg of product

Source: AP-42

Table 5.2-21 Emission factor for industrial process (mineral products: asphalt plant) (non-PM, Part 1)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Asphalt plant - Batch Mix Hote Mix	Natural gas fired dryer, hot screens, and mixer	CO	0.20	kg/Mg of product
		CO_2	18.5	kg/Mg of product
		NO_x	0.0125	kg/Mg of product
		SO_2	0.0023	kg/Mg of product
		NMVOC	0.0041	kg/Mg of product
	Fuel oil-fired dryer, hot screens, and mixer	CO	0.20	kg/Mg of product
		CO_2	18.5	kg/Mg of product
		NO_x	0.06	kg/Mg of product
		SO_2	0.044	kg/Mg of product
		NMVOC	0.0041	kg/Mg of product
	Waste oil-fired dryer, hot screens, and mixer	CO	0.20	kg/Mg of product
		CO_2	18.5	kg/Mg of product
		NO_x	0.06	kg/Mg of product
		SO_2	0.044	kg/Mg of product
	Fuel oil-fired dryer, hot screens, and mixer	NMVOC	0.018	kg/Mg of product
	Coal-fired dryer, hot screen, and mixer	CO	ND	kg/Mg of product
		CO_2	18.5	kg/Mg of product
		NO_x	ND	kg/Mg of product
		SO_2	0.0215	kg/Mg of product

Source: AP-42

Table 5.2-22 Emission factor for industrial process (mineral products: asphalt plant) (non-PM, Part 2)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Asphalt plant - Drum Mix Hot Mix	Natural gas fired dryer	CO	0.065	kg/Mg of product
		CO_2	16.5	kg/Mg of product
		NO_x	0.013	kg/Mg of product
		SO_2	0.0017	kg/Mg of product
		NMVOC	0.016	kg/Mg of product
	Fuel oil-fired dryer	CO	0.065	kg/Mg of product
		CO_2	16.5	kg/Mg of product
		NO_x	0.0275	kg/Mg of product
		SO_2	0.0055	kg/Mg of product
		NMVOC	0.016	kg/Mg of product
	Waste oil-fired dryer	CO	0.065	kg/Mg of product
		CO_2	16.5	kg/Mg of product
		NO_x	0.0275	kg/Mg of product
		SO_2	0.029	kg/Mg of product
		NMVOC	0.016	kg/Mg of product
	Coal-fired dryer	CO	ND	kg/Mg of product
		CO_2	16.5	kg/Mg of product
		NO_x	ND	kg/Mg of product
		SO_2	0.095	kg/Mg of product

Source: AP-42

Emission factor for bricks industry of AP-42 is shown in Table 5.2-23 and Table 5.2-24.

Table 5.2-23 emission factor for industrial process (mineral products: bricks industry) (Part 1)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Bricks industry	Primary crusher with fabric filter	TSP	ND	kg/Mg fired bricks produced
		PM_{10}	0.000295	kg/Mg fired bricks produced
		$PM_{2.5}$	ND	kg/Mg fired bricks produced
	Grinding and screening operations (processing dry material)	TSP	4.25	kg/Mg fired bricks produced
		PM_{10}	0.265	kg/Mg fired bricks produced
		$PM_{2.5}$	ND	kg/Mg fired bricks produced
	Grinding and screening operations (processing wet material)	TSP	0.0125	kg/Mg fired bricks produced
		PM_{10}	0.00115	kg/Mg fired bricks produced
		$PM_{2.5}$	ND	kg/Mg fired bricks produced
	Grinding and screening operations (with fabric filter	TSP	0.0031	kg/Mg fired bricks produced
		PM_{10}	0.0016	kg/Mg fired bricks produced
		$PM_{2.5}$	ND	kg/Mg fired bricks produced
	Extrusion line with fabric filter	TSP	ND	kg/Mg fired bricks produced
		PM_{10}	0.0018	kg/Mg fired bricks produced
		$PM_{2.5}$	ND	kg/Mg fired bricks produced

Note: ESP: Electro-static Precipitator

Source: AP-42

Table 5.2-24 Emission factor for industrial process (mineral products: bricks industry) (Part 2)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Bricks industry	Natural gas-fired kiln	TSP	0.48	kg/Mg fired bricks produced
		PM_{10}	0.435	kg/Mg fired bricks produced
		$PM_{2.5}$	ND	kg/Mg fired bricks produced
	Coal-fired kiln (uncontrolled)	TSP	0.9	kg/Mg fired bricks produced
		PM_{10}	0.7	kg/Mg fired bricks produced
		$PM_{2.5}$	0.435	kg/Mg fired bricks produced
	Coal-fired kiln (with fabric filter)	TSP	0.315	kg/Mg fired bricks produced
		PM_{10}	ND	kg/Mg fired bricks produced
		$PM_{2.5}$	ND	kg/Mg fired bricks produced
	Sawdust-fired kiln	TSP	0.465	kg/Mg fired bricks produced
		PM_{10}	0.425	kg/Mg fired bricks produced
		$PM_{2.5}$	0.375	kg/Mg fired bricks produced
	Sawdust-fired kiln and sawdust dryer	TSP	0.7	kg/Mg fired bricks produced
		PM_{10}	0.155	kg/Mg fired bricks produced
		$PM_{2.5}$	ND	kg/Mg fired bricks produced

Note: ESP: Electro-static Precipitator

Source: AP-42

Emission factor of quarrying and mining of minerals other than coal is shown in Table 5.2-25.

Table 5.2-25 Emission factor for industrial process (mineral products: non-coal mining)

Sub-category	Air pollutant	Emission factor	Unit
Quarrying and mining of minerals other than coal	TSP	0.07	g/Mg mineral
	PM_{10}	0.04	g/Mg mineral
	$PM_{2.5}$	0.004	g/Mg mineral

Source: EMEP/EEA Guidebook

Emission factor for construction and demolition works is shown in Table 5.2-26.

Table 5.2-26 Emission factor for industrial process (mineral products: construction and demolition)

Sub-category	Air pollutant	Emission factor	Unit
Construction and demolition works	TSP	0.162	$kg/m^2/year$
	PM_{10}	0.0812	$kg/m^2/year$
	$PM_{2.5}$	0.00812	$kg/m^2/year$

Source: EMEP/EEA Guidebook

Emission factor of storage, processing and transportation of mining product is shown in Table 5.2-27.

Table 5.2-27 Emission factor for industrial process (mineral products: storage, processing, transportation)

Sub-category	Air pollutant	Emission factor	Unit
Storage, processing and transportation of mining products	TSP	10	g/Mg product
	PM_{10}	5	g/Mg product
	$PM_{2.5}$	0.5	g/Mg product

Source: EMEP/EEA Guidebook

Emission factors for other inorganic item manufacturing of EMEP/EEA Guidebook are shown in Table 5.2-28.

Table 5.2-28 Emission factor for industrial process (mineral products: inorganic item manufacturing)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Other inorganic item manufacturing	Glass manufacturing Default value	TSP	300	g/Mg glass
		PM_{10}	270	g/Mg glass
		$PM_{2.5}$	240	g/Mg glass
	Flat glass (abated furnaces (primary/ secondary methods)	TSP	130	g/Mg glass
		PM_{10}	120	g/Mg glass
		$PM_{2.5}$	100	g/Mg glass
	Container glass (primary measures; without secondary abatement)	TSP	280	g/Mg glass
		PM_{10}	250	g/Mg glass
		$PM_{2.5}$	220	g/Mg glass
	Glass fiber (primary abatement methods; no secondary abatement)	TSP	100	g/Mg glass
		PM_{10}	90	g/Mg glass
		$PM_{2.5}$	70	g/Mg glass
	Glass wool manufacturing	NMVOC	500	g/Mg glass
		NH_3	1400	g/Mg glass
		TSP	670	g/Mg glass
		PM_{10}	590	g/Mg glass
		$PM_{2.5}$	520	g/Mg glass
	Lead crystal glass (filters in operation)	TSP	10	g/Mg glass
		PM_{10}	9	g/Mg glass
		$PM_{2.5}$	8	g/Mg glass
	Other glasses	TSP	200	g/Mg glass
		PM_{10}	180	g/Mg glass
		$PM_{2.5}$	160	g/Mg glass

Source: EMEP/EEA Guidebook

Reduction rate for other inorganic item manufacturing of EMEP/EEA Guidebook is shown in Table 5.2-29.

Table 5.2-29 Reduction rate for industrial process (mineral products: inorganic item manufacturing)

Sub-category	Technology	Reduction rate	Remarks
Flat glass	Policy A: particle > 10μm	75 %	Policy A either use gas/oil as fuel to burn, or introduce a limited policy
	Policy A: 10μm > particle > 2.5μm	75 %	
	Policy A: 2.5μm > particle	75 %	
	Policy B: particle > 10μm	99 %	Policy B introduces electric heater, electro-static precipitator, scrubber or continuous filtering.
	Policy B: 10μm > particle > 2.5μm	99 %	
	Policy B: 2.5μm > particle	99 %	
Glass fiber	Policy A: particle > 10μm	50 %	Policy A either use gas/oil as fuel to burn, or introduce a limited policy
	Policy A: 10μm > particle > 2.5μm	50 %	
	Policy A: 2.5μm > particle	50 %	
	Policy B: particle > 10μm	75 %	Policy B introduces electric heater, electro-static precipitator, scrubber or continuous filtering
	Policy B: 10μm > particle > 2.5μm	75 %	
	Policy B: 2.5μm > particle	75 %	

Source: EMEP/EEA Guidebook

Emission factors for other inorganic item manufacturing in AP-42 are shown in Table 5.2-30.

Table 5.2-30 Industrial process (mineral products: inorganic item manufacturing) emission factor

Sub-category	Technology	Air pollutant	Emission factor	Unit
Glass manufacturing (container)	Uncontrolled	TSP	0.7	kg/Mg glass produced
	w/low-energy scrubber	TSP	0.4	kg/Mg glass produced
	w/venture scrubber	TSP	<0.1	kg/Mg glass produced
Glass manufacturing (flat glass)	Uncontrolled	TSP	1.0	kg/Mg glass produced
	w/low-energy scrubber	TSP	0.5	kg/Mg glass produced
Glass manufacturing (Press and blown)	Uncontrolled	TSP	8.4	kg/Mg glass produced
	w/low-energy scrubber	TSP	4.2	kg/Mg glass produced
	w/venture scrubber	TSP	0.5	kg/Mg glass produced
	w/low-energy scrubber	TSP	0.1	kg/Mg glass produced
	w/venture scrubber	TSP	0.1	kg/Mg glass produced
Glass manufacturing (Forming and finishing)		TSP	Negligible	kg/Mg glass produced

Source: AP-42

5.2.2.4 Temporal change and spatial distribution

1. *Temporal change*

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. *Spatial distribution*

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

5.3 Chemical products

5.3.1 Simple method

5.3.1.1 Outline of emission estimation method

Air pollutant emission amount is estimated by multiplying activity data and emission factors. Generally activity data are the production volume of product in each industrial process, and statistics data of country or province are used for estimation.

5.3.1.2 Estimation of activity data

Activity data is basically the production volume of each industrial product, and is assumed to be available in the statistics data of each country, which use is the priority. If activity data is not available in the statistics data of the country, the following international statistics data can be used.

1) Industrial Commodity Statistics Yearbook
2) FAOSTAT: http://faostat.fao.org/

Activity data of chemical industry air pollutant emission amount is shown as in Table 5.3-1.

Table 5.3-1 Activity data of industrial process (chemical industries)

Sub-category	Activity data	Source	Remarks
Ammonia	Ammonia production volume	Statistics data of each country; UN statistics	
Acetic acid	Acetic acid production volume(100% Acetic acid amount)	Statistics data of each country; UN statistics	
Adipic acid	Adipic acid production volume	Statistics data of each country; UN statistics	
Black carbon	Black carbon production volume	Statistics data of each country; UN statistics	
Urea	Urea production volume	Statistics data of each country; UN statistics	
Ammonium nitrate	Ammonium nitrate production volume	Statistics data of each country; UN statistics	
Ammonium phosphate	Ammonium phosphate production volume	Statistics data of each country; UN statistics	
Sulfuric acid	Sulfuric acid production volume(100% Sulfuric acid amount)	Statistics data of each country; UN statistics	
Titanium dioxide	Titanium dioxide production volume	Statistics data of each country; UN statistics	

5.3.1.3 Setting of emission factors

Emission factor are compiled based on the default values of GAP Forum Manual, using the values listed in Table 5.3-2. However, it is important to note that these emission factors are set as a single value for industrial process that has wide values technically. If emission factors can be set in accordance with the features of the country, those values should be the priority in usage. And emission factors with more technical details are shown in “5.3.2 Detailed method”, “5.3.2.3 Setting of emission factor”, and if emission factor that should be used as a priority in the country is available, it should be used as a priority.

Table 5.3-2 Emission factors of industrial process (chemical industries) (GAP Forum Manual based value)

Sub-category	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Ammonia	kg/Mg output	0.3$^{b)}$	NA$^{b)}$	7.9$^{b)}$	4.7$^{b)}$	2.1$^{b)}$		NA$^{b)}$	NA$^{b)}$			1694 - 3273$^{a)}$		
Nitric acid	kg/Mg (100% acid)	NA$^{b)}$	12$^{b)}$	NA$^{b)}$	NA$^{b)}$	0.01$^{b)}$		NA$^{b)}$	NA$^{b)}$					2 - 9$^{a)}$
Adipic acid	kg/Mg output	NA$^{b)}$	8.1$^{b)}$	34.4$^{b)}$	9$^{b)}$	NA$^{b)}$	0.5$^{c)}$	0.5$^{b)}$	-$^{b)}$					300$^{a)}$
Carbon black	kg/Mg output	3.1$^{b)}$	0.4$^{b)}$	10$^{b)}$	40$^{b)}$	NA$^{b)}$	6.56$^{c)}$	6.56$^{b)}$	-$^{b)}$			780 - 5250$^{a)}$		
Urea(uncontrolled)	kg/Mg output	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	11.8$^{b)}$		125.6$^{b)}$	-$^{b)}$					
Urea(wet scrubber)	kg/Mg output	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	11.8$^{b)}$		0.71$^{b)}$	-$^{b)}$					
Ammonium nitrate	kg/Mg output	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	29 - 63$^{b)}$		4.7 - 9.0$^{b)}$	-$^{b)}$					
Ammonium phosphate	kg/Mg output	0.04$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	0.07$^{b)}$	0.34$^{c)}$	0.34$^{b)}$	-$^{b)}$					
Sulfuric acid	kg/Mg output	0 - 48$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$		NA$^{b)}$	-$^{b)}$					
Titanium dioxide	kg/Mg output	14.6$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$		-$^{b)}$	-$^{b)}$			1340 - 1430$^{a)}$		

Source: $^{a)}$ 2006 IPCC Guidelines, $^{b)}$ GAP Forum Manual, $^{c)}$ AP-42

Note: NA: “Not applicable”, -: “Not available”

5.3.1.4 Temporal change and spatial distribution

1. <u>Temporal change</u>

Temporal change is shown in Table 2.5-1 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

2. <u>Spatial distribution</u>

Spatial distribution is shown in Table 2.5-2 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

5.3.2 <u>Detailed method</u>

5.3.2.1 Outline of emission estimation method

The basic formula in emission amount estimation is the same as "5.3.1 Simple method", that is air pollutant emission amount is estimated by multiplying activity data and emission factors. Generally activity data are the production volume of product in each industrial process, and statistics data of country or province are used for estimation. The emission factor is the emission amount per unit of production volume, but compared to the emission factor of "5.3.1 Simple method". It is more detailed technically.

$$\mathrm{Emissions} = \mathrm{AD} \times \mathrm{EF} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (5.3\text{-}1)$$

Where,

Emissions: Air pollutant and greenhouse gas emission amount

AD: Activity data (production volume of industrial product)

EF: Emission factor

The detailed information on the emission amount can be obtained through questionnaire survey and interview survey ("questionnaire survey"). The questionnaire survey is basically assumed to be the same as estimation of air pollutant amount of large point source, of fuel consumption from which, the factory location, production volume, pollution prevention policy can be obtained. Further, the emission factor or air pollutant emission amount data should be preferably obtainable too.

The contents that have to identify by questionnaire or interview of the are shown as in Table 5.3-3, based on survey form for large point source of fuel consumption

Table 5.3-3 Information material to collect for estimation of emission amount

Survey item	Survey content
Stationary source information	Product items, number of employee, stationary source address, large point source ground plan, stack location and height
Product information	Annual fuel consumption amount, annual raw material consumption amount, annual production volume Production volume of the year, month Fuel condition (calorific value, sulfur concentration ash concentration, nitrogen concentration, etc)
Pollutant control measure	Condition of pollution control measure introduction
Others	Air pollutant emission amount actual survey result, emission factor condition (if any), other information as required

However, in the total national activity data of industrial, activity data is not estimated by "5.3.2 Detailed method", is treated as area source, and estimated using by "5.3.1 Simple method".

5.3.2.2 Estimation of activity data

Activity data of air pollutant emission amount from chemical industry is shown as in Table 5.3-4 and Table 5.3-5.

Table 5.3-4 Activity data of industrial process (chemical industries: Part 1)

Sub-category	Activity data	Source	Remarks
Ammonia	Ammonia production volume	Statistics data of each country; UN statistics	
Nitric acid	Nitric acid production volume (100% Acetic acid)	Statistics data of each country; UN statistics	
Adipic acid	Adipic acid production volume	Statistics data of each country; UN statistics	
Calcium carbide	Calcium carbide production volume	Statistics data of each country; UN statistics	
Sulfuric acid	Sulfuric acid production volume(100% Sulfuric acid)	Statistics data of each country; UN statistics	
Ammonium sulfate	Ammonium sulfate production volume	Statistics data of each country; UN statistics	
Ammonium nitrate	Ammonium nitrate production volume	Statistics data of each country; UN statistics	
Ammonium phosphate	Ammonium phosphate production volume	Statistics data of each country; UN statistics	
Carbon black	Carbon black production volume	Statistics data of each country; UN statistics	
Urea	Urea production volume	Statistics data of each country; UN statistics	
Titanium dioxide	Titanium dioxide production volume	Statistics data of each country; UN statistics	
Phosphate fertilizers	Phosphate fertilizers production volume	Statistics data of each country; UN statistics	
Ethylene and Propylene	Ethylene and Propylene production volume	Statistics data of each country; UN statistics	
1,2 dichloroethane and Vinyl chloride	Vinyl chloride monomer (VCM) production volume	Statistics data of each country; UN statistics	
Polyethylene	Low density polyethylene (LDPE) production volume	Statistics data of each country; UN statistics	LDPE with specific gravity below 0.94, based on UN statistics
	High density polyethylene (HDPE)production volume	Statistics data of each country; UN statistics	According to the UN statistics, HDPE with specific gravity more than 0.94
Poly vinyl chloride (PVC)	Suspended PVC production volume	Statistics data of each country; UN statistics data	
	Emulsion PVC process production volume	Statistics data of each country; UN statistics data	

Table 5.3-5 Activity data of industrial process (chemical industries: Part 2)

Sub-category	Activity data	Source	Remarks
Polypropylene	Polypropylene production volume	Statistics data in each country; UN statistics	
Styrene	Styrene production volume	Statistics data in each country; UN statistics	
Polystyrene	General purpose polystyrene production volume	Statistics data in each country; UN statistics	
	High impact polystyrene production volume	Statistics data in each country; UN statistics	
	Expandable polystyrene production volume	Statistics data in each country; UN statistics	
Styrene-butadiene	General styrene-butadiene polymer production volume	Statistics data in each country; UN statistics	
	Styrene-butadiene latex production volume	Statistics data in each country; UN statistics	
	Styrene-butadiene rubber production volume	Statistics data in each country; UN statistics	
Acrylnitrile-butadiene-Styrene (ABS)	Acrylnitrile- butadiene-styrene (ABS) resin production volume	Statistics data in each country; UN statistics	
Ethylene oxide	Ethylene oxide production volume	Statistics data in each country; UN statistics	
Formaldehyde	Formaldehyde production volume	Statistics data in each country; UN statistics	
Ethyl benzene	Ethyl benzene production volume	Statistics data in each country; UN statistics	
Phthalic anhydride	Using o-xylene as feed	Statistics data in each country; UN statistics	
	Using naphthalene as feed	Statistics data in each country; UN statistics	
Acrylnitrile	Acrylnitile production volume	Statistics data in each country; UN statistics	

However, it is assumed that activity data which are obtained through questionnaire survey is as same as activity data in Table 5.3-4 and Table 5.3-5.

5.3.2.3 Setting of emission factors

Chemical industry is classified into ammonia production, nitric acid production, Adipic acid production, carbide production and other chemical industry, storage, handling and transport of chemical production.

Emission factor from ammonia production is shown as in Table 5.3-6. However, emission factors for CO_2, N_2O and other greenhouse gas from ammonia production should be refer to 2006 IPCC Guidelines.

Table 5.3-6 Emission factor from Industrial process (chemical industries: ammonia production)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Ammonia	Default value	NO_x	1 [b)]	kg/t NH_3
		CO	0.1 [b)]	kg/t NH_3
		NH_3	0.01 [b)]	kg/t NH_3
	Average value - Natural gas	CO_2	2.104 [a)]	ton/t NH_3
	Average value - partially oxidized	CO_2	3.273 [a)]	ton/t NH_3
	Steam reformoming (conventional as well as advanced process)	NO_x	1 [b)]	kg/ton NH_3
		CO	0.006 [b)]	kg/ton NH_3
		NMVOC	0.09 [b)]	kg/ton NH_3
		NH_3	0.05 [b)]	kg/ton NH_3
	Various (auxiliary. boiler, super heater, post combustion)	NMVOC	1 [b)]	kg/ton NH_3
		CO	0.1 [b)]	kg/ton NH_3

Source: [a)]2006 IPCC Guidelines, [b)]EMEP/EEA Guidebook, [c)] AP-42

Emission factor from nitric acid production is shown as in Table 5.3-7.

Table 5.3-7 Emission factor from industrial process (chemical industries: nitric acid production)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Nitric acid	Default value	NO_x	10000 b)	g/Mg prod., 100% acid
		N_2O	2 - 9 a)	kg/ton 100% pure acid
	Low pressure process	NO_x	12000 b)	g/Mg (100% Acid)
		NO_x	3500 c)	g/Mg (100% Acid)
	(Uncontrolled)	NO_x	28500 c)	g/Mg (100% Acid)
	Medium pressure process	NO_x	7500 b)	g/Mg (100% Acid)
	High pressure process	NO_x	3000 b)	g/Mg (100% Acid)
	Direct strong acid process	NO_x	500 b)	g/Mg (100% Acid)
		NO_x	5000 c)	g/Mg (100% Acid)
	Catalyst reduction (low, medium, high pressure process)	NO_x	400 b)	g/Mg (100% Acid)
	Catalyst reduction (natural gas)	NO_x	200 c)	g/Mg (100% Acid)
	Catalyst reduction (hydrogen)	NO_x	400 c)	g/Mg (100% Acid)
	Catalyst reduction (Mixture of hydrogen, and natural gas)	NO_x	450 c)	g/Mg (100% Acid)
	Extended absorption (low, medium, high pressure process)	NO_x	900 b)	g/Mg (100% Acid)
	Extended absorption (Single-stage process)	NO_x	950 c)	g/Mg (100% Acid)
	Extended absorption (2-stage process)	NO_x	1050 c)	g/Mg (100% Acid)
	Chilled absorption and caustic scrubber	NO_x	1100 c)	g/Mg (100% Acid)

Source: a) 2006 IPCC Guidelines, b) EMEP/EEA Guidebook, c) AP-42

Emission factor from adipic acid production is shown as in Table 5.3-8.

Table 5.3-8 Emission factor from industrial process (chemical industries: Adipic acid production)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Adipic acid	Default value (EMEP/EEA Guidebook value)	NO_x	8 b)	kg/Mg
		CO	0.4 b)	kg/Mg
		N_2O	300 a)	kg/ton adpic acid
	Total value of primary and secondary oxidization process t (US EPA value: uncontrolled)	NO_x	8.1 c)	kg/Mg
		CO	34.4 c)	kg/Mg
		NMVOC	9 c)	kg/Mg
		TSP	0.5 c)	kg/Mg

Source: a) 2006 IPCC Guidelines, b) EMEP/EEA Guidebook, c) AP-42

Emission factor from calcium carbide production is shown as in Table 5.3-9.

Table 5.3-9 Emission factor from industrial process (chemical industries: carbide production)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Carbide	Default value	TSP	100 [b)]	g/Mg product
	CaC_2 production without the usage of furnace gas	TSP	49 [b)]	g/Mg produced
	CaC_2 production without the usage of furnace gas (e.g. lime kiln); Venturi scrubber	TSP	80.9 [b)]	g/Mg produced
	Silicon carbide production volume	CO_2	2.30 [a)]	ton CO_2/ton raw material used
		CH_4	10.2 [a)]	kg CH_4/ton raw material used
		CO_2	2.62 [a)]	ton CO_2/ton carbide produced
		CH_4	11.6 [a)]	kg CH_4/ton carbide produced
	Calcium carbide production volume	CO_2	1.70 [a)]	ton CO_2/ton raw material used
		CO_2	1.090 [a)]	ton CO_2/ton carbide produced
		CO_2	not relevant [a)]	ton CO_2/ton raw material used
		CO_2	1.100 [a)]	ton CO_2/ton carbide produced

Source: [a)] 2006 IPCC Guidelines, [b)]EMEP/EEA Guidebook

Emission factor from other chemical industry is shown as in Table 5.3-10 to Table 5.3-18.

Table 5.3-10 Emission factor from industrial process (chemical industries: other chemical industry, Part 1: sulfuric acid, sulfuric acid ammonium, nitric acid ammonium, phosphoric acid ammonium)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Sulfuric acid	Single absorption	SO_x	9050 [b)]	g/Mg (100% H_2SO_4)
	Double absorption	SO_x	3000 [b)]	g/Mg (100% H_2SO_4)
	Double absorption (decomposition plants spent sulfuric acid)	SO_x	7000 [b)]	g/Mg (100% H_2SO_4)
	Wet contact process (98% and 78% sulfuric acid)	SO_x	17000 [b)]	g/Mg (100% H_2SO_4)
	Wet type/dry type contact process with intermediate condensation and absorption	SO_x	3500 [b)]	g/Mg (100% H_2SO_4)
	Sulfuric acid plant (SO_2 to SO_3 Conversion Efficiency: 93% ~ 100%)	SO_x	0 - 48 [c)]	kg/Mg of Product
Ammonium sulfate	Uncontrolled	TSP	60 [b)]	kg/ton
Ammonium nitrate	Uncontrolled	NO_x	30 [b)]	kg/ton
		TSP	200 [b)]	kg/ton
Ammonium phosphate	Default value	TSP	300 [b)]	g/ton
		PM_{10}	240 [b)]	g/ton
		$PM_{2.5}$	180 [b)]	g/ton
	Default value (average controlled)	SO_2	0.04 [c)]	kg/ton
		NH_3	0.07 [c)]	kg/ton
		TSP	0.34 [c)]	kg/ton

Source: [a)] 2006 IPCC Guidelines, [b)] EMEP/EEA Guidebook, [c)] AP-42, [d)] 1996 IPCC Guidelines

Table 5.3-11 Emission factor from industrial process (chemical industries: other chemical industry, Part 2: urea)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Urea	Default value	NH_3	2.5 [b)]	kg/Mg
		TSP	1.5 [b)]	kg/Mg
		PM_{10}	1.2 [b)]	kg/Mg
		$PM_{2.5}$	0.9 [b)]	kg/Mg
Urea (Solution formation and concentration)	Uncontrolled	NH_3	0.0105 [c)]	kg/Mg
		TSP	9.23 [c)]	kg/Mg
Urea (Nonfluidized bed prilling process)	Agricultural grade (Uncontrolled)	NH_3	0.43 [c)]	kg/Mg
		TSP	1.9 [c)]	kg/Mg
		PM_{10}	1.71 [c)]	kg/Mg
		$PM_{2.5}$	1.50 [c)]	kg/Mg
	Agricultural grade (Controlled)	TSP	0.032 [c)]	kg/Mg
		PM_{10}	0.0288 [c)]	kg/Mg
		$PM_{2.5}$	0.0253 [c)]	kg/Mg
	Feed grade (Uncontrolled)	TSP	1.8 [c)]	kg/Mg
		PM_{10}	1.53 [c)]	kg/Mg
		$PM_{2.5}$	0.9 [c)]	kg/Mg

Source: [a)] 2006 IPCC Guidelines, [b)] EMEP/EEA Guidebook, [c)] AP-42, [d)] 1996 IPCC Guidelines

Table 5.3-12 Emission factor from industrial process (chemical industries: other chemical industry, Part 3: urea)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Urea: Fluidized bed priiling	Agricultural grade (Uncontrolled)	NH_3	1.46 [c)]	kg/Mg
		TSP	3.1 [c)]	kg/Mg
		PM_{10}	1.86 [c)]	kg/Mg
		$PM_{2.5}$	1.33 [c)]	kg/Mg
	Agricultural grade (Controlled)	TSP	0.39 [c)]	kg/Mg
		PM_{10}	0.234 [c)]	kg/Mg
		$PM_{2.5}$	0.168 [c)]	kg/Mg
	Feed grade (Uncontrolled)	NH_3	2.07 [c)]	kg/Mg
		TSP	1.8 [c)]	kg/Mg
		PM_{10}	0.432 [c)]	kg/Mg
		$PM_{2.5}$	0.252 [c)]	kg/Mg
	Feed grade (Controlled)	TSP	0.24 [c)]	kg/Mg
		PM_{10}	0.058 [c)]	kg/Mg
		$PM_{2.5}$	0.034 [c)]	kg/Mg
Urea (drum granulation)	Uncontrolled	NH_3	1.07 [c)]	kg/Mg
		TSP	120 [c)]	kg/Mg
	Controlled	TSP	0.115 [c)]	kg/Mg
Urea (rotary drum cooler)	Uncontrolled	NH_3	0.0256 [c)]	kg/Mg
		TSP	3.89 [c)]	kg/Mg
		PM_{10}	0.027 [c)]	kg/Mg
		$PM_{2.5}$	0.0016 [c)]	kg/Mg
	Controlled	TSP	0.10 [c)]	kg/Mg
		PM_{10}	0.0007 [c)]	kg/Mg
		$PM_{2.5}$	0.00004 [c)]	kg/Mg
Urea (bagging)	Uncontrolled	TSP	0.095 [c)]	kg/Mg

Source: [c)] AP-42

Table 5.3-13 Emission factor from industrial process (chemical industries: other chemical industry, Part 4: carbon black)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Carbon black	Furnace black (conventional process)	NO_x	15 [b)]	kg/ton carbon black
		CO	3 [b)]	kg/ton carbon black
		NMVOC	0.7 [b)]	kg/ton carbon black
		SO_x	22 [b)]	kg/ton carbon black
		TSP	0.3 [b)]	kg/ton carbon black
	Default value (2006 IPCC Guidelines)	NO_x	0.4 [d)]	kg/ton carbon black
		CO	10 [d)]	kg/ton carbon black
		NMVOC	40 [d)]	kg/ton carbon black
		SO_x	3.1 [d)]	kg/ton carbon black
		TSP	6.56 [d)]	kg/ton carbon black
	Furnace back process	CO_2	2.62 [a)]	tons/ton carbon black
	Thermal black process	CO_2	5.25 [a)]	tons/ton carbon black
	Acetylene black process	CO_2	0.78 [a)]	tons/ton carbon black
	No thermal treatment	CH_4	28.7 [a)]	kg/ton carbon black
	Thermal Treatment	CH_4	0.06 [a)]	kg/ton carbon black
	Oil furnace process Main process vent	PM [*)]	3.27 [c)]	kg/ton carbon black
		CO	1400 [c)]	kg/ton carbon black
		NO_x	0.28 [c)]	kg/ton carbon black
		SO_x	0 [c)]	kg/ton carbon black
		CH_4	25 [c)]	kg/ton carbon black

Source: [a)] 2006 IPCC Guidelines, [b)] EMEP/EEA Guidebook, [c)] AP-42, [d)] 1996 IPCC Guidelines

Note: [*)] PM is Black Carbon

Table 5.3-14 Emission factor from industrial process (chemical industries: other chemical industry, Part 5: carbon black)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Carbon black	Oil furnace process Flare	PM [*)]	1.35 [c)]	kg/ton carbon black
		CO	122 [c)]	kg/ton carbon black
		NO_x	ND [c)]	kg/ton carbon black
		SO_x	25 [c)]	kg/ton carbon black
	Oil furnace process CO boiler and incinerator	PM [*)]	1.04 [c)]	kg/ton carbon black
		CO	0.88 [c)]	kg/ton carbon black
		NO_x	4.65 [c)]	kg/ton carbon black
		SO_x	17.5 [c)]	kg/ton carbon black
	Combined dryer vent (Bag filter)	PM [*)]	0.12 [c)]	kg/ton carbon black
		NO_x	0.36 [c)]	kg/ton carbon black
		SO_x	0.26 [c)]	kg/ton carbon black
	Combined dryer vent (Scrubber)	PM [*)]	0.36 [c)]	kg/ton carbon black
		NO_x	1.10 [c)]	kg/ton carbon black
		SO_x	0.20 [c)]	kg/ton carbon black
	Pneumatic system vent (Bag filter)	PM [*)]	0.29 [c)]	kg/ton carbon black
	Vacuum cleanup system vent (Bag filter)	PM [*)]	0.03 [c)]	kg/ton carbon black
	Fugitive emissions	PM [*)]	0.10 [c)]	kg/ton carbon black
	Solid waste incinerator	PM [*)]	0.12 [c)]	kg/ton carbon black

Source: [a)] 2006 IPCC Guidelines, [b)] EMEP/EEA Guidebook, [c)] AP-42, [d)] 1996 IPCC Guidelines

Note: [*)] PM is Black Carbon

Table 5.3-15 Emission factor from industrial process (chemical industries: other chemical industry, Part 6: Bi-acid Titan, phosphoric acid fertilizer)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Titanium dioxide	Chloride process	NO_x	0.1 [b)]	kg/ton
		CO	159 [b)]	kg/ton
		SO_x	1.14 [b)]	kg/ton
		TSP	0.2 [b)]	kg/ton
	Sulphate process	NO_x	0.108 [b)]	kg/ton
		SO_x	3.97 [b)]	kg/ton
		TSP	0.3 [b)]	kg/ton
	2006 IPCC Guidelines default value	SO_x	14.6 [d)]	kg/ton
Phosphate fertilizers		TSP	0.3	kg/ton produced
		PM_{10}	0.24	kg/ton produced
		$PM_{2.5}$	0.18	kg/ton produced

Source: [a)] 2006 IPCC Guidelines, [b)] EMEP/EEA Guidebook, [c)] AP-42, [d)] 1996 IPCC Guidelines

Table 5.3-16 Emission factor from industrial process (chemical industries: other chemical industry, Part 7)

Sub-category	Substance	Air pollutant	Emission factor	Unit
Ethylene and propylene		NMVOC	0.6 [b)]	ton/kton produced
1,2 dichloroethane + Vinyl chloride	DCE unit (unabated)	NMVOC	2500 [b)]	g/ton produced
	VCM unit (unabated)	NMVOC	2500 [b)]	g/ton produced
Polyethylene	Low density polyethylene (LDPE with specific gravity below 0.94, based on UN statistics)	NMVOC	2.4 [b)]	kg/ton produced
		TSP	31 [b)]	g/ton produced
	HDPE (LDPE with specific gravity more than 0.94, based on UN statistics)	NMVOC	2.3 [b)]	kg/ton produced
		TSP	97 [b)]	g/ton produced
Poly vinyl chloride (PVC)	Suspension PVC process	NMVOC	96 [b)]	g/ton produced
		TSP	263 [b)]	g/ton produced
		PM_{10}	100 [b)]	g/ton produced
		$PM_{2.5}$	5 [b)]	g/ton produced
	Emulsion PVC process	NMVOC	813 [b)]	g/ton produced
		TSP	263 [b)]	g/ton produced
		PM_{10}	100 [b)]	g/ton produced
		$PM_{2.5}$	5 [b)]	g/ton produced
	Uncontrolled (Usually controlled with fabric filter, efficiency of 98-99%)	TSP	17.5 [c)]	kg/ton produced
Polypropylene		NMVOC	4 [b)]	kg/ton produced
		TSP	1.5 [b) c)]	kg/ton produced
Styrene		NMVOC	1 [b)]	kg/ton produced

Source: [a)] 2006 IPCC Guidelines, [b)] EMEP/EEA Guidebook, [c)] AP-42, [d)] 1996 IPCC Guidelines

Table 5.3-17 Emission factor from industrial process (chemical industries: other chemical industry, Part 8)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Polystyrene	Production of general purpose polystyrene (GPPS)	NMVOC	120	g/ton produced
		TSP	4	g/ton produced
	High impact polystyrene(HIPS)	NMVOC	120	g/ton produced
		TSP	4	g/ton produced
	Expandable polystyrene	NMVOC	3.2	kg/ton produced
		TSP	30	g/ton produced
Styrene butadiene	Styrene butadiene polymer in general	NMVOC	0.27	kg/ton produced
	Styrene butadiene latex	NMVOC	9	kg/ton produced
	Styrene butadiene rubber (SBR)	NMVOC	5	kg/ton produced
Acrylnitryl-Butadiene Styrene (ABS)	ABS resin	NMVOC	3	kg/ton produced
Ethylene oxide	Ethylene oxide	NMVOC	2	kg/ton produced
Formaldehyde	Silver process (catalysic oxidation under air deficiency)	CO	12	kg/ton produced
		NMVOC	7	kg/ton produced
	Oxide process(catalysic oxidation under air excess)	CO	0.2	kg/ton produced
		NMVOC	1.5	kg/ton produced
	Silver process (thermal of catalyst incineration)	CO	0.2	kg/ton produced
		NMVOC	0.0016	kg/ton produced
		TSP	0.0005	kg/ton produced

Source: EMEP/EEA Guidebook

Table 5.3-18 Emission factor from industrial process (chemical industries: other chemical industry, Part 9)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Ethyl benzene		NMVOC	0.1	kg/ton produced
Phtalic anhydride	Using o-xylene as feed	NMVOC	1.3	kg/ton produced
	Using naphthalene as feed	NMVOC	6	kg/ton produced
Acrylonitrile		NMVOC	1	kg/ton produced

Source: EMEP/EEA Guidebook

Abatement efficiencies for industrial process of chemical industry are shown as in Table 5.3-19.

Table 5.3-19 Abatement efficiencies for industrial process (chemical industries)

Sub-category	Pollutant	Efficiency	Remarks
Conventional Plant	Particle > 10μm	88 %	Installation with average; conventionaldedusting;ESP;wet scrubber, some fugitives capturing
	10μm > particle > 2.5μm	81 %	
	2.5μm > particle	76 %	
Modern Plant	Particle > 10μm	98 %	High efficiency ESP or equivalent to control primary source; fabric filters for fugitive emissions
	10μm > particle > 2.5μm	96 %	
	2.5μm > particle	93 %	

Source: EMEP/EEA Guidebook

In AP-42, other chemical industry emission factors are shown as in Table 5.3-20 to Table 5.3-22.

Table 5.3-20 Emission factor from industrial process (chemical industries: other chemical industry, Part 10)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Polyethylene terephthalate (PET) and dimethyl terephthalate (DMT) process	With spray condenser	NMVOC	0.1	g/kg of product
	With no spray condenser	NMVOC	3.9	g/kg of product
		TSP	0.17	g/kg of product
Polyethylene terephthalate (PET) and terephthalic acid (TPA) process	With spray condenser	NMVOC	0.36	g/kg of product
	With no spray condenser	NMVOC	3.6	g/kg of product
		TSP		g/kg of product
Polystyrene (Continuous process)	Using vacuum pumps	NMVOC	0.21	g/kg of product
	Using steam jets	NMVOC	3.34	g/kg of product
Polystyrene (Continuous process)	Total plant	NMVOC	5.37	g/kg of product
Synthetic Rubber	Emulsion Crumb			
	Monomer recovery, uncontrolled	NMVOC	2.6	g/kg of copolymer produced
	Absorber vent	NMVOC	0.26	g/kg of copolymer produced
	Blend/coagulation tank, uncontrolled	NMVOC	0.42	g/kg of copolymer produced
	Dryers	NMVOC	2.51	g/kg of copolymer produced
	Emulsion Latex			g/kg of copolymer produced
	Monomer removal condenser vent	NMVOC	8.45	g/kg of copolymer produced
	Blend tanks, uncontrolled	NMVOC	0.1	g/kg of copolymer produced

Source: AP-42

Table 5.3-21 Emission factor from industrial process (chemical industries: other chemical industry, Part 11)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Oxidation of o-xylene				
Main process stream	Uncontrolled	TSP	69	kg/Mg of phthalic athydride produced
		SOx	6.7	
		CO	151	
	With scrubber and thermal incinerator	TSP	3	
		SOx	4.7	
		CO	6	
	With thermal incinerator	TSP	4	
		SOx	4.7	
		CO	8	
	With incinerator with steam generator	TSP	4	
		SOx	4.7	
		CO	8	
Pretreatment	Uncontrolled	TSP	6.4	kg/Mg of phthalic athydride produced
	With scrubber and thermal incinerator	TSP	0.3	
	With thermal incinerator	TSP	0.4	
Distillation	Uncontrolled	TSP	45	kg/Mg of phthalic athydride produced
		NMVOC	1.2	
	With scrubber and thermal incinerator	TSP	2	
		NMVOC	<0.1	
	With thermal incinerator	TSP	2	
		NMVOC	<0.1	

Source: AP-42

Table 5.3-22 Emission factor from industrial process (chemical industries: other chemical industry, Part 12)

Sub-category	Technology	Air pollutant	Emission factor	Unit
Oxidation of naphthalene				
Main process stream	Uncontrolled	TSP	28	kg/Mg of phthalic athydride produced
		CO	50	
	With thermal incinerator	TSP	6	
		CO	10	
	With scrubber	TSP	0.3	
		CO	50	
Pretreatment	Uncontrolled	TSP	2.5	kg/Mg of phthalic athydride produced
	With thermal incinerator	TSP	0.5	
	With scrubber	TSP	<0.1	
Distillation	Uncontrolled	TSP	19	kg/Mg of phthalic athydride produced
		NMVOC	5	
	With scrubber and thermal incinerator	TSP	4	
		NMVOC	1	
	With thermal incinerator	TSP	0.2	
		NMVOC	<0.1	

Source: AP-42

5.3.2.4 Temporal change and spatial distribution

1. *Temporal change*

Temporal change is shown as in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. *Spatial distribution*

Spatial distribution is shown as in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

5.4 Metal production

5.4.1 Simple method

5.4.1.1 Outline of emission estimation method

The calculation of emission is basically by multiplying the activity data with emission factor. Activity data generally means the production rate of product in each industrial process, and it is assumed that statistics at national or provincial level are available.

5.4.1.2 Estimation of activity data

Activity data is basically the production volume of each industrial product, and is assumed to be available in the statistics of each country, which use is priority. The activity data not derived from the statistics of each country is assumed to be based on the following international statistics data.

1) Industrial Commodity Statistics Yearbook
2) International Steel Institute (IISI: http://www.worldsteel.org/pictures/publicationfiles/SSY%202010.pdf)
3) USA Geological Survey (USGS) Minerals Yearbook (http://minerals.usgs.gov/minerals/pubs/country)

Activity data for metal industry is shown in Table 5.4-1.

Table 5.4-1 Activity data for Industrial process (metal production)

Sub-category	Activity data	Activity data source, remarks
Metal products		
Pig iron production	Iron and steel production volume	Statistics in each country,IISI (International Iron and Steel Institute) statistics
Aluminum production	Aluminum production volume	Statistics in each country, UN statistics
Copper smelting (primary)	High density ore volume processed in refining plant	Statistics in each country, UN statistics
Lead smelting (primary)	Burnt lead volume	Statistics in each country, UN statistics
Lead smelting (secondary)	Lead processed volume	Statistics in each country, UN statistics
Zinc smelting	Processed zinc ore volume, zinc usage	Statistics in each country, UN statistics

5.4.1.3 Setting of emission factors

Emission factor based on GAP Forum Manual is as shown in Table 5.4-2. However, these emission factors are single value set as emission factor of industrial process that contains a technically wide range of values. If emission factors can be set in accordance with the features of the country, these should be preferentially used. In “5.4.2.3 Setting of emission factor” of “5.4.2 Detailed method”, a technically more detailed emission factor is indicated, and if there is priority to use the emission factor of the country, that one should be preferentially used.

Table 5.4-2 Emission factors for Industrial process (metal production, GAP Forum Manual-based value)

Sub-category	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Metal products														
Pig iron production	kg/ton iron or steel produced	3$^{b)}$	0.076$^{b)}$	1.34$^{b)}$	0.12$^{b)}$	NA$^{b)}$		0.05$^{b)}$	-$^{b)}$			1060$^{a)}$		
Aluminum production	kg/ton primary aluminum	15.1$^{b)}$	2.15$^{b)}$	135$^{b)}$	0.02$^{b)}$	NA$^{b)}$		47$^{b)}$	-$^{b)}$			1600 - 1700$^{a)}$		
Copper smelting (primary)	kg/ton of concentrated ore processed by the smelter	2120$^{b)}$	NA$^{b)}$	NA$^{b)}$	0.03$^{b)}$	NA$^{b)}$		230$^{b)}$	193$^{b)}$					
Lead smelting (primary)	kg/ton sinter produced	320$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$		0.43$^{b)}$	-$^{b)}$			250 - 590$^{a)}$		
Lead smelting (secondary)	kg/ton charge	40$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$		162$^{b)}$	-$^{b)}$			200$^{a)}$		
Zinc smelting	kg/ton zinc ore processed	1000$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$		293$^{b)}$	-$^{b)}$			430 - 3660$^{a)}$		

Source: $^{a)}$ 2006 IPCC Guidelines, $^{b)}$ GAP Forum Manual, $^{c)}$ AP-42

Note: NA: “Not applicable”, -: “Not available”, neg.: “Negligible”

5.4.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

5.4.2 Detailed method

5.4.2.1 Outline of emission estimation method

The emission calculating method is basically the same as "5.4.1 Simple method" that is by multiplying the activity data with the emission factor. Activity data generally means the production volume in industrial process, and it is assumed that statistics at national or provincial level are available. The emission factor is the emission per unit of production volume. Compared to the emission factor of "5.4.1 Simple method", it is technically more detail.

$$\mathrm{Emissions} = \mathrm{AD} \times \mathrm{EF} \quad \cdots\cdots (5.4\text{-}1)$$

Where,

Emissions: Air pollutant and greenhouse gas emission

AD: activity data for industrial process (industrial product production volume)

EF: emission factor for industrial process

The detailed information on the emission can be obtained through plant/workplace questionnaire survey/interview ("questionnaire survey"). This questionnaire survey is basically assumed to be the same as the survey of large scale factory. By this suevey, the location of factory, production volume, pollution prevention policy can be obtained. Further, the emission factor or air pollutant emission data should be preferably obtainable too.

The contents that have to identify by questionnaire or interview of the plant are shown in Table 5.4-3. It is the same as the survey carried out in large scale factory in "3 Fuel consumption air pollutant emission estimating".

Table 5.4-3 Contents for collection of emission estimation

Survey item	Survey content
Plant basic information	Product items, number of employee, factory address, factory map, location and height of chimney
Product information	Annual fuel consumption, annual raw material consumption, annual production volume Monthly production volume in the year Fuel property (calorific value, sulfur content, ash content, nitrogen content, etc)
Anti-pollution policy	Introduction of anti-pollution measure
Others	Actual survey result for air pollutant emission, emission factor condition (if any), other information as required

However, in the activity data for industrial process of the country, activity data not derived in this “5.4.2 Detailed method”, it is treated as area source, and is calculated with “5.4.1 Simple method”

5.4.2.2 Estimation of activity data

Activity data for metal production is shown in Table 5.4-4

Table 5.4-4 Activity data for industrial process (metal production)

Sub-category	Technical	Reduction rate	Remarks
Iron and steel production (overall)	Steel production volume	Statistics of the country, IISI (International Iron and Steel Institute) Statistics	
Iron and steel production (Sinter)	Sinter production		
Iron and steel production (blast furnace)	Pig iron production volume		
Iron and steel production (steel production: hearth furnace, rotary furnace, electric furnace)	Steel production volume		
Iron and steel production (rolling)	Steel volume		Steel volume used in press rolled process
Ferroalloy production	Alloy production volume	Statistics of the country, UN statistics	If data of the country is unavailable, conduct questionnaire survey, interview at relevant ministries and agencies of the country and the companies.
Aluminum production	Aluminum production volume	Statistics of the country, UN statistics	
Copper smelting	High density ore volume processed at smelting plant	Statistics of the country, UN statistics	
Lead smelting	Lead ore volume, burnt lead volume, lead processing volume etc	Statistics of the country, UN statistics	
Nickel production	Nickel production volume	Statistics of the country, UN statistics	
Zinc smelting	Processed zinc ore volume, zinc usage	Statistics of the country, UN statistics	
Other metal production	Other metal product production volume	Statistics of the country, UN statistics	
Storage, handling and transport of metal products	Metal product production volume	Statistics of the country, UN statistics	

Then, activity data that should be obtained in questionnaire survey will be shown in Table 5.4-4.

5.4.2.3 Setting of emission factors

Metal productions are classified into iron and steel production, ferroalloy production, aluminum production, copper smelting, nickel production, zinc smelting, other metals production, and storage, handling and transport of metal products

In the emission factors for iron and steel production, the emission factors for sinter or pig iron, iron and steel products etc is shown in Table 5.4-5 and Table 5.4-6.

Table 5.4-5 Emission factor for Industrial process (metal production: iron and steel production: Part 1)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Iron and steel production	Default value (Iron and steel production)	NMVOC	150	g/Mg steel
		TSP	300	g/Mg steel
		PM_{10}	180	g/Mg steel
		$PM_{2.5}$	140	g/Mg steel
	Sinter Production (Sinter and pelletizing plants)	NMVOC	138	g/Mg sinter produced
		TSP	200	g/Mg sinter produced
		PM_{10}	100	g/Mg sinter produced
		$PM_{2.5}$	80	g/Mg sinter produced
	Pellet production (Sinter and pelletizing plant)	NMVOC	14	g/Mg pellets
		TSP	50	g/Mg pellets
		PM_{10}	25	g/Mg pellets
		$PM_{2.5}$	20	g/Mg pellets
	Pig iron production (Blast furnace charging)	TSP	50	g/Mg pig iron produced
		PM_{10}	40	g/Mg pig iron produced
		$PM_{2.5}$	25	g/Mg pig iron produced

Source: EMEP/EEA Guidebook

Table 5.4-6 Emission factor for industrial process (metal production: iron and steel production: Part 2)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Iron and steel production	Steel production (Open hearth furnace: average value of controlled and uncontrolled)	NMVOC	0.02	kg/Mg steel produced
		TSP	1	kg/Mg steel produced
		PM_{10}	0.8	kg/Mg steel produced
		$PM_{2.5}$	0.6	kg/Mg steel produced
	Steel production (Hearth furnace: Eastern Europe, Caucasus, Central Asia (EECCA) countries	NMVOC	0.02	kg/Mg steel produced
		TSP	0.7	kg/Mg steel produced
		PM_{10}	0.57	kg/Mg steel produced
		$PM_{2.5}$	0.38	kg/Mg steel produced
	Steel production (Basic oxygen furnace: average value, the facility with ESP and wet scrubber etc)	NO_x	10	g/Mg steel produced
		CO	3.5	kg/Mg steel produced
		TSP	35	g/Mg steel produced
		PM_{10}	32	g/Mg steel produced
		$PM_{2.5}$	28	g/Mg steel produced
	Steel production (Basic oxygen furnace: EECCA countries, limited control)	NO_x	10	g/Mg steel produced
		CO	3.5	kg/Mg steel produced
		TSP	0.5	kg/Mg steel produced
		PM_{10}	0.47	kg/Mg steel produced
		$PM_{2.5}$	0.46	kg/Mg steel produced
	Steel production (Electric furnace)	NO_x	130	g/Mg steel produced
		CO	1.7	kg/Mg steel produced
		NMVOC	46	g/Mg steel produced
		SO_x	60	g/Mg steel produced
		TSP	30	g/Mg steel produced
		PM_{10}	24	g/Mg steel produced
		$PM_{2.5}$	21	g/Mg steel produced

Source: EMEP/EEA Guidebook

Emission factor for specific technology is shown in Table 5.4-7.

Table 5.4-7 Emission factor for industrial process (metal production: iron and steel production: Part 3)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Iron and steel production	Steel production (Basic oxygen furnace: dry ESP, wSV)	TSP	30	g/Mg steel produced
		PM_{10}	24	g/Mg steel produced
		$PM_{2.5}$	21	g/Mg steel produced
	Steel production (Electric furnace: dry ESP, fabric filter)	NO_x	130	g/Mg steel produced
		CO	1.7	kg/Mg steel produced
		NMVOC	46	g/Mg steel produced
		SO_x	60	g/Mg steel produced
		TSP	30	g/Mg steel produced
		PM_{10}	24	g/Mg steel produced
		$PM_{2.5}$	21	g/Mg steel produced
	Steel production (Electric furnace: EECCA countries, more than 99% high efficiency bag filter controlled)	TSP	0.2	kg/Mg steel produced
		PM_{10}	0.16	kg/Mg steel produced
		$PM_{2.5}$	0.14	kg/Mg steel produced

Source: EMEP/EEA Guidebook

Emission factor for rolling process is shown in Table 5.4-8.

Table 5.4-8 Emission factor for industrial process (metal production: iron and steel production: Part 4)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Iron and steel production	Cold rolling mills	TSP	96	g/Mg steel
	Heat rolling mills	NMVOC	7	g/Mg steel
		TSP	9	g/Mg steel

Source: EMEP/EEA Guidebook

Abatement efficiencies by anti-pollution measure technology for iron and steel production is shown in Table 5.4-9.

Table 5.4-9 Abatement efficiencies for industrial process (metal production: iron and steel production)

Sub-category	Technical	Abatement efficiency	Remarks
Sinter and pelletizing products	Moderate: particle > 10μm	70 %	Moderate control of fugitive sources
	Moderate: 10μm > particle > 2.5μm	63 %	
	Moderate: 2.5μm > particle	50 %	
	Effective: particle > 10μm	90 %	Effective control of fugitive sources
	Effective: 10μm > particle > 2.5μm	88 %	
	Effective: 2.5μm > particle	80 %	
Pig iron production	Conventional: particle > 10μm	88 %	Installation with average age; conventional dedusting; ESP; wet scrubber; some fugitives capturing
	Conventional: 10μm > particle > 2.5μm	81 %	
	Conventional: 2.5μm > particle	76 %	
	Modern: particle > 10μm	98 %	High efficiency ESP or equivalent to control primary sources; fabric filters for fugitive emissions
	Modern: 10μm > particle > 2.5μm	96 %	
	Modern: 2.5μm > particle	93 %	
Open hearth furnace (Electro-Static Precipitator: ESP)	ESP: particle > 10μm	99 %	
	ESP: 10μm > particle > 2.5μm	99 %	
	ESP: 2.5μm > particle	99 %	
Basic oxygen furnace	Conventional: particle > 10μm	42 %	Conventional installation of average age: primary dedusting by ESP, wet scrubbing; limited capture of secondary dust emissions
	Conventional: 10μm > particle > 2.5μm	42 %	
	Conventional: 2.5μm > particle	42 %	
	Modern: particle > 10μm	80 %	High efficiency ESP or added fabric filter to control primary sources; extensive secondary dedusting using fabric filters
	Modern: 10μm > particle > 2.5μm	79 %	
	Modern: 2.5μm > particle	78 %	

Source: EMEP/EEA Guidebook

Iron and steel production Emission factor for iron and steel production by using technology is shown in Table 5.4-10 to Table 5.4-13, which source is AP-42.

Table 5.4-10 Emission factor for industrial process (metal production: iron and steel production: Part 5)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Iron and steel production (sintering) (Windbox) (Uncontrolled)	Leaving grate	TSP	5.56	kg/Mg finished sinter
	After coarse particulate removal	TSP	4.35	kg/Mg finished sinter
Iron and steel production (sintering) (Windbox) (Controlled)	Controlled by dry ESP	TSP	0.8	kg/Mg finished sinter
	Controlled by wet ESP	TSP	0.085	kg/Mg finished sinter
	Controlled by venturi scrubber	TSP	0.235	kg/Mg finished sinter
	Controlled by cyclone	TSP	0.5	kg/Mg finished sinter
Iron and steel production (sintering) (Sinter discharge) (breaker and hot screens)	Uncontrolled	TSP	3.4	kg/Mg finished sinter
	Controlled by baghouse	TSP	0.05	kg/Mg finished sinter
	Controlled by venturi scrubber	TSP	0.295	kg/Mg finished sinter
Iron and steel production (sintering) (Windbox and discharge)	Controlled by baghouse	TSP	0.15	kg/Mg finished sinter
Iron and steel production (blast furnace) (Slip)	Uncontrolled casthouse	TSP	39.5	kg/Mg slip
Iron and steel production (blast furnace) (Uncontrolled casthouse)	Roof monitor	TSP	0.3	kg/Mg hot metal
Iron and steel production (blast furnace)	Furnace with local evacuation	TSP	0.65	kg/Mg hot metal
	Taphole and trough only (not runners)	TSP	0.15	kg/Mg hot metal
Iron and steel production (Hot metal desulfurization)	Uncontrolled	TSP	0.55	kg/Mg hot metal
	Controlled by baghouse	TSP	0.0045	kg/Mg hot metal

Source: AP-42

Table 5.4-11 Emission factor for industrial process (metal production: iron and steel production: Part 6)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Iron and steel production (Basic oxygen furnace: BOF) (Top blown furnace melting and smelting)	Uncontrolled	TSP	14.25	kg/Mg steel
Iron and steel production (BOF) (Controlled by open hood vented to:)	ESP	TSP	0.065	kg/Mg steel
	Scrubber	TSP	0.045	kg/Mg steel
Iron and steel production (BOF) (Controlled by closed hood vented to:)	Scrubber	TSP	0.0034	kg/Mg steel
Iron and steel production (BOF) (BOF charging)	At source	TSP	0.3	kg/Mg hot metal
	At building monitor	TSP	0.071	kg/Mg hot metal
	Controlled by baghouse	TSP	0.0003	kg/Mg hot metal
Iron and steel production (BOF) (BOF tapping)	At source	TSP	0.46	kg/Mg steel
	At building monitor	TSP	0.145	kg/Mg steel
	Controlled by baghouse	TSP	0.0013	kg/Mg steel
Iron and steel production (BOF) (Hot metal transfer)	At source	TSP	0.095	kg/Mg hot metal
	At building monitor	TSP	0.028	kg/Mg hot metal
Iron and steel production (BOF)	BOF monitor (all sources)	TSP	0.25	kg/Mg steel
Iron and steel production (rotary furnace) (Q-BOF melting and smelting)	Controlled by scrubber	TSP	0.028	kg/Mg steel

Source: AP-42

Table 5.4-12 Emission factor for industrial process (metal production: iron and steel production: Part 7)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Iron and steel production (electric arc furnace) (Melting and refining)	Uncontrolled carbon steel	TSP	19.0	kg/Mg steel
Iron and steel production (electric arc furnace) (Charging, tapping, and slagging)	Uncontrolled emissions escaping monitor	TSP	0.7	kg/Mg steel
Iron and steel production (electric arc furnace) (Melting, refining, charging, tapping, and slagging)	Uncontrolled (Alloy steel)	TSP	5.65	kg/Mg steel
	Uncontrolled (Carbon steel)	TSP	25.0	kg/Mg steel
	Controlled by building evacuation (plus charging hood) to baghouse for alloy steel	TSP	0.15	kg/Mg steel
	Controlled by direct shell evacuation vented to common baghouse for carbon steel	TSP	0.0215	kg/Mg steel
Iron and steel production (open hearth furnace) (Melting and refining)	Uncontrolled	TSP	10.55	kg/Mg steel
	Controlled by ESP	TSP	0.14	kg/Mg steel
Iron and steel production (hearth furnace) (Roof monitor)		TSP	0.084	kg/Mg steel
Iron and steel production (Teeming) (Leaded steel)	Uncontrolled (measured at source)	TSP	0.405	kg/Mg steel
	Controlled by side draft hood vented to baghouse	TSP	0.0019	kg/Mg steel
Iron and steel production (teeming) (Unleaded steel)	Uncontrolled (measured at source)	TSP	0.035	kg/Mg steel
	Controlled by side draft hood vented to baghouse	TSP	0.0008	kg/Mg steel
Iron and steel production (Machine scarfing)	Uncontrolled	TSP	0.05	kg/Mg steel
	Controlled by ESP	TSP	0.0115	kg/Mg steel
Iron and steel production (Miscellaneous combustion sources) (boiler, soaking pit and slab reheat)	Blast furnace gas	TSP	0.015	kg/10^9 J
	Coke oven gas	TSP	0.052	kg/10^9 J

Source: AP-42

Table 5.4-13 Emission factor for industrial process (metal production: iron and steel production: Part 8)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Iron and steel production	Sintered windbox	CO	22	kg/Mg finished sinter
	Basic oxygen furnace (BOF)	CO	69	kg/Mg finished sinter
	Electric arc furnace	CO	9	kg/Mg finished sinter

Source: AP-42

Black Carbon (BC) and Organic Carbon (OC) emission factor for iron and steel production is the emission factor for blast furnace cokes, which is set as follows, based on “A technology-based global inventory of black and organic carbon emission from combustion” (Tami C. Bond, etc 2004).

$$EF_{BC} = EF_{PM} \times F_{1.0} \times F_{BC} \times F_{cont} \quad \cdots\cdots (5.4\text{-}2)$$

$$EF_{OC} = EF_{PM} \times F_{1.0} \times F_{OC} \times F_{cont} \quad \cdots\cdots (5.4\text{-}3)$$

Where,

EF_{PM}: PM emission factor (g/kg)

$F_{1.0}$: Ratio of particle pollutant diameter of 1 micro-meter or less

F_{BC}: Ratio of Black Carbon, in particle pollutant

F_{OC}: Ratio of Organic Carbon, in particle pollutant

F_{cont}: Ratio of PM, after passing the filter of emission reduction equipment

Then, organic matter and organic carbon ratio R_{org} are not considered here.

Table 5.4-14 Emission factor (BC and OC) for industrial process (metal production: iron and steel production: Part 9)

Fuel	Technology	EF_{PM} (g/kg)	$F_{1.0}$	F_{BC}	F_{OC}	F_{cont}
Coke	Blast furnace	0.4	0.28	0.28	0.05	0.05-1.0

Source: “A technology-based global inventory of black and organic carbon emission from combustion” (Tami C. Bond, etc 2004)

Greenhouse gas emission factor (CO_2 and CH_4) for iron and steel production is shown in Table 5.4-15.

Table 5.4-15 Emission factor for industrial process (metal production: iron and steel production: Part 10)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Iron and steel production	Sinter production	CO_2	200	kg/Mg sinter produced
		CH_4	0.07	kg/Mg sinter produced
	Cokes oven	CO_2	560	kg/Mg coke produced
		CH_4	0.1	g/Mg coke produced
	Iron production	CO_2	1350	kg/Mg pig iron produced
	Direct Reduced Iron production (DRI)	CO_2	700	kg/Mg DRI produced
	Pellet production	CO_2	30	kg/Mg pellet produced
	Basic Oxygen Furnace (BOF)	CO_2	1460	kg/Mg of steel produced
	Electric Arc Furnace (EAF)	CO_2	80	kg/Mg of steel produced
	Open Hearth Furnace (OHF)	CO_2	1720	kg/Mg of steel produced
	Global Average Factor (65% BOF, 30% EAF and 5% OHF)	CO_2	1060	kg/Mg of steel produced

Source: 2006 IPCC Guidelines

Emission factors for ferroalloys production are shown in Table 5.4-16 to Table 5.4-19. The emission factor in Table 5.4-16 is the default values for ferroalloys production process as a whole, whereas the emission factors in Table 5.4-17 and Table 5.4-18 are based on alloy type, technical type. And Table 5.4-19 indicates the greenhouse gas emission factors.

Table 5.4-16 Emission factor for industrial process (metal production: ferroalloy production) (Part 1, EMEP/EEA Guidebook)

Sub-category	Air pollutant	Emission factor	Unit
Ferroalloy production	TSP	1	kg/Mg alloy produced

Source: EMEP/EEA Guidebook

Table 5.4-17 Emission factor for industrial process (metal production: ferroalloy production) (Part 2, AP-42)

Sub-category	Technical	Air pollutant	Emission factor	Unit
FeSi (50%)	Open (Uncontrolled)	TSP	35	kg/Mg alloy produced
	Open (Baghouse)	TSP	0.9	kg/Mg alloy produced
	Covered (Uncontrolled)	TSP	46	kg/Mg alloy produced
	Covered (Scrubber: High energy)	TSP	0.24	kg/Mg alloy produced
	Covered (Scrubber: Low energy)	TSP	4.5	kg/Mg alloy produced
FeSi (75%)	Open (Uncontrolled)	TSP	158	kg/Mg alloy produced
	Open (Scrubber: Low energy)	TSP	4.0	kg/Mg alloy produced
	Covered (Uncontrolled)	TSP	103	kg/Mg alloy produced
	Covered (Controlled)	TSP	ND	kg/Mg alloy produced
FeSi (90%)	Open (Uncontrolled)	TSP	282	kg/Mg alloy produced
	Open (Controlled)	TSP	ND	kg/Mg alloy produced
Si metal (98%)	Open (Uncontrolled)	TSP	436	kg/Mg alloy produced
	Open (Baghouse)	TSP	16	kg/Mg alloy produced
FeMn (80%)	Open (Uncontrolled)	TSP	14	kg/Mg alloy produced
	Open (Baghouse)	TSP	0.24	kg/Mg alloy produced
	Covered (Scrubber: High energy)	TSP	0.8	kg/Mg alloy produced
FeMn (1% Si)	Covered (Uncontrolled)	TSP	6	kg/Mg alloy produced
	Covered (Scrubber: High energy)	TSP	0.25	kg/Mg alloy produced
	Sealed (Uncontrolled)	TSP	37	kg/Mg alloy produced
	Sealed (Controlled)	TSP	ND	kg/Mg alloy produced

Source: AP-42

Table 5.4-18 Emission factor for industrial process (metal production: ferroalloy production) (Part 3, AP-42)

Sub-category	Technical	Air pollutant	Emission factor	Unit
FeCr (high carbon)	Open (Uncontrolled)	TSP	78	kg/Mg alloy produced
	Open (ESP)	TSP	1.2	kg/Mg alloy produced
SiMn	Open (Uncontrolled)	TSP	96	kg/Mg alloy produced
	Open (Scrubber)	TSP	2.1	kg/Mg alloy produced
	Sealed (Uncontrolled)	TSP	-	kg/Mg alloy produced
	Sealed (Scrubber: High energy)	TSP	0.15	kg/Mg alloy produced

Source: AP-42

Table 5.4-19 Emission factor for industrial process (metal production: ferroalloy production) (Part 4, 2006 IPCC Guidelines)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Ferro-silicon	45% Si	CO_2	2.5	Tones/ton produced
	65% Si	CO_2	3.6	Tones/ton produced
	75% Si	CO_2	4.0	Tones/ton produced
	90% Si	CO_2	4.8	Tones/ton produced
Ferro-manganese	7% C	CO_2	1.3	Tones/ton produced
	1% C	CO_2	1.5	Tones/ton produced
Silicomanganese		CO_2	1.4	Tones/ton produced
Silicon metal		CO_2	5.0	Tones/ton produced
Ferrochromium	1.6 with sinter plant	CO_2	1.3	Tones/ton produced
Si-metal		CH_4	1.2	kg/ton produced
FeSi 90		CH_4	1.1	kg/ton produced
FeSi 75		CH_4	1.0	kg/ton produced
FeSi 65		CH_4	1.0	kg/ton produced

Source: 2006 IPCC Guidelines

Emission factors for aluminum production are shown in Table 5.4-20 and Table 5.4-21.

Table 5.4-20 Emission factor for industrial process (metal production: aluminum production)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Aluminum production	Electrolysis	NO_x	2.15	kg/Mg primary aluminum
		CO	135	kg/Mg primary aluminum
		SO_x	14.2	kg/Mg primary aluminum
	Anode baking	NO_x	NE	kg/Mg primary aluminum
		CO	400	kg/Mg primary aluminum
		SO_x	0.9	kg/Mg primary aluminum

Source: 1996 IPCC Guidelines

Table 5.4-21 Emission factor for industrial process (metal production: aluminum production)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Aluminum production	Primary aluminum production: Pre-baked anodes	NO_x	1	kg/Mg aluminum
		CO	120	kg/Mg aluminum
		SO_x	6	kg/Mg aluminum
		TSP	4	kg/Mg aluminum
		PM_{10}	3.2	kg/Mg aluminum produced
		$PM_{2.5}$	1.4	kg/Mg aluminum produced
	Primary aluminum production smelting: Soderberg anodes	NO_x	1	kg/Mg aluminum
		CO	122	kg/Mg aluminum
		SO_x	6	kg/Mg aluminum
		TSP	4	kg/Mg aluminum
		PM_{10}	3.2	kg/Mg aluminum produced
		$PM_{2.5}$	1.4	kg/Mg aluminum produced
	Secondary aluminum production smelting	TSP	2	kg/Mg aluminum
		PM_{10}	1.4	kg/Mg aluminum
		$PM_{2.5}$	0.55	kg/Mg aluminum

Source: EMEP/EEA Guidebook

Abatement efficiencies by antipollution measure technology for primary aluminum production are shown in Table 5.4-22 and Table 5.4-23.

Table 5.4-22 Abatement efficiencies for industrial process (metal production: aluminum production; pre-bake cell)

Sub-category	Technical	Abatement efficiency	Remarks
Multi-cyclone	particle > 10µm	79 %	
	10µm > particle > 2.5µm	76 %	
	Particle size <2.5µm	75 %	
Dry alumina scrubber fabric filter	particle > 10µm	98 %	
	10µm > particle > 2.5µm	96 %	
	Particle size <2.5µm	94 %	
ESP + spray tower	particle > 10µm	95 %	
	10µm > particle > 2.5µm	95 %	
	Particle size <2.5µm	96 %	
Coated fabric filter	particle > 10µm	98 %	
	10µm > particle > 2.5µm	96 %	
	Particle size <2.5µm	94 %	
Crossflow packed bed	particle > 10µm	72 %	
	10µm > particle > 2.5µm	68 %	
	Particle size <2.5µm	77 %	
Dry + secondary scrubber	particle > 10µm	99 %	
	10µm > particle > 2.5µm	98 %	
	Particle size <2.5µm	98 %	

Source: EMEP/EEA Guidebook

Table 5.4-23 Abatement efficiencies for industrial process (metal production: aluminum production; Soderberg cell)

Sub-category	Technical	Abatement efficiency	Remarks
Spray tower	particle > 10µm	78 %	
	10µm > particle > 2.5µm	74 %	
	2.5µm > particle	73 %	
Floating bed scrubber	particle > 10µm	80 %	
	10µm > particle > 2.5µm	77 %	
	2.5µm > particle	75 %	
Scrubber + wet ESP	particle > 10µm	98 %	
	10µm > particle > 2.5µm	96 %	
	Particle size <2.5µm	94 %	
Wet ESP	particle > 10µm	98 %	
	10µm > particle > 2.5µm	96 %	
	2.5µm > particle	94 %	
Dry alumina scrubber	particle > 10µm	98 %	
	10µm > particle > 2.5µm	98 %	
	2.5µm > particle	94 %	

Source: EMEP/EEA Guidebook

Abatement efficiencies by antipollution measure technology for secondary aluminum production are shown in Table 5.4-24.

Table 5.4-24 Abatement efficiencies for industrial process (metal production: secondary aluminum production)

Sub-category	Technical	Abatement efficiency	Remarks
Conventional Plant	Conventional: particle > 10μm	25 %	ESP, settles scrubbers; moderate control of fugitive sources
	Conventional: 10μm > particle > 2.5μm	14 %	
	Conventional: 2.5μm > particle	13 %	
Modern Plant	Modern: particle > 10μm	50 %	Fabric filters for most emission sources
	Modern: 10μm > particle > 2.5μm	36 %	
	Modern: 2.5μm > particle	26 %	

Source: EMEP/EEA Guidebook

In AP-42, emission factor for aluminum production is shown in Table 5.4-25 to Table 5.4-29, which are classified in detailed, based on antipollution technology. Emission factors in EMEP/EEA Guidebook are also compiled separately by abatement efficiency, based on antipollution technology, and there is no difference basically between the two. And out of the two emission factors, select one which is applicable.

Table 5.4-25 Emission factor for industrial process (metal production: primary aluminum production, Part 1)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Primary aluminum production (Bauxite grinding)	Uncontrolled	TSP	3.0 [c)]	kg/Mg [*)]
	Spray tower	TSP	0.9 [c)]	kg/Mg [*)]
	Floating bed scrubber	TSP	0.85 [c)]	kg/Mg [*)]
	Quench tower and spray screen	TSP	0.5 [c)]	kg/Mg [*)]
Primary aluminum production (Aluminum hydroxide calcining)	Uncontrolled	TSP	100.0 [c)]	kg/Mg [*)]
	Splay tower	TSP	30.0 [c)]	kg/Mg [*)]
	Floating bed scrubber	TSP	28.0 [c)]	kg/Mg [*)]
	Quench tower	TSP	17.0 [c)]	kg/Mg [*)]
	ESP	TSP	2.0 [c)]	kg/Mg [*)]

Note: [*)] Unit: kg /Mg of aluminum produced

Source: [c)] AP-42

Table 5.4-26 Emission factor for industrial process (metal production: primary aluminum production, Part 2)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Primary aluminum production (Anode baking furnace)	Uncontrolled	TSP	1.5 [c)]	kg/Mg [*)]
	Fugitive	TSP	ND [c)]	kg/Mg [*)]
	Spray tower	TSP	0.375 [c)]	kg/Mg [*)]
	ESP	TSP	0.375 [c)]	kg/Mg [*)]
	Dry alumina scrubber	TSP	0.03 [c)]	kg/Mg [*)]
Primary aluminum production (Prebake cell)	Uncontrolled	TSP	47.0 [c)]	kg/Mg [*)]
	Fugitive	TSP	2.5 [c)]	kg/Mg [*)]
	Emissions to collector	TSP	44.5 [c)]	kg/Mg [*)]
	Multiple cyclones	TSP	9.8 [c)]	kg/Mg [*)]
	Dry alumina scrubber	TSP	0.9 [c)]	kg/Mg [*)]
	Dry ESP plus spray tower	TSP	2.25 [c)]	kg/Mg [*)]
	Spray tower	TSP	56.4 [c)]	kg/Mg [*)]
	Floating bed scrubber	TSP	56.4 [c)]	kg/Mg [*)]
	Coated bag filter dry scrubber	TSP	0.9 [c)]	kg/Mg [*)]
	Crossflow packed bed	TSP	13.15 [c)]	kg/Mg [*)]
	Dry plus secondary scrubber	TSP	0.35 [c)]	kg/Mg [*)]

Note: [*)] Unit: kg /Mg of aluminum produced

Source: [c)] AP-42

Table 5.4-27 Emission factor for industrial process (metal production: primary aluminum production, Part 3)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Primary aluminum production (Vertical Soderberg stud cell)	Uncontrolled	TSP	39.0 [c)]	kg/Mg [*)]
	Fugitive	TSP	6.0 [c)]	kg/Mg [*)]
	Emissions to collector	TSP	33.0 [c)]	kg/Mg [*)]
	Spray tower	TSP	8.25 [c)]	kg/Mg [*)]
	Venturi scrubber	TSP	1.3 [c)]	kg/Mg [*)]
	Multiple cyclones	TSP	16.5 [c)]	kg/Mg [*)]
	Dry alumina scrubber	TSP	0.65 [c)]	kg/Mg [*)]
	Scrubber plus ESP plus spray screen and scrubber	TSP	3.85 [c)]	kg/Mg [*)]
Primary aluminum production (Horizontal Soderberg stud cell)	Uncontrolled	TSP	49.0 [c)]	kg/Mg [*)]
	Fugitive	TSP	5.0 [c)]	kg/Mg [*)]
	Emissions to collector	TSP	44.0 [c)]	kg/Mg [*)]
	Spray tower	TSP	11.0 [c)]	kg/Mg [*)]
	Floating bed scrubber	TSP	9.7 [c)]	kg/Mg [*)]
	Scrubber plus wet ESP	TSP	0.9 [c)]	kg/Mg [*)]
	Wet ESP	TSP	0.9 [c)]	kg/Mg [*)]
	Dry alumina scrubber	TSP	0.9 [c)]	kg/Mg [*)]

Note: [*)] Unit: kg /Mg of aluminum produced

Source: [c)] AP-42

CO_2 emission factor for primary aluminum production is shown in Table 5.4-28.

Table 5.4-28 Emission factor for industrial process (metal production: primary aluminum production, CO_2)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Aluminum production (primary refining)	Soderberg Process	CO_2	1835 [c)]	kg/ Mg Al produced
	Soderberg	CO_2	1.7 [a)]	tones CO_2/ ton Al
	Prebake Process	CO_2	1540 [c)]	kg/ Mg Al produced
	Prebake	CO_2	1.6 [a)]	tones CO_2/ ton Al
	Electrolysis	SO_2	14.2 [d)]	kg SO_2/ ton Al
	Anode baking	SO_2	14.2 [d)]	kg SO_2/ ton Al
	Electrolysis	NO_x	2.15 [d)]	kg NO_x/ ton Al
	Anode baking	NO_x	NE [d)]	kg NO_x / ton Al
	Electrolysis	CO	135 [d)]	kg CO/ ton Al
	Anode baking	CO	400 [d)]	kg CO/ ton Al

Source: [a)] 2006 IPCC Guidelines, [c)] AP-42,

Table 5.4-29 Emission factor for industrial process (metal production: secondary aluminum production)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Secondary aluminum production (Sweating furnace)	Uncontrolled	TSP	7.25 [c)]	kg/Mg [*)]
	Baghouse	TSP	1.65 [c)]	kg/Mg [*)]
	Electrostatic Precipitator	TSP	ND [c)]	kg/Mg [*)]
Secondary aluminum production (Smelting) (Crucible furnace)	Uncontrolled	TSP	0.95 [c)]	kg/Mg [*)]
	Baghouse	TSP	ND [c)]	kg/Mg [*)]
	Electrostatic Precipitator	TSP	ND [c)]	kg/Mg [*)]
Secondary aluminum production (Smelting) (Reverberatory)	Uncontrolled	TSP	2.15 [c)]	kg/Mg [*)]
	Baghouse	TSP	0.65 [c)]	kg/Mg [*)]
	Electrostatic Precipitator	TSP	0.65 [c)]	kg/Mg [*)]
Secondary aluminum production (Chlorine demagging)	Uncontrolled	TSP	500 [c)]	kg/Mg [*)]
	Baghouse	TSP	25 [c)]	kg/Mg [*)]
	Electrostatic Precipitator	TSP	ND [c)]	kg/Mg [*)]

Note: [*)] Unit: kg /Mg of metal processed

Source: [c)] AP-42

Emission factors for copper smelting are shown in Table 5.4-30, which can be different, depending on whether it is primary or secondary copper smelting process.

Table 5.4-30 Emission factor for industrial process (metal production: copper smelting)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Copper smelting	Default value	TSP	400	g/Mg copper
		PM_{10}	320	g/Mg copper
		$PM_{2.5}$	240	g/Mg copper
	Primary copper smelting	TSP	400	g/Mg copper
		PM_{10}	320	g/Mg copper
		$PM_{2.5}$	240	g/Mg copper
	Primary copper smelting (EECCA countries, traditional method: ESP, limited control (98%))	TSP	45	kg/Mg copper
		PM_{10}	36	kg/Mg copper
		$PM_{2.5}$	27	kg/Mg copper
	Primary copper smelting (EECCA countries, traditional method: ESP, abatement efficiency (99% or higher))	TSP	5	kg/Mg copper
		PM_{10}	4	kg/Mg copper
		$PM_{2.5}$	3	kg/Mg copper
	Secondary copper smelting	TSP	320	g/Mg copper
		PM_{10}	260	g/Mg copper
		$PM_{2.5}$	190	g/Mg copper
	Secondary copper smelting (EECCA countries, traditional method: ESP, limited control	TSP	1.5	kg/Mg copper
		PM_{10}	1.2	kg/Mg copper
		$PM_{2.5}$	0.9	kg/Mg copper

Source: EMEP/EEA Guidebook

Abatement efficiencies by antipollution measure technology for copper smelting are shown in Table 5.4-31.

Table 5.4-31 Abatement efficiencies for industrial process (metal production: copper smelting)

Sub-category	Technical	Abatement efficiency	Remarks
Conventional Plant	Conventional: particle > 10µm	88 %	ESP and settling chambers; moderate control of fugitive sources
	Conventional: 10µm > particle > 2.5µm	68 %	
	Conventional: 2.5µm > particle	28 %	
Modern Plant	Modern: particle > 10µm	95 %	Fabric filters for most emission sources
	Modern: 10µm > particle > 2.5µm	84 %	
	Modern: 2.5µm > particle	60 %	

Source: EMEP/EEA Guidebook

Emission factors for copper smelting are shown in Table 5.4-32 to Table 5.4-37.

Table 5.4-32 Emission factor for industrial process (metal production: primary copper smelting, Part 1)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Primary copper smelting	RF: Reverberatory furnace (RF) followed by converter (C)	SO_x	160 [c)]	kg/Mg [*)]
		TSP	25 [c)]	kg/Mg [*)]
	C: Reverberatory furnace (RF) followed by converter (C)	SO_x	370 [c)]	kg/Mg [*)]
		TSP	18 [c)]	kg/Mg [*)]
Primary copper smelting	MHR: Multiple hearth roaster (MHR) followed by reverberatory furnace (RF) and converter (C)	SO_x	140 [c)]	kg/Mg [*)]
		TSP	22 [c)]	kg/Mg [*)]
	RF: Multiple health roaster (MHR) followed by reverberatory furnace (RF) and converter (C)	SO_x	90 [c)]	kg/Mg [*)]
		TSP	25 [c)]	kg/Mg [*)]
	C: Multiple health roaster (MHR) followed by reverberatory furnace (RF) and converter (C)	SO_x	300 [c)]	kg/Mg [*)]
		TSP	18 [c)]	kg/Mg [*)]

Note: [*)] Unit: kg of pollutant/Mg of concentrated ore processed by the smelter

Source: [c)] AP-42

Table 5.4-33 Emission factor for industrial process (metal production: primary copper smelting, Part 2)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Primary copper smelting	FBR: Fluid bed roaster (FBR) followed by reverberatory furnace (RF) and converter (C)	SO_x	180 [c)]	kg/Mg [*)]
		TSP	ND [c)]	kg/Mg [*)]
	RF: Fluid bed roaster (FBR) followed by reverberatory furnace (RF) and converter (C)	SO_x	90 [c)]	kg/Mg [*)]
		TSP	25 [c)]	kg/Mg [*)]
	C: Fluid bed roaster (FBR) followed by reverberatory furnace (RF) and converter (C)	SO_x	270 [c)]	kg/Mg [*)]
		TSP	18 [c)]	kg/Mg [*)]
Primary copper smelting	CD: Concentrate dryer (CD) followed by electric furnace (EF) and converter (C)	SO_x	0.5 [c)]	kg/Mg [*)]
		TSP	5 [c)]	kg/Mg [*)]
	EF: Concentrate dryer (CD) followed by electric furnace (EF) and converter (C)	SO_x	120 [c)]	kg/Mg [*)]
		TSP	50 [c)]	kg/Mg [*)]
	C: Concentrate dryer (CD) followed by electric furnace (EF) and converter (C)	SO_x	410 [c)]	kg/Mg [*)]
		TSP	18 [c)]	kg/Mg [*)]
Primary copper smelting	FBR: Fluid bed roaster (FBR) followed by electric furnace (EF) and converter (C)	SO_x	180 [c)]	kg/Mg [*)]
		TSP	ND [c)]	kg/Mg [*)]
	EF: Fluid bed roaster (FBR) followed by electric furnace (EF) and converter (C)	SO_x	45 [c)]	kg/Mg [*)]
		TSP	50 [c)]	kg/Mg [*)]
	C: Fluid bed roaster (FBR) followed by electric furnace (EF) and converter (C)	SO_x	300 [c)]	kg/Mg [*)]
		TSP	18 [c)]	kg/Mg [*)]

Note: [*)] Unit: kg of pollutant/Mg of concentrated ore processed by the smelter

Source: [c)] AP-42

Table 5.4-34 Emission factor for industrial process (metal production: primary copper smelting, Part 3)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Primary copper smelting	CD: Concentrate dryer (CD) followed by flash furnace (FF), cleaning furnace (SS) and converter (C)	SO_x	0.5 [c)]	kg/Mg [*)]
		TSP	5 [c)]	kg/Mg [*)]
	FF: Concentrate dryer (CD) followed by flash furnace (FF), cleaning furnace (SS) and converter (C)	SO_x	410 [c)]	kg/Mg [*)]
		TSP	70 [c)]	kg/Mg [*)]
	SS: Concentrate dryer (CD) followed by flash furnace (FF), cleaning furnace (SS) and converter (C)	SO_x	0.5 [c)]	kg/Mg [*)]
		TSP	5 [c)]	kg/Mg [*)]
	C: Concentrate dryer (CD) followed by flash furnace (FF), cleaning furnace (SS) and converter (C)	SO_x	120 [c)]	kg/Mg [*)]
		TSP	ND [c)]	kg/Mg [*)]
Primary copper smelting	CD: Concentrate dryer (CD) followed by Noranda reactors (NR) and converter (C)	SO_x	0.5 [c)]	kg/Mg [*)]
		TSP	5 [c)]	kg/Mg [*)]
	NR: Concentrate dryer (CD) followed by Noranda reactors (NR) and converter (C)	SO_x	ND [c)]	kg/Mg [*)]
		TSP	ND [c)]	kg/Mg [*)]
	C: Concentrate dryer (CD) followed by Noranda reactors (NR) and converter (C)	SO_x	ND [c)]	kg/Mg [*)]
		TSP	ND [c)]	kg/Mg [*)]

Note: [*)] Unit: kg of pollutant/Mg of concentrated ore processed by the smelter

Source: [c)] AP-42

Abatement efficiencies are published as follows. Overall particulate removal in Hot ESPs may range 20 to 80% and in cold ESP may be 99%. Typical Single Contact Acid Plants (SCAP) are about 96% efficient and Double Contact Acid Plants (DCAP) are up to 99.8% efficient in SO_2 removal.

Table 5.4-35 Emission factor for industrial process (metal production: secondary copper smelting, Part 1)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Secondary copper smelting (Cupola)	Scrap iron	TSP	0.002 [c)]	kg/Mg [*)]
		PM_{10}	ND [c)]	kg/Mg [*)]
	Insulated copper wire (Control Equipment; None)	TSP	120 [c)]	kg/Mg [*)]
		PM_{10}	105.6 [c)]	kg/Mg [*)]
	Insulated copper wire (Control Equipment; ESP)	TSP	5 [c)]	kg/Mg [*)]
		PM_{10}	ND [c)]	kg/Mg [*)]
	Scrap copper and brass (Control Equipment; None)	TSP	35 [c)]	kg/Mg [*)]
		PM_{10}	32.1 [c)]	kg/Mg [*)]
	Scrap copper and brass (Control Equipment; ESP)	TSP	1.2 [c)]	kg/Mg [*)]
		PM_{10}	ND [c)]	kg/Mg [*)]
Secondary copper smelting (Fugitive emissions)	(Control Equipment; None)	TSP	ND [c)]	kg/Mg [*)]
		PM_{10}	1.1 [c)]	kg/Mg [*)]

Note: [*)] Unit: kg of pollutant/Mg ore processed

Source: [c)] AP-42

Table 5.4-36 Emission factor for industrial process (metal production: secondary copper smelting, Part 2)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Secondary copper smelting (Reverberatory furnace)	Copper (Control Equipment; None)	TSP	2.6 c)	kg/Mg *)
		PM_{10}	2.5 c)	kg/Mg *)
	Copper (Control Equipment; Baghouse)	TSP	0.2 c)	kg/Mg *)
		PM_{10}	ND c)	kg/Mg *)
	Brass and bronze (Control Equipment; None)	TSP	18 c)	kg/Mg *)
		PM_{10}	10.8 c)	kg/Mg *)
	Brass and bronze (Control Equipment; Baghouse)	TSP	1.3 c)	kg/Mg *)
		PM_{10}	ND c)	kg/Mg *)
	Fugitive emissions (Control Equipment; None)	TSP	ND c)	kg/Mg *)
		PM_{10}	1.5 c)	kg/Mg *)
Secondary copper smelting (Rotary furnace)	Brass and bronze (Control Equipment; None)	TSP	150 c)	kg/Mg *)
		PM_{10}	88.3 c)	kg/Mg *)
	Brass and bronze (Control Equipment; ESP)	TSP	7 c)	kg/Mg *)
		PM_{10}	ND c)	kg/Mg *)
	Fugitive emissions (Control Equipment; None)	TSP	ND c)	kg/Mg *)
		PM_{10}	1.3 c)	kg/Mg *)

Note: *) Unit: kg of pollutant/Mg ore processed

Source: c) AP-42

Table 5.4-37 Emission factor for industrial process (metal production: secondary copper smelting, Part 3)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Secondary copper smelting (Crucible and pot furnace)	Brass and bronze (Control Equipment; None)	TSP	11 [c]	kg/Mg [*]
		PM_{10}	6.2 [c]	kg/Mg [*]
	Brass and bronze (Control Equipment; ESP)	TSP	0.5 [c]	kg/Mg [*]
		PM_{10}	ND [c]	kg/Mg [*]
	Fugitive emissions (Control Equipment; None)	TSP	ND [c]	kg/Mg [*]
		PM_{10}	0.14 [c]	kg/Mg [*]
Secondary copper smelting (Electric furnace)	Copper (Control Equipment; None)	TSP	2.5 [c]	kg/Mg [*]
		PM_{10}	2.5 [c]	kg/Mg [*]
	Copper (Control Equipment; Baghouse)	TSP	0.5 [c]	kg/Mg [*]
		PM_{10}	ND [c]	kg/Mg [*]
	Brass and bronze (Control Equipment; None)	TSP	5.5 [c]	kg/Mg [*]
		PM_{10}	3.2 [c]	kg/Mg [*]
	Brass and bronze (Control Equipment; Baghouse)	TSP	3 [c]	kg/Mg [*]
		PM_{10}	ND [c]	kg/Mg [*]
Secondary copper smelting (Electric induction)	Copper (Control Equipment; None)	TSP	3.5 [c]	kg/Mg [*]
		PM_{10}	3.5 [c]	kg/Mg [*]
	Copper (Control Equipment; Baghouse)	TSP	0.25 [c]	kg/Mg [*]
		PM_{10}	ND [c]	kg/Mg [*]
	Brass and bronze (Control Equipment; None)	TSP	10 [c]	kg/Mg [*]
		PM_{10}	10 [c]	kg/Mg [*]
	Brass and bronze (Control Equipment; Baghouse)	TSP	0.35 [c]	kg/Mg [*]
		PM_{10}	ND [c]	kg/Mg [*]
	Fugitive emissions (Control Equipment; None)	TSP	ND [c]	kg/Mg [*]
		PM_{10}	0.04 [c]	kg/Mg [*]

Note: [*] Unit: kg of pollutant/Mg ore processed

Source: [c] AP-42

Emission factors for lead smelting are a shown in Table 5.4-38 to Table 5.4-41.

Table 5.4-38 Emission factor for industrial process (metal production: primary lead smelting)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Primary lead smelting	Ore crushing	SO_x	NA [c)]	kg/Mg of lead in ore
		TSP	0.023 [c)]	kg/Mg of lead in ore
		PM_{10}	0.018 [c)]	kg/Mg of lead in ore
	Ore screening	SO_x	NA [c)]	kg/Mg ore
		TSP	0.004 [c)]	kg/Mg ore
		PM_{10}	0.005 [c)]	kg/Mg ore
	Tetrahedrite drier	SO_x	NA [c)]	kg/Mg dried
		TSP	0.012 [c)]	kg/Mg dried
		PM_{10}	0.013 [c)]	kg/Mg dried
	Sinter machine (weak gas)	SO_x	275 [c)]	kg/Mg sinter produced
		TSP	0.051 [c)]	kg/Mg sinter produced
		PM_{10}	0.052 [c)]	kg/Mg sinter produced
	Sinter building fugitives	SO_x	NA [c)]	kg/Mg sinter produced
		TSP	0.118 [c)]	kg/Mg sinter produced
		PM_{10}	0.058 [c)]	kg/Mg sinter produced
	Sinter storage	SO_x	NA [c)]	kg/Mg through put
		TSP	NA [c)]	kg/Mg through put
		PM_{10}	NA [c)]	kg/Mg through put
	Blast furnace	SO_x	23 [c)]	kg/Mg of bullion
		TSP	0.21 [c)]	kg/Mg of bullion
		PM_{10}	0.43 [c)]	kg/Mg of bullion
	Speiss pit	SO_x	NA [c)]	kg/Mg granulated
		TSP	NA [c)]	kg/Mg granulated
		PM_{10}	NA [c)]	kg/Mg granulated

Source: [c)] AP-42

Table 5.4-39 Emission factor for industrial process (metal production: secondary lead smelting)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Secondary lead smelting	Sweating (Uncontrolled)	SO_x	ND [c)]	kg/Mg charge
		TSP	16-35 [c)]	kg/Mg charge
	Sweating (Controlled)	SO_x	-	kg/Mg charge
		TSP	ND [c)]	kg/Mg charge
	Reverberatory smelting (Uncontrolled)	SO_x	40 [c)]	kg of pollutant/Mg metal produced
		TSP	162 [c)]	kg of pollutant/Mg metal produced
	Reverberatory smelting (Controlled)	SO_x	-	kg of pollutant/Mg metal produced
		TSP	0.50 [c)]	kg of pollutant/Mg metal produced
	Blast smelting-cupola (Uncontrolled)	SO_x	27 [c)]	kg of pollutant/Mg metal produced
		TSP	153 [c)]	kg of pollutant/Mg metal produced
	Blast smelting-cupola (Controlled)	SO_x	-	kg of pollutant/Mg metal produced
		TSP	1.12 [c)]	kg of pollutant/Mg metal produced
	Kettle refining (Uncontrolled)	SO_x	ND [c)]	kg of pollutant/Mg metal produced
		TSP	0.02 [c)]	kg of pollutant/Mg metal produced
	Kettle refining (Controlled)	SO_x	-	kg of pollutant/Mg metal produced
		TSP	ND [c)]	kg of pollutant/Mg metal produced
	Kettle Oxidation (Uncontrolled)	SO_x	ND [c)]	kg of pollutant/Mg metal produced
		TSP	<=20 [c)]	kg of pollutant/Mg metal produced
	Kettle Oxidation (Controlled)	SO_x	-	kg of pollutant/Mg metal produced
		TSP	ND [c)]	kg of pollutant/Mg metal produced
	Casting (Uncontrolled)	SO_x	ND [c)]	kg of pollutant/Mg metal produced
		TSP	0.02 [c)]	kg of pollutant/Mg metal produced
	Casting (Controlled)	SO_x	-	kg of pollutant/Mg metal produced
		TSP	ND [c)]	kg of pollutant/Mg metal produced

Source: [c)] AP-42

Table 5.4-40 Emission factor for industrial process (metal production: primary lead smelting: default value)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Lead smelting	Default value	TSP	500	g/Mg lead
		PM_{10}	400	g/Mg lead
		$PM_{2.5}$	200	g/Mg lead
	Primary lead smelting	TSP	500	g/Mg lead
		PM_{10}	400	g/Mg lead
		$PM_{2.5}$	200	g/Mg lead
	Primary lead smelting (controlled after various technical measures taken)	TSP	29	g/Mg lead
		PM_{10}	28	g/Mg lead
		$PM_{2.5}$	20	g/Mg lead
	Primary lead smelting (EECCA countries, limited control)	TSP	2.5	kg/Mg lead
		PM_{10}	2	kg/Mg lead
		$PM_{2.5}$	1.6	kg/Mg lead
	Primary lead smelting (EECCA countries, high effective control)	TSP	0.5	kg/Mg lead
		PM_{10}	0.4	kg/Mg lead
		$PM_{2.5}$	0.3	kg/Mg lead

Source: EMEP/EEA Guidebook

Table 5.4-41 Emission factor for industrial process (metal production: secondary lead smelting)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Lead smelting	Secondary lead smelting	TSP	500	g/Mg lead
		PM_{10}	400	g/Mg lead
		$PM_{2.5}$	200	g/Mg lead
	Secondary lead smelting (controlled after various technical measures taken)	TSP	29	g/Mg lead
		PM_{10}	28	g/Mg lead
		$PM_{2.5}$	20	g/Mg lead
	Secondary lead smelting (EECCA countries, limited control)	TSP	1.5	kg/Mg lead
		PM_{10}	1.2	kg/Mg lead
		$PM_{2.5}$	1	kg/Mg lead

Source: EMEP/EEA Guidebook

Abatement efficiencies by antipollution measure for lead smelting are shown in Table 5.4-42.

Table 5.4-42 Abatement efficiencies for industrial process (metal production: lead smelting)

Sub-category	Technical	Abatement efficiency	Remarks
Conventional Plant	Conventional: particle > 10μm	95.0 %	Electro-static precipitator, scrubber, sinking device, scrubber, intermediate control against leaks
	Conventional: 10μm > particle > 2.5μm	86.7 %	
	Conventional: Particle size <2.5μm	66.7 %	
Modern Plant	Modern: particle > 10μm	98.8 %	Use of fiber filter against most sources
	Modern: 10μm > particle > 2.5μm	96.2 %	
	Modern: 2.5μm > particle	90.0 %	

Source: EMEP/EEA Guidebook

Emission factor for nickel production is shown in Table 5.4-43.

Table 5.4-43 Emission factor for industrial process (metal production: nickel production)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Nickel production	Secondary production	TSP	0.66	kg/Mg nickel produced

Source: EMEP/EEA Guidebook

Emission factors for zinc smelting are shown in Table 5.4-44 and Table 5.4-45.

Table 5.4-44 Emission factor for industrial process (metal production: primary zinc smelting: default value)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Zinc smelting	Default value	TSP	500	g/Mg zinc
		PM_{10}	400	g/Mg zinc
		$PM_{2.5}$	300	g/Mg zinc
	Primary zinc smelting	TSP	500	g/Mg zinc
		PM_{10}	400	g/Mg zinc
		$PM_{2.5}$	300	g/Mg zinc
	Primary zinc smelting (controlled after various technical measures taken)	TSP	39	g/Mg zinc
		PM_{10}	30	g/Mg zinc
		$PM_{2.5}$	22	g/Mg zinc
	Primary zinc smelting (EECCA countries, limited control)	TSP	5	kg/Mg zinc
		PM_{10}	4	kg/Mg zinc
		$PM_{2.5}$	3	kg/Mg zinc
	Primary zinc smelting (EECCA countries, high effective control)	TSP	1.5	kg/Mg zinc
		PM_{10}	1.2	kg/Mg zinc
		$PM_{2.5}$	0.9	kg/Mg zinc

Source: EMEP/EEA Guidebook

Table 5.4-45 Emission factor for industrial process (metal production: secondary zinc smelting)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Zinc smelting	Secondary zinc smelting	TSP	500	g/Mg zinc
		PM_{10}	400	g/Mg zinc
		$PM_{2.5}$	300	g/Mg zinc
	Secondary zinc smelting (Best available techniques, fabric filter)	TSP	39	g/Mg zinc
		PM_{10}	30	g/Mg lead
		$PM_{2.5}$	22	g/Mg lead
	Secondary zinc smelting (dry ESP)	TSP	19	kg/Mg lead
		PM_{10}	16	kg/Mg lead
		$PM_{2.5}$	12	kg/Mg lead

Source: EMEP/EEA Guidebook

Abatement efficiencies by antipollution measurement for zinc smelting are shown in Table 5.4-46.

Table 5.4-46 Abatement efficiencies for industrial process (metal production: zinc smelting)

Sub-category	Technical	Abatement efficiency	Remarks
Conventional Plant	Conventional: particle > 10µm	91.7 %	ESP, settlers, scrubbers; moderate control of fugitive sources
	Conventional: 10µm > particle > 2.5µm	92.0 %	
	Conventional: 2.5µm > particle	92.5 %	
Modern Plant	Modern: particle > 10µm	96.7 %	Fabric filters for most emission sources
	Modern: 10µm > particle > 2.5µm	96.4 %	
	Modern: 2.5µm > particle	96.0 %	

Source: EMEP/EEA Guidebook

In US-EPA AP-42, Emission factors for zinc smelting are shown in Table 5.4-47 to Table 5.4-49, which mainly comes from blende, and sulfur oxide is produced in smelting process, but it is used producing sulfuric acid, so discharge to the air is little.

Table 5.4-47 Emission factor for industrial process (metal production: primary zinc smelting)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Primary zinc smelting	Roasting; Multiple hearth (Uncontrolled)	TSP	113	kg/Mg *)
	Roasting; Suspension (Uncontrolled)	TSP	1000	kg/Mg *)
	Roasting; Suspension (Controlled)	TSP	4	kg/Mg *)
	Roasting; Fluidized bed (Uncontrolled)	TSP	1083	kg/Mg *)
	Sinter plant (Uncontrolled)	TSP	62.5	kg/Mg *)
	Sinter plant (With cyclone)	TSP	24.1	kg/Mg *)
	Sinter plant (With cyclone and ESP)	TSP	8.25	kg/Mg *)
	Vertical retort (Uncontrolled)	TSP	7.15	kg/Mg *)
	Electric retort (Uncontrolled)	TSP	10.0	kg/Mg *)
	Electric process (Uncontrolled)	TSP	3.3	kg/Mg *)

Note: *) Unit: kg /Mg of zinc ore processed

Source: AP-42

Table 5.4-48 Emission factor for industrial process (metal production: secondary zinc smelting, Part 1)

Sub-category	Technical	Air pollutant	Emission factor*	Unit
Secondary zinc smelting	Reverbetatory sweating (Clean metallic scarp)	TSP	Negligible	kg/Mg $^{*)}$
	Reverbetatory sweating (General metallic scarp)	TSP	6.5	kg/Mg $^{*)}$
	Reverbetatory sweating (Residual scarp)	TSP	16	kg/Mg $^{*)}$
	Rotary sweating	TSP	5.5-12.5	kg/Mg $^{*)}$
	Muffle sweating	TSP	5.4-16	kg/Mg $^{*)}$
	Kettle sweating (Clean metallic scrap)	TSP	Negligible	kg/Mg $^{*)}$
	Kettle sweating (General metallic scrap)	TSP	5.5	kg/Mg $^{*)}$
	Kettle sweating (Residual scrap)	TSP	12.5	kg/Mg $^{*)}$
	Electric resistance sweating	TSP	< 5	kg/Mg $^{*)}$
	Sodium carbonate leaching calcining	TSP	44.5	kg/Mg $^{*)}$
	Kettle pot (Unit: g/Mg product)	TSP	0.05	kg/Mg
	Crucible melting	TSP	ND	kg/Mg $^{*)}$
	Reverberatory melting	TSP	ND	kg/Mg $^{*)}$
	Electric induction melting	TSP	ND	kg/Mg $^{*)}$
	Alloying	TSP	ND	kg/Mg $^{*)}$

Note: $^{*)}$ Unit: kg /Mg of zinc used

Source: AP-42

Table 5.4-49 Emission factor for industrial process (metal production: secondary zinc smelting, Part 2)

Sub-category	Technical	Air pollutant	Emission factor*	Unit
Secondary zinc smelting	Retort and muffle distillation (Unit: kg/Mg product) (Pouring)	TSP	0.2 - 0.4	kg/Mg
	Retort and muffle distillation (Unit: kg/Mg product) (Casting)	TSP	0.1 - 0.2	kg/Mg
	Retort and muffle distillation (Unit: kg/Mg product) (Muffle distillation)	TSP	22.5	kg/Mg
	Graphite rod distillation	TSP	Negligible	kg/Mg *)
	Retort distillation/ oxidation	TSP	10 - 20	kg/Mg *)
	Muffle distillation/ oxidation	TSP	10 - 20	kg/Mg *)
	Retort reduction	TSP	23.5	kg/Mg *)
	Galvanizing	TSP	2.5	kg/Mg *)

Note: *) Unit: kg /Mg of zinc used

Source: AP-42

Emission factor for other metal production is shown in Table 5.4-50.

Table 5.4-50 Emission factor for industrial process (metal production: other metal production)

Sub-category	Air pollutant	Emission factor	Unit
Other metal production	TSP	0.8	kg/Mg metal produced

Source: EMEP/EEA Guidebook

Emission factor for storage, handling and transport of metal products is shown in Table 5.4-51.

Table 5.4-51 Emission factor for industrial process (metal production: metal storage, handling, transport)

Sub-category	Air pollutant	Emission factor	Unit
Storage, handling and transport of metal products	TSP	1	kg/Mg metal products

Source: EMEP/EEA Guidebook

5.4.2.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

5.5 Other product manufacturing

5.5.1 Simple method

5.5.1.1 Outline of emission estimation method

Estimation of emission is basically multiplied activity data and emission factor. Active data generally mean the production rate of product in each industrial process, and their statistics data by national or by provincial level are assumed .

5.5.1.2 Estimation of activity data

Active data is basically the production amount of each industrial product. Activity data is assumed to be statistics of each country, these values are priority use. The active data not to be acquired from statistics of each country is assumed to be used following international statistics data.

1) Industrial Commodity Statistics Yearbook
2) FAOSTAT: Collection from http://faostat.fao.org/

Activity data related air pollutants emission from drinks and foods industry is shown in Table 5.5-2.

Table 5.5-1 Activity data for industrial process (paper, pulp industries)

Sub-category	Activity Data	Activity data source	Remarks
Paper, pulp industry			
Kraft paper or alkali-soda pulp manufacturing	Dry pulp amount	Statistics of each country, UN statistics	
Sulfur acid pulp manufacturing	Dry pulp amount	Statistics of each country, UN statistics	
Neutral sulfur acid semi-chemical pulp	Pulp production amount	Statistics of each country, UN statistics	

Table 5.5-2 Activity data for industrial process (drinks, food industries)

Sub-category	Activity data	Activity data source	Remarks
Alcoholic drinks, beverage			
Beer	Production amount	Statistics of each country, UN statistics	
Red wine	Production amount	Statistics of each country, UN statistics	
White wine	Production amount	Statistics of each country, UN statistics	
Wine (unspecified)	Production amount	Statistics of each country, UN statistics	
Malt Whisky	Production amount	Statistics of each country, UN statistics	
Grain Whisky	Production amount	Statistics of each country, UN statistics	
Brandy	Production amount	Statistics of each country, UN statistics	
Other spirit (unspecified)	Production amount	Statistics of each country, UN statistics	
Foods production			
Meat, fish, chicken meat	Production amount	Statistics of each country, UN statistics	
Sugar	Production amount	Statistics of each country, UN statistics	
Margarine, solid edible fat	Production amount	Statistics of each country, UN statistics	
Cakes, biscuits, cereals	Production amount	Statistics of each country, UN statistics	
Bread	Production amount	Statistics of each country, UN statistics	
Animal feeds	Production amount	Statistics of each country, UN statistics	
Brewing coffee	Production amount	Statistics of each country, UN statistics	

5.5.1.3 Setting of emission factors

Emission factors are used values from Table 5.5-3 to Table 5.5-5 to be arranged by GAP Forum Manual values. However, it is necessary to note that these emission factors are set using single value of industrial process that technically contains a wide range of values. If emission factors can be set in accordance with the features of the country, they should be used preferentially. In “5.5.2.3 Setting of emission factor” for “5.5.2 Detailed method” shows more detailed technical emission factor, and if the emission factors to be used preferentially for target country exist, they should be used.

Table 5.5-3 Emission factors for industrial process (pulp, paper industries) (GAP Forum Manual-based value)

Sub-category	単位	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Paper, pulp industry														
Kraft paper or alkali-soda pulp manufacturing	kg/ton dried pulp	3.8[b)]	1.5[b)]	5.6[b)]	3.7[b)]	NA[b)]		92[b)]	81[b)]					
Sulfurous acid pulp manufacturing	kg/ton dried pulp	30[b)]	NA[b)]	NA[b)]	NA[b)]	NA[b)]		1.5[b)]	1.3[b)]					
Neutral sulfurous acid chemical pulp	kg/ton output	-[b)]	0.5[b)]	NA[b)]	0.15[b)]	NA[b)]		-[b)]	-[b)]					

Source: [a)] 2006 IPCC Guidelines, [b)] GAP Forum Manual, [c)] AP-42

Note: NA: “Not applicable”, -: “Not available”

Table 5.5-4 Emission factors for industrial process (drinks industry) (GAP Forum Manual-based value)

Sub-category	Unit	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Alcoholic drinks, beverage														
Beer	kg/hectolitre	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	0.035$^{b)}$	NA$^{b)}$		-$^{b)}$	-$^{b)}$					
Red wine	kg/hectolitre	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	0.08$^{b)}$	NA$^{b)}$		-$^{b)}$	-$^{b)}$					
White wine	kg/hectolitre	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	0.035$^{b)}$	NA$^{b)}$		-$^{b)}$	-$^{b)}$					
Wine (unspecified)	kg/hectolitre	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	0.08$^{b)}$	NA$^{b)}$		-$^{b)}$	-$^{b)}$					
Malt Whisky	kg/hectolitre	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	15$^{b)}$	NA$^{b)}$		-$^{b)}$	-$^{b)}$					
Cereal Whisky	kg/hectolitre	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	7.5$^{b)}$	NA$^{b)}$		-$^{b)}$	-$^{b)}$					
Brandy	kg/hectolitre	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	3.5$^{b)}$	NA$^{b)}$		-$^{b)}$	-$^{b)}$					
Other spirit (unspecified)	kg/hectolitre	NA$^{b)}$	NA$^{b)}$	NA$^{b)}$	15$^{b)}$	NA$^{b)}$		-$^{b)}$	-$^{b)}$					

Source: $^{a)}$ 2006 IPCC Guidelines, $^{b)}$ GAP Forum Manual, $^{c)}$ AP-42

Note: NA: “Not applicable”, -: “Not available”

Table 5.5-5 Emission factors for industrial process (foods industry) (GAP Forum Manual-based value)

Sub-category	単位	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Foods production														
Meat, fish, chicken meat	kg/ton	NA[b)]	NA[b)]	NA[b)]	0.3[b)]	NA[b)]		-[b)]	-[b)]					
Sugar	kg/ton	NA[b)]	NA[b)]	NA[b)]	10[b)]	NA[b)]		-[b)]	-[b)]					
Margarine, solid edible fat	kg/ton	NA[b)]	NA[b)]	NA[b)]	10[b)]	NA[b)]		-[b)]	-[b)]					
Cakes, biscuits, cereals	kg/ton	NA[b)]	NA[b)]	NA[b)]	1[b)]	NA[b)]		-[b)]	-[b)]					
Bread	kg/ton	NA[b)]	NA[b)]	NA[b)]	4.5[b)]	NA[b)]		-[b)]	-[b)]					
Animal feeds	kg/ton	NA[b)]	NA[b)]	NA[b)]	1[b)]	NA[b)]		-[b)]	-[b)]					
Brewing coffee	kg/ton	NA[b)]	NA[b)]	NA[b)]	0.55[b)]	NA[b)]		-[b)]	-[b)]					

Source: [a)] 2006 IPCC Guidelines, [b)] GAP Forum Manual, [c)] AP-42

Note: NA: “Not applicable”, -: “Not available”

5.5.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

5.5.2 Detailed method

5.5.2.1 Outline of emission estimation method

Estimation method of emission is basically the same as “5.5.1 Simple method”, namely emission is estimated by multiplying activity data and emission factors. Activity data generally means the production amount of each industrial process, and their statistics data is assumed by national or by provincial level. The emission factors are the emission per unit of production amount, and compare with emission factor for “5.5.1 Simple method”, the emission factors are more technically detailed.

$$\text{Emissions} = \text{AD} \times \text{EF} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (5.5\text{-}1)$$

Where,

Emissions: Emission of air pollutant and greenhouse gas

AD: Activity data related industrial process (industrial product production amount)

EF: Emission factor related industrial process

The detailed information on the emission can be obtained through questionnaire survey and interview (“questionnaire survey”) for factories and workplaces. The questionnaire survey is basically assumed to be the same as the survey of large scale factory ”3 Estimation of air pollutants emission related fuel combustion”, factory position, production amount, pollution control facility which is by the questionnaire survey. Furthermore, the emission factor and data of emission of air pollutants are acquired preferably.

The contents to be acquired by implementation of questionnaire survey and interview survey for each plant is shown in Table 5.5-6, the survey form is based on questionnaire of large scale plant in “3 Fuel consumption air pollutant emission”.

Table 5.5-6 Contents to be necessarily collected for emission estimation

Survey item	Survey content
Plant basic information	Product items, number of employee, plant address, plant plan drawing, chimney position and height
Product manufacturing information	Annual fuel consumption rate, annual raw material consumption rate, annual production rate Production rate of the year, month Fuel condition (calorific value, sulfur content, ash content, nitrogen content, etc)
Pollution control measures	Introduction condition of pollution control measures
Others	Measurement results of emission of air pollutants, emission factor condition (if any), other information to be necessary

However, among activity data in industrial process of whole country, the activity data not to be estimated by “5.5.2 Detailed method” is estimated as area source by “5.5.1 Simple method”

5.5.2.2 Estimation of activity data

Activity data related to air pollutants emission from other product manufacturing is shown in Table 5.5-7.

However, about estimation of activity data from questionnaire survey, activity data to be necessarily estimated is assumed to be the same as Table 5.5-7.

Table 5.5-7 Activity data for industrial process (others)

Sub-category	Active	Activity data source	Remarks
Paper, pulp	Air-dried pulp amount	Statistics in the country, UN statistics, or paper, pulp related statistics data	Tall-oil, terpen volume, black liquid volume, etc may be able to be obtained from paper, pulp related statistics
	Dried pulp amount		
	Non-bleached dried pulp amount		
Foods, drinks	Foods manufacturing amount	Statistics in each country	The sum of the foods, drinks stated below.
	Livestock processing		Household meat
	Fish		
	Cereals		
	Maize		
	Beer		
	Alcohol		Fermentation, container storage, ageing
	Agricultural goods		Agricultural goods (cereals, beans)processing
	Bread		Typical bread, yeast bread, white, corn bread, rye bread
	Cakes		Cakes, biscuits, cereals
	Refined meat		Meat, fish, household meat
	Sugar		
	Food fat		Margarine, solid cooking fat
	Feed		
	Coffee beans		Coffee beans frying
	Wine		Red wine, white wine etc
	Beers		Beer, cider
	Steamed wine		Spirit, malt whiskey, grain whiskey, brandy, other whiskey
Timber processing	Timber product quality	Statistics in each country	

5.5.2.3 Setting of emission factors

Other products manufacturing is classified into paper, pulp manufacturing, foods, drinks manufacturing, and timber processing industry.

Emission factors for paper and pulp manufacturing are shown in Table 5.5-8 to Table 5.5-10.

Table 5.5-8 Emission factors for industrial process (other product manufacturing: paper pulp manufacturing, Part 1)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Paper, pulp manufacturing	Default value	NO_x	1	kg/Mg air dried pulp
		CO	5.5	kg/Mg air dried pulp
		NMVOC	2	kg/Mg air dried pulp
		SO_x	2	kg/Mg air dried pulp
		TSP	1	kg/Mg air dried pulp
		PM_{10}	0.8	kg/Mg air dried pulp
		$PM_{2.5}$	0.6	kg/Mg air dried pulp
	Kraft pulp manufacturing process (with scrubber and ESP)	NO_x	1	kg/Mg air dried pulp
		CO	5.5	kg/Mg air dried pulp
		NMVOC	2	kg/Mg air dried pulp
		SO_x	2	kg/Mg air dried pulp
		TSP	1	kg/Mg air dried pulp
		PM_{10}	0.8	kg/Mg air dried pulp
		$PM_{2.5}$	0.6	kg/Mg air dried pulp
	Sulfurous acid pulp manufacturing process (with scrubber and ESP)	NO_x	2	kg/Mg air dried pulp
		NMVOC	0.2	kg/Mg air dried pulp
		SO_x	4	kg/Mg air dried pulp
		TSP	1	kg/Mg air dried pulp
		PM_{10}	0.75	kg/Mg air dried pulp
		$PM_{2.5}$	0.67	kg/Mg air dried pulp
	Neutral sulfurous acid semi-chemical method	NMVOC	0.05	kg/Mg air dried pulp

Source: EMEP/EEA Guidebook

Table 5.5-9 Emission factors for industrial process (other product manufacturing: paper pulp manufacturing, Part 2)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Paper, pulp manufacturing (Kraft pulp)	Recovery boiler and direct evaporator (all type of control)	SO_x	3.5 [c)]	kg/Mg
		CO	5.5 [c)]	kg/Mg
	Untreated	TSP	90 [c)]	kg/Mg
	Venture scrubber	TSP	24 [c)]	kg/Mg
	EAP	TSP	1 [c)]	kg/Mg
	Auxiliary scrubber	TSP	1.5 - 7.5 [c)]	kg/Mg
	Noncontact recovery boiler without direct contact evaporator (untreated)	CO	5.5 [c)]	kg/Mg
		TSP	115 [c)]	kg/Mg
	Noncontact recovery boiler without direct contact evaporator (ESP)	CO	5.5 [c)]	kg/Mg
		TSP	1 [c)]	kg/Mg
	Smelt dissolving tank (Untreated)	SO_x	0.1 [c)]	kg/Mg
		TSP	3.5 [c)]	kg/Mg
	Smelt dissolving tank (Mesh pad)	SO_x	0.1 [c)]	kg/Mg
		TSP	0.5 [c)]	kg/Mg
	Smelt dissolving tank (Scrubber)	TSP	0.1 [c)]	kg/Mg
	Lime kiln (Untreated)	SO_x	0.15 [c)]	kg/Mg
		CO	0.05 [c)]	kg/Mg
		TSP	28 [c)]	kg/Mg
	Lime kiln (Scrubber or ESP)	CO	0.05 [c)]	kg/Mg
		TSP	0.25 [c)]	kg/Mg
	IPCC default value	NO_x	1.5 [d)]	kg/Mg
		CO	5.6 [d)]	kg/Mg
		NMVOC	3.7 [d)]	kg/Mg
		SO_x	7 [d)]	kg/Mg

Source: [c)] AP-42, [d)] 1996 IPCC Guidelines

For instance, uncontrolled default values are the same as GAP Forum Manual, and can be set using “Untreated” value of “Recovery boiler with direct contact evaporator + Lime kiln + Smelt dissolving tank” .

Table 5.5-10 Emission factors for industrial process (other product manufacturing: paper pulp manufacturing, Part 3)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Sulfurous acid pulp	Digester/blow pit or dump tank (None)	SO_x	3 to 35 [c)]	kg/Mg
	Digester/blow pit or dump tank (Process change)	SO_x	1 to 3 [c)]	kg/Mg
	Digester/blow pit or dump tank (Scrubber)	SO_x	0.5 [c)]	kg/Mg
	Digester/blow pit or dump tank (process change and Scrubber)	SO_x	0.1 [c)]	kg/Mg
	Digester/blow pit or dump tank (All exhaust vented through recovery system)	SO_x	0 [c)]	kg/Mg
	Digester/blow pit or dump tank (Process change)	SO_x	12.5 [c)]	kg/Mg
	Digester/blow pit or dump tank (Process change)	SO_x	0.2 [c)]	kg/Mg
	Digester/blow pit or dump tank (process change and Scrubber)	SO_x	1 [c)]	kg/Mg
	Digester/blow pit or dump tank (Unknown)	SO_x	33.5 [c)]	kg/Mg
	Recovery system (Multi-cyclone and venture scrubbers)	SO_x	4.5 [c)]	kg/Mg
		TSP	1 [c)]	kg/Mg
	Recovery system (Ammonia absorption and mist eliminator)	SO_x	3.5 [c)]	kg/Mg
		TSP	0.35 [c)]	kg/Mg
	Recovery system (Sodium carbonate scrubber)	SO_x	1 [c)]	kg/Mg
		TSP	2 [c)]	kg/Mg
	IPCC default value	SO_x	30 [d)]	kg/Mg
Neutral sulfite semi-chemical	Default value	NO_x	1.5 [e)]	kg/Mg
		NMVOC	3.7 [e)]	kg/Mg

Source: [c)] AP-42,[d)] 1996 IPCC Guidelines, [e)] GAP Forum Manual

Emission factors for other product industry process are shown in Table 5.5-11 to Table 5.5-13. Also Table 5.5-12 set more detailed emission factors.

Table 5.5-11 Emission factors for industrial process (other product manufacturing: drinks, foods industries)

Sub-category	Technical	Air pollutant	Emission factor	Unit
Foods, drinks industry	Default value	NMVOC	2	kg/Mg product produced
	Livestock processing (uncontrolled)	NMVOC	0.33	kg/Mg meet
	Fish meat processing (uncontrolled)	NMVOC	1	kg/Mg fish
	Cereal drying	NMVOC	1.3	kg/Mg grain dried
	Corn malt	NMVOC	0.55	kg/Mg barley
	Hop processing	NMVOC	7.8	g/Mg beer
	Fermentation	NMVOC	2	kg/Mg alcohol
	Storage in container	NMVOC	0.5	kg/Mg alcohol
	Ageing	NMVOC	20	kg/Mg alcohol
	Agricultural product processing (cereals, beans) (uncontrolled)	PM_{10}	24	g/ton

Source: EMEP/EEA Guidebook

Table 5.5-12 Emission factors for industrial process (other product manufacturing: foods material, drinks material industries, foods (solid))

Sub-category	Technical	Air pollutant	Emission factor	Unit
Foods, drinks industry	Bread making: Europe	NMVOC	4.5	kg/Mg bread
	Bread making: North America	NMVOC	8	kg/Mg bread
	Bread making: Yeast bread producing area	NMVOC	8	kg/Mg bread
	Bread making: white bread	NMVOC	4.5	kg/Mg bread
	Bread making: white bread shortened process	NMVOC	2	kg/Mg bread
	Bread making: all corn bread	NMVOC	2	kg/Mg bread
	Bread making: rye bread	NMVOC	3	kg/Mg bread
	Cakes, biscuits, cereals	NMVOC	1	kg/Mg product
	Meat, fish, livestocks	NMVOC	0.3	kg/Mg product
	Sugar	NMVOC	10	kg/Mg sugar
	Margarine, solid fat	NMVOC	10	kg/Mg product
	Livestock feed	NMVOC	1	kg/Mg feed
	Coffee frying	NMVOC	0.55	kg/Mg beans

Source: EMEP/EEA Guidebook

Table 5.5-13 Emisson factors for industrial process (other product manufacturing: foods material, drinks material industries, foods (liquid))

Sub-category	Technical	Air pollutant	Emission factor	Unit
Foods, drinks industry	Wine (general)	NMVOC	0.08	kg/hl wine
	Red wine	NMVOC	0.08	kg/hl wine
	White wine	NMVOC	0.035	kg/hl wine
	Beer (including non-alcoholic (cider))	NMVOC	0.035	kg/hl beer
	Distilled spirit	NMVOC	15	kg/hl alcohol
	Malt whiskey	NMVOC	15	kg/hl alcohol
	Grain whiskey	NMVOC	7.5	kg/hl alcohol
	Brandy	NMVOC	3.5	kg/hl alcohol
	Other distilled spirit	NMVOC	0.4	kg/hl alcohol

Source: EMEP/EEA Guidebook

Emission factor for air pollutant about timber processing is shown in Table 5.5-14.

Table 5.5-14 Emission factor for industrial process (other product manufacturing: timber processing)

Sub-category	Air pollutant	Emission factor	Unit
Timber processing	TSP	1	kg/Mg wood product

Source: EMEP/EEA Guidebook

5.5.2.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1, “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2, “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

6 Estimating emissions of air pollutants from solvents and other product use

6.1 Targets of Estimation

The sources of the air pollutants from solvent and other product use are categorized based on EMEP/EEA guidebook as follows. Manufacture of chemical products is manufacturing of products using solvents, and the manufactures of solvents are calculated in the section of industrial process. The pollutants emitted from solvent and other product use are NMVOC (non-methane volatile organic compounds).

1) Paint application
2) Metal and other surface treatment
3) Dry cleaning
4) Chemical product manufacturing
5) Painting application
6) Household solvent use
7) Other product use

Table 6.1-1 shows relevant air pollutants from solvent and other product use for calculation.

Table 6.1-1 Solvent and other product use relevant for calculation

Category	Subcategory	NMVOC
Paint application	Manufacture of automobiles	○
	Car repairing	○
	Construction and buildings	○
	Domestic use	○
	Coil coating	○
	Boat building	○
	Timber products	○
	Other industrial products	○
	Other non-industrial products	○
Metal and other surface treatment	Metal degreasing	○
	Electronic components manufacturing	○
	Other industrial product cleaning	○
Dry cleaning	Dry cleaning	○
Chemical product manufacturing	Polyester processing	○
	Polyvinylchloride processing	○
	Polyurethane foam processing	○
	Rubber products	○
	Asphalt blowing	○
	Textile finishing	○
	Glues, paints and paints manufacturing	○
	Leather tanning	○
Printing	Printing	○
Household solvent use	Household solvent use (other than paints)	○
Other products use	Glass wool coating	○
	Mineral wool coating	○
	Fat, edible and non-edible oil extraction	○
	Application of glues and adhesives	○
	Preservation of timber	○
	Underseal treatment and conservation of	○

	vehicles	
	Vehicles dewaxing	○
	Household use of pharmaceutical products	○
	Other products use	○

6.2 Paint application

6.2.1 Simple method

6.2.1.1 Outline of emission estimation method

Emissions are calculated by multiplying activity data by an emission factor. The activity data is product consumption. When the product consumption is not available, it can be substituted with the result of the following equation: the quantity of a product produced + the quantity of the product imported - the product stock volume. The emission factor is an emission per the product consumption. The calculation equation for emissions is shown below.

$$\text{Emissions} = \text{AD} \times \text{EF} \quad \cdots\cdots (6.2\text{-}1)$$

Where:

Emissions: NMVOC emissions

AD: Activity data on solvent use (product volume of an industrial product)

EF: Emission factor on solvent use

6.2.1.2 Estimation of activity data

The activity data is the total use of paints. Below are possible sources of activity data:

1) Statistics of the county
2) UN Industrial Commodity Statistics Yearbook
3) Monthly Bulletin of Statistic (http://unstats.un.org/unsd/mbs/app/DataSearchTable.aspx)
4) International Trade Statistics Yearbook
   v.1 Trade by Country: total import/export value (long term), total trade index (long term), import rate by economic category field and export rate by industry, trade value by major producing countries, trade volume and amount by commodities.
   v.2 Trade by Commodities: foreign trade amount by counties.

6.2.1.3 Setting of emission factors

Table 6.2-1 shows emission factors related to paint application.

Table 6.2-1 Emission factors for paint application (NMVOC)

Subcategory	Technology identification	Emission Factor	Unit
Decorative paint application	Default value	150	g/kg paint applied
Industrial paint application		400	g/kg paint applied
Other paint application		200	g/kg paint applied

Reference: EMEP/EEA Guidebook

6.2.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

6.2.2 Detailed method

6.2.2.1 Outline of emission estimation method

Emissions are estimated by plant and business facility that use paints and added together. When abatement measure is not applied, emissions from each business facility can be approximated by the following equation.

Emissions = the amount of solvent and other product used × the content rate of the relevant material[1] - chemicals contained in wastewater

[1]: Chemical composition of the product is required. (use MSDS and others for reference)

When the content rate of a solvent and its chemical composition are not available, activity data corresponding to an existing emission factor may be calculated from statistics and surveys and multiply by an emission factor. If an anti-pollution measure is implemented, emissions may be calculated by multiplying the efficiency of the anti-pollution measure with the emission factor. The equation to calculate emissions is as follows.

$$\mathrm{Emissions} = \sum \mathrm{AD} \times (1-\eta) \times \mathrm{EF} \qquad \cdots\cdots (6.2\text{-}2)$$

Where:

Emissions: Emissions of air pollutants and Greenhouse gas

AD: Activity data on solvent and other product use (production volume of industrial products)

EF: Emission factor on solvent and other product use

η: Decontamination rate by the abatement efficiency measure

6.2.2.2 Estimation of activity data

The activity data includes product consumption at plants and business facilities and the numbers of housing and building construction starts. For plants of a certain scale, data on product consumption should be collected by a questionnaire survey or fieldwork. For other facilities, data may be estimated by subtracting the portion of the large-scale facilities from the statistic data by sector.

When emissions are estimated from the existing emission factors, the following activity data may be used.

Table 6.2-2 shows the activity data related to NMVOC emissions from paint application.

Table 6.2-2 Solvent and other product use (paint application)

Subcategory	Activity data	Source of activity data	Note
Manufacture of automobiles	Number of produced automobiles	Statistics of each country and UN statistics	
Car repairing	Use of paint (kg)	Questionnaire survey to relevant organizations	
Construction and buildings	Use of paint (kg)	Questionnaire survey to relevant organizations	
Household use	Use of paint (kg)	Questionnaire survey to relevant organizations	
Coil coating	Use of paint (kg)	Statistics of each country and UN statistics	
Boat building	Painted area (m^2)	Statistics of each country and UN statistics	
Timber	Use of paint (kg)	Questionnaire survey to relevant organizations	
Wire coating	Production volume of wire (kg)	Statistics of each country and UN statistics	
Leather tanning	Production volume of leather(kg)	Statistics of each country	
Other industrial paint application	Use of paint (kg)	Statistics of each country and UN statistics	
Other non-industrial paint application	Use of paint (kg)	Statistics of each country and UN statistics	

Source: EMEP/EEA Guidebook

6.2.2.3 Setting of emission factors

Emission factor for each subcategory of construction and buildings, household use, manufacture of automobiles, car repairing, coils coating, timber coating, and other industrial paint application is set as follows. The default values are average values in Europe and North America, therefore the values should be applied with caution. In addition, when an emission factor is obtained from observed value, that factor should be prioritized.

Coatings are categorized into paint application in plants (paint application on automobiles, coils and wires) and shipbuilding, construction and buildings (interior and exterior), and household use. Table 6.2-3 shows emission factors on coatings.

Table 6.2-3 Emission factors of solvent and other product use (NMVOC)

Subcategory	Technology identification	Emission factor	Unit
Construction and buildings	Default value	230	g/kg paint
House hold use	Solvent borne paint with 50%-wt solvent content	230	g/kg paint
Manufacture of automobiles	Default value	8	kg/car
Car repairing		720	g/kg paint
Coil coating		480	g/kg paint applied
Timber		950	g/kg paint applied
Other industrial paint application	Truck/van coating	28	kg/vehicle
	Truck cabin coating	8	kg/vehicle
	Bus coating	150	kg/bus
	Wire coating	17	g/kg wire
	Leather finishing	200	g/kg leather
	Boat coating	125	g/m^2
	Others	740	g/kg paint

Source: EMEP/EEA Guidebook

6.2.2.4 Emissions abatement efficiency

VOC abatement technologies and the efficiency for coatings are shown below.

The abatement technologies are:

1) Reduction of paint use by improvements in the coating systems (automobile coating)
2) Installation of exhaust gas treatment equipment in a coating booth (automobile coating)
3) Reduction of cleaning thinner by reducing paint types in use (boat coating)
4) Collection and recycle of solvent (automobile coating)
5) Sealing of unused solvents and waste cloths used for cleaning(In-plant coatings)
6) Use of low-VOC paints (emulsion paint, high solids paint, and powder/water-based paint, used for automobiles, buildings, boats and heavy-duty)

Table 6.2-4 shows abatement efficiencies (η) by measure for building coating

Table 6.2-4 Building coating abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Substitution with emulsion paints	39
Substitution with water-based paints	26
Substitution with high solids paints	4
Substitution with emulsion and water-based paints	65
Substitution with emulsion and high solids paints	43
Substitution with emulsion, water-based and high solids paints	70

Source: EMEP/EEA Guidebook

Table 6.2-5 shows abatement efficiency (η) by measure for car coating.

Table 6.2-5 Car coating abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Combination of waterborne primer and solvent- based basecoat	10
Combination of solvent-primer and water-based basecoat	40
Combination of waterborne primer and water-based basecoat	50
Installation of exhaust gas incinerator on dry oven	10
Installation of exhaust gas incinerator on dry oven; installation of activated carbon adsorption on spray booth	40

Source: EMEP/EEA Guidebook

Table 6.2-6 shows abatement efficiency (η) by measure for car repair coating.

Table 6.2-6 Car repair coating abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Combination of conventional primer, high solid surface, conventional topcoat(s) and basic cleaning agent	8
Combination of conventional primer, high solid surface, improved topcoat(s) and improved cleaning agent	60
Combination of conventional primer, very high solid surface, improved topcoat(s) and improved cleaning agent	70

Source: EMEP/EEA Guidebook

Table 6.2-7 shows abatement efficiency (η) by measure for coil coating.

Table 6.2-7 Coil coating abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Use of water-based paints (10 wt-% solvent content)	75
Use of powder paints (solvent free)	100
Addition of thermal oxidation equipment	90

Source: EMEP/EEA Guidebook

Table 6.2-8 shows abatement efficiency (η) by measure for timber coating.

Table 6.2-8 Timber coating abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Medium solids system (55% solvent content)	31
High solids system (20% solvent content)	75
Very high solids system (5 % solvent content)	94
Addition of thermal oxidation equipment	75

Source: EMEP/EEA Guidebook

Table 6.2-9 shows abatement efficiency (η) by measure for truck/van coating.

Table 6.2-9 Truck/van coating abatement efficiency by measure

Emission abatement technology	Efficiency (%)
50% two layer-50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration process on dry oven; improved solvent recovery and consumption reduction; incineration on primer and enamel	34
50% two layer-50% one layer; waterborne primer, high solid basecoat, clear coat and seal coat; improvement of cleaning stages; incineration process on dry oven; improved solvent recovery and consumption reduction; incineration on primer and enamel; partial VOC abatement in the enamel spray booths	37
80% two layer-20% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration process on dry oven; improved solvent recovery and consumption reduction; incineration on primer and enamel	54

Source: EMEP/EEA Guidebook

Table 6.2-10 shows abatement efficiency (η) by measure for truck cabin coating.

Table 6.2-10 Truck cabin coating abatement efficiency by measure

Emission abatement technology	Efficiency (%)
50% two layer-50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration process on dry oven; improved solvent recovery and consumption reduction; incineration on primer and enamel	40
50% two layer-50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration process on dry oven; improved solvent recovery and consumption reduction; incineration on primer and enamel; partial VOC abatement in the enamel spray booths	45
80% two layer-20% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration process on dry oven; improved solvent recovery and consumption reduction; incineration on primer and enamel; partial VOC abatement in the enamel spray booths	60

Source: EMEP/EEA Guidebook

Table 6.2-11 shows abatement efficiency (η) by measure for bus coating.

Table 6.2-11 Coil coating abatement efficiency by measure

Emission abatement technology	Efficiency (%)
50% two layer-50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration process on dry oven; improved solvent recovery and consumption reduction; incineration on primer and enamel	48
80% two layer-20% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration process on dry oven; improved solvent recovery and consumption reduction; incineration on primer and enamel; partial VOC abatement in the enamel spray booths	62

Source: EMEP/EEA Guidebook

Table 6.2-12 shows abatement efficiency (η) by measure for wire coating.

Table 6.2-12 Coil coating abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Reduction of solvent content in enamel (62%); use of low-VOC wax; reduced fugitive emissions; 97% abatement efficiency in oven	76

Source: EMEP/EEA Guidebook

Table 6.2-13 shows abatement efficiency (η) by measure for leather product finishing.

Table 6.2-13 Leather product finishing abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Use of water based paints (30 wt% solvent content)	65
Installation of thermal oxidation equipment	81
Installation of biofiltration unit	81

Source: EMEP/EEA Guidebook

6.2.2.5 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. *Spatial distribution*

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

6.3 Metal and other surface treatment

6.3.1 Simple method

6.3.1.1 Outline of emission estimation method outline

Emissions are calculated by multiplying activity data by an emission factor. The activity data is product consumption. When the product consumption is not available, it can be substituted with the result of the following equation: the quantity of a product produced + the quantity of the product imported - the product stock volume. The emission factor is an emission per consumption of a product. The calculation equation for emissions is shown below.

$$\text{Emissions} = AD \times EF \quad \cdots\cdots (6.3\text{-}1)$$

Where:

Emissions: NMVOC emissions

AD: Activity data on solvent use (Production volume of an industrial product)

EF: Emission factor for solvent use

6.3.1.2 Estimation of activity data

The activity data is the total sales of solvents; for cleaning agent, only organic solvents should be in consideration. The possible sources of activity data are shown below:

1) Statistics of the county
2) UN Industrial Commodity Statistics Yearbook
3) Monthly Bulletin of Statistic (http://unstats.un.org/unsd/mbs/app/DataSearchTable.aspx)
4) International Trade Statistics Yearbook
    v.1 Trade by Country: total import/export value (long term), total trade index (long term), import rate by economic category field and export rate by industry, trade value by major producing countries, trade volume and amount by commodities.
    v.2 Trade by Commodities: foreign trade amount by counties.

6.3.1.3 Setting of emission factors

Table 6.3-1 shows emission factors for metal and other surface treatment.

Table 6.3-1 Emission factor for metal and other surface treatment (NMVOC)

Subcategory	Technology identification	Emission factor	Unit
Metal and other surface treatment	Default value	460	g/kg cleaning products

Source: EMEP/EEA Guidebook

6.3.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

6.3.2 Detailed method

6.3.2.1 Outline of emission estimation method

Emissions are estimated by plant and business facility that implement metal and other surface treatment and added together. When abatement measure is not taken, emissions from each business facility can be approximated by the following equation.

> Emissions = the amount of solvent and other product used × the content rate of the relevant material[1] - chemicals contained in wastewater
>
> [1]: Chemical composition of the product is required. (See MSDS and others)

When the content rate of a solvent and its chemical composition are not available, obtain and calculate activity data from corresponding existing emission factor from statistics and surveys. Multiply the obtained activity data to an emission factor for emission calculation. If an emission abatement measure is implemented, emissions may be calculated by multiplying the efficiency of the emission abatement measure with the emission factor. The equation to calculate emissions is as follows.

$$\mathrm{Emissions} = \sum \mathrm{AD} \times (1-\eta) \times \mathrm{EF} \quad \cdots\cdots (6.3\text{-}2)$$

Where:

Emissions: Emissions of air pollutants and Greenhouse gas

AD: Activity data for the solvent and other product use (production volume of industrial products)

EF: Emission factor for solvent and other product use

η: Removal rate by emission abatement

6.3.2.2 Estimation of activity data

The activity data includes product consumption at plants and business facilities and production volume of electronic components. For plants of a certain scale, data on product consumption should be collected by a questionnaire survey or fieldwork. For other facilities, data may be estimated by subtracting the portion of the large-scale facilities from the statistic data by sector.

When emissions are estimated from the existing emission factors, the following activity data in Table 6.3-2 may be used.

Table 6.3-2 Solvent and other product use (metal and other surface treatment) activity data

Subcategory	Activity data	Source of activity data	Note
Metal degreasing	Cleaning products (kg)	Statistics of each country	International Institute for Applied Systems Analysis (IIASA)
Electronic components manufacturing	Production of wafers (ton)	Statistics of each country	

Source: EMEP/EEA Guidebook

6.3.2.3 Setting of emission factors

Emission factors for metal degreasing and electronic component cleaning are set as follows. The default values are average values in Europe and North America, therefore, the values should be applied with caution. In addition, when an emission factor is obtained from observed value, then the factor should be prioritized.

Table 6.3-3 shows emission factors for metal and other surface treatment.

Table 6.3-3 Emission factors for metal surface treatment (degreasing, cleaning) (NMVOC)

Subcategory	Technology identification	Emission factor	Unit
Metal degreasing	Default value	710	g/kg cleaning products
Cleaning of electronic components	Default value	740	kg/ton wafer

Source: EMEP/EEA Guidebook

6.3.2.4 Emission abatement efficiency

Table 6.3-4 shows abatement efficiency (η) by measure for metal and other surface treatment.

Table 6.3-4 Metal and other surface treatment abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Installation of carbon filter (open-top)	80
Installation of partial lid/cover and good house keeping	25
Installation of partial lid/cover and good house keeping, installation of carbon filter	85
Sealed chamber system using chlorinated solvents	95
Use of Cold cleaner	89
Introduction of closed cleaning system (degreasing by HFC and HFE)	98
Introduction of closed cleaning system (degreasing by HFC and HFE) with activated carbon filter	97
Aqueous cleaning process	100

Source: EMEP/EEA Guidebook

Good housekeeping is, for example, abidance of the following rules.

a) Store unused cleaning agents in a closed location.
b) Prevent solvent leakage and promptly remove solvent in case of leakage.
c) Store waste cloths used in cleaning in a closed container until disposal.
d) Regular maintenance and repairing to minimize leakage.

6.3.2.5 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

6.4 Dry Cleaning

6.4.1 Simple method

6.4.1.1 Outline of emission estimation method

Emissions are calculated by multiplying activity data by an emission factor. The activity data is product consumption. When the product consumption is not available, substitute with the result of the following equation: the quantity of a product produced + the quantity of the product imported **-** the product stock volume.

The emission factor is an emission per the consumption of a product. The calculation equation for emissions is shown below.

$$\mathrm{Emissions} = \mathrm{AD} \times \mathrm{EF} \quad \cdots\cdots (6.4\text{-}1)$$

Where:

Emissions: NMVOC emissions

AD: Activity data for solvent use (Product volume of an industrial product)

EF: Emission factor for solvent use

6.4.1.2 Estimation of activity data

The activity data is the total quantity of cleaned material. Possible source of the activity data is the statistics of the country.

6.4.1.3 Setting of emission factors

Table 6.4-1 shows the emission factor for dry cleaning.

Table 6.4-1 Emission factor for dry cleaning (NMVOC)

Subcategory	Technology identification	Emission factor	Unit
Dry cleaning	Default value	40	g/kg textile treated

Source: EMEP/EEA Guidebook

6.4.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

6.4.2 Detailed method

6.4.2.1 Outline of emission estimation method

Emissions by cleaning plant and business facility are estimated and added together. When abatement measure is not taken, emissions from each business facility can be approximated by the following equation.

Emissions = the amount of solvent and other product used × the content rate of the relevant material[1] - chemicals contained in wastewater

[1]: Chemical composition of the product is required. (See MSDS and others)

When the content rate of a solvent and its chemical composition are not available, activity data corresponding to an existing emission factor may be calculated from statistics and surveys, and multiply to an emission factor to calculate emission. If an emission abatement measure is implemented, emissions may be calculated by multiplying the efficiency of the emission abatement measure with the emission factor. The equation to calculate emissions is as follows.

$$\mathrm{Emissions} = \sum \mathrm{AD} \times (1-\eta) \times \mathrm{EF} \quad \cdots\cdots(6.4\text{-}2)$$

Where:

Emissions: Emissions of air pollutants and Greenhouse gas

AD: Activity data for the solvent and other product use (production volume of industrial products)

EF: Emission factor for solvent and other product use

η: Removal rate by emission abatement

6.4.2.2 Estimation of activity data

The activity data is the total quantity of material cleaned. For plants of a certain scale, data on product consumption should be collected by a questionnaire survey or fieldwork. For other facilities, data may be estimated by subtracting the portion of the large-scale facilities from the statistic data by sector.

When emissions are estimated from the existing emission factors, the following activity data in Table 6.4-2 may be used.

Table 6.4-2 Solvent and other product use (dry cleaning) activity data

Subcategory	Activity data	Activity data source	Note
Dry cleaning	Material cleaned (kg)	Statistics of each country	

Source: EMEP/EEA Guidebook

6.4.2.3 Setting of emission factors

Table 6.4-3 shows the emission factor for dry cleaning. The default values are average values in Europe and North America, and the values should be applied with caution. In addition, when an emission factor is obtained from observed value, that factor should be prioritized.

Table 6.4-3 Emission factor for dry cleaning (NMVOC)

Subcategory	Technology identification	Emission factor	Unit
Dry cleaning	Open-circuit washer	177	g/kg textiles cleaning

Source: EMEP/EEA Guidebook

6.4.2.4 Emission abatement efficiency

Emission abatement measures for dry cleaning are shown below:

1) Shift to hot dry cleaner (closed system)
2) Installation of exhaust gas treatment equipment
3) Introduction of wet cleaning

Table 6.4-4 shows abatement efficiency by measure for dry cleaning.

Table 6.4-4 Dry cleaning abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Open-circuit washer with activated carbon filter	70
Conventional closed-circuit PER machine	89
Conventional closed-circuit PER machine with activated carbon filter	91
New generation closed-circuit PER machine	95
Hydrocarbon machines	95
Wet cleaning	100

Source: EMEP/EEA Guidebook

6.4.2.5 Temporal change and spatial distribution

1. ***Temporal change***

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. ***Spatial distribution***

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

6.5 Chemical product manufacturing

6.5.1 Simple method

6.5.1.1 Outline of emission estimation method

Emissions are calculated by multiplying activity data by an emission factor. The activity data is product consumption. When the product consumption is not available, it can be substituted with the result of the following equation: the quantity of a product produced + the quantity of the product imported - the product stock volume. The emission factor is an emission per the consumption of a product. The calculation equation for emissions is shown below.

$$\text{Emissions} = \text{AD} \times \text{EF} \quad \cdots\cdots (6.5\text{-}1)$$

Where:

Emissions: NMVOC emissions

AD: Activity data for solvent use (Product volume of an industrial product)

EF: Emission factor for solvent use

6.5.1.2 Estimation of activity data

The activity data is the total quantity of all chemical products. The products include products incorporating solvents, polystyrene processing, polyvinylchloride processing, and synthetic rubber processing. The possible sources of activity data are shown below:

1) Statistics of the county
2) UN Industrial Commodity Statistics Yearbook
3) Monthly Bulletin of Statistic (http://unstats.un.org/unsd/mbs/app/DataSearchTable.aspx)
4) International Trade Statistics Yearbook
    v.1 Trade by Country: total import/export value (long term), total trade index (long term), import rate by economic category field and export rate by industry, trade value by major producing countries, trade volume and amount by commodities.
    v.2 Trade by Commodities: foreign trade amount by counties.

6.5.1.3 Setting of emission factors

Table 6.5-1 shows emission factor for chemical product manufacturing.

Table 6.5-1 Emission factor for chemical product manufacturing (NMVOC)

Subcategory	Technology identification	Emission factor	Unit
Chemical product manufacturing	Default value	10	g/kg product

Source: EMEP/EEA Guidebook

6.5.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

6.5.2 Detailed method

6.5.2.1 Outline of emission estimation method

Emissions are estimated by chemical product manufacturing plant and business facility and added together. When abatement measure is not taken, emissions from each business facility can be approximated by the following equation.

> Emissions = the amount of solvent and other product used × the content rate of the relevant material[1] - chemicals contained in wastewater
>
> [1]: Chemical composition of the product is required. (See MSDS and others)

When the content rate of a solvent and its chemical composition are not available, activity data corresponding to an existing emission factor may be calculated from statistics and surveys, and multiply by an emission factor. If an emission abatement measure is implemented, emissions may be calculated by multiplying the efficiency of the emission abatement measure with the emission factor. The equation to calculate emissions is as follows.

$$\text{Emissions} = \sum \text{AD} \times (1 - \eta) \times \text{EF} \quad \cdots\cdots (6.5\text{-}2)$$

Where:

Emissions: Emissions of air pollutants and Greenhouse gas

AD: Activity data for the solvent and other product use (production volume of industrial products)

EF: Emission factor for solvent and other product use

η: Removal rate by emission abatement

6.5.2.2 Estimation of activity data

The activity data includes the consumption of solvents, production volume of the product, and chemical processing volume by plants and business facilities and production. For plants of a certain scale, data on cleaning quantity should be collected by a questionnaire survey or fieldwork. For other facilities, data may be estimated by subtracting the portion of the large-scale facilities from the statistic data by sector.

When emissions are estimated from the existing emission factors, the following activity data in Table 6.5-2 may be used.

Table 6.5-2 Solvent and other product use (chemical product manufacturing) activity data

Subcategory	Activity data	Source of activity data	Note
Polyester processing	Polyester monomer use (kg)	Statistics of each country	
Polyvinylchloride processing	Polyurethane foam processed (kg)	Statistics of each country	
Polyurethane foam processing	Polystyrene foam processed (kg)	Statistics of each country	
Rubber processing (not including tire manufacturing)	Production volume of rubber products (kg)	Statistics of each country	
Rubber manufacturing	Production volume of tires (kg)	Statistics of each country, UN statistics	
Pharmaceutical products	Solvent use volume in processes of manufacturing pharmaceutical products (kg)	Statistics of each country	
Asphalt blowing	Use volume of asphalt (Mg)	Questionnaire survey to relevant organizations	
Manufacture of paints, inks and adhesives	Production volume (kg)	Statistics of each country, UN statistics	
Adhesive tape manufacturing	Production volume of tapes (m^2)	Statistics of each country	
Leather tanning	Raw hide (kg)	Statistics of each country	

Source: EMEP/EEA Guidebook

6.5.2.3 Setting of emission factors

Emission factor for each subcategory of polyester processing, polyvinylchloride processing, Polyurethane foam processing, rubber processing (not including tire manufacturing), manufacture of paints, ink and adhesives, and others is set as follows. The default values are average values in Europe and North America, therefore the values should be applied with caution. In addition, when an emission factor is obtained from observation value, that factor should be prioritized.

Table 6.5-3 to Table 6.5-5 shows emission factors for chemical product manufacturing.

Table 6.5-3 Chemical product manufacturing emission factors (NMVOC)

Subcategory	Technology identification	Emission factor	Unit
Polyester processing		50	g/kg monomer used
Polyurethane processing		120	g/kg form processed
Polystyrene form processing		60	g/kg form processed
Rubber processing (not including tire production)		8	g/kg rubber produced
Manufacture of paints, inks, varnishes and glues		11	g/kg product
Others	Tire manufacturing	10	g/kg tires
	Pharmaceutical products manufacturing	300	g/kg solvents used
	Adhesive tape manufacturing	3	g/m^2
	Manufacture of shoes	45	g/pair of shoes
	Leather tanning	0.68	g/kg raw hide

Source: EMEP/EEA Guidebook

Table 6.5-4 Emission factors for chemical product manufacturing (asphalt blowing)

Subcategory	Technology identification	Emission factor	Unit
Asphalt blowing	NMVOC	27200	g/Mg asphalt
	TSP	400	
	Cd	0.0001	
	As	0.0005	
	Cr	0.006	
	Ni	0.05	
	Se	0.0005	
	Total 4 PAHs	4,000	

Source: EMEP/EEA Guidebook

Table 6.5-5 Emission factor for chemical product manufacturing (leather tanning) (NH_3)

Subcategory	Technology identification	Emission factor	Unit
Others	Leather tanning	0.68	g/kg raw hide

Source: EMEP/EEA Guidebook

6.5.2.4 Emission abatement efficiency

Table 6.5-6 shows abatement efficiency (η) by measure for polystyrene processing.

Table 6.5-6 Abatement efficiency by measure for polystyrene processing

Emission abatement technology	Efficiency (%)
Use of 100% of 6% pentane expandable beads; thermal incineration on the expander	34
Use of 85% of 6% pentane expandable beads + 15% of EPS wastes (recycling); no secondary measure	15
Use of 85% of 6% pentane expandable beads + 15% of EPS wastes (recycling); thermal incineration on the expander	44
Use of 100% of 4% pentane expandable beads; no secondary measure	33

Table 6.5-7 shows abatement efficiency (η) by measure for pharmaceutical product manufacturing.

Table 6.5-7 Pharmaceutical product manufacturing abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Low use of secondary measures	73
Secondary measures (both incineration, adsorption and/or condensation)	88

Source: EMEP/EEA Guidebook

Table 6.5-8 shows abatement efficiency (η) by measure for asphalt blowing.

Table 6.5-8 Asphalt blowing abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Secondary measures (unknown measure level)	98

Source: EMEP/EEA Guidebook

Table 6.5-9 shows abatement efficiencies by measure for tire manufacturing.

Table 6.5-9 Tire manufacturing Abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Process optimization Use of 70% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvent)	30
New processes Use of 25% solvent-based adhesives, paints, inks, and cleaning agents (90 wt-% solvent)	75

Source: EMEP/EEA Guidebook

Table 6.5-10 shows abatement efficiency by measure （η） for manufacturing paints, inks and glues.

Table 6.5-10 Paints, inks and glues manufacturing abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Improved production mix: 80% water-based coatings (4 wt-% solvent); 15% high solvent based coatings (50 wt-% solvent); 5% other products (100 wt-% solvent)	50
Use of good practices	27
Upgrading of the condensation units or carbon adsorption and solvent recovery	50

Source: EMEP/EEA Guidebook

Examples of what ‘good practices’ may include:

1) Recovery of solvent vapors during raw material distribution
2) Unloading of the barrels with forklifts to avoid leakages
3) Coverage of mobile reactors
4) Use of heavier solvents to reduce fugitive emissions
5) Use of cleaning agents containing less solvents
6) Use of automatic cleaning devices as possible
7) Recycling of cleaning solutions

6.5.2.5 Temporal change and spatial distribution

1. *Temporal change*

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. *Spatial distribution*

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

6.6 Printing

6.6.1 Simple method

6.6.1.1 Outline of emission estimation method

Emissions are calculated by multiplying activity data by an emission factor. The activity data is product consumption. When the product consumption is not available, it can be substituted with the result of the following equation: the quantity of a product produced + the quantity of the product imported - the product stock volume. The emission factor is an emission per the consumption of a product. The calculation equation for emissions is shown below.

$$\mathrm{Emissions} = \mathrm{AD} \times \mathrm{EF} \quad \text{(6.6-1)}$$

Where:

Emissions: NMVOC emissions

AD: Activity data for solvent use (Product volume of an industrial product)

EF: Emission factor for solvent use

6.6.1.2 Estimation of activity data

The activity data is basically the production volumes of each industrial product. The possible sources of activity data is shown below:

1) Statistics of the county
2) UN Industrial Commodity Statistics Yearbook
3) Monthly Bulletin of Statistic (http://unstats.un.org/unsd/mbs/app/DataSearchTable.aspx)
4) International Trade Statistics Yearbook

v.1 Trade by Country: total import/export value (long term), total trade index (long term), import rate by economic category field and export rate by industry, trade amount by major producing countries, trade volume and amount by commodities.
v.2 Trade by Commodities: foreign trade amount by counties.

6.6.1.3 Setting of emission factors

Table 6.6-1 shows emission factor for printing.

Table 6.6-1 Emission factor for printing (NMVOC)

Subcategory	Technology identification	Emission factor	Unit
Printing	Default value	500	g/kg ink

Source: EMEP/EEA Guidebook

6.6.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

6.6.2 Detailed method

6.6.2.1 Outline of emission estimation method

Emissions are estimated by printing plant and business facility and added together. When abatement measure is not taken, emissions from each business facility can be approximated by the following equation.

Emissions = the amount of solvent and other product used × the content rate of the relevant material[1] - chemicals contained in wastewater

[1]: Chemical composition of the product is required. (See MSDS and others)

When the content rate of a solvent and its chemical composition are not available, activity data corresponding to an existing emission factor may be calculated from statistics and surveys, and multiply by an emission factor. If an emission abatement measure is implemented, emissions may be calculated by multiplying the efficiency of the emission abatement measure with the emission factor. The equation to calculate emissions is as follows.

$$\mathrm{Emissions} = \sum \mathrm{AD} \times (1-\eta) \times \mathrm{EF} \quad \cdots\cdots (6.6\text{-}2)$$

Where:

Emissions: Emissions of air pollutants and Greenhouse gas

AD: Activity data for the solvent and other product use (production volume of industrial products)

EF: Emission factor for solvent and other product use

η: Removal rate by emission abatement

6.6.2.2 Estimation of activity data

The activity data are the total consumption of inks for printing. For plants of a certain scale, data on inks consumption should be collected by a questionnaire survey or fieldwork. For other facilities, data may be estimated by subtracting the portion of the large-scale facilities from the statistic data by sector.

Table 6.6-2 shows the activity data of NMVOC emissions from printing.

Table 6.6-2 Solvent and other product use (printing) activity data

Subcategory	activity data	Source of activity data	Note
Printing	Inks use (kg)	Statistics of each country	

Source: EMEP/EEA Guidebook

6.6.2.3 Setting of emission factors

Table 6.6-3 shows emission factors for printing. The default values are average values in Europe and North America, and the values should be applied with caution. In addition, when an emission factor is obtained from observation value, that factor should be prioritized.

Table 6.6-3 Emission factors for printing

Subcategory	Technology identification	Emission factor	Unit
Offset printing		730	g/kg ink
Publication gravure		300	g/kg ink non diluted
Small flexography in packaging		900	g/kg ink ready to use
Large flexography in packaging		800	g/kg ink ready to use
Rotogravure in packaging		800	g/kg ink ready to use

Source: EMEP/EEA Guidebook

6.6.2.4 Emission abatement efficiency

Emission abatement measures in printing are as follows:

1) Reduced consumption of cleaning agents, measure for leakage emissions, shift to low VOC cleaning agents

2) Installation of exhaust gas treatment equipment
3) Low-VOC glues for lamination
4) Storage of inks and solvents
5) UV curing inks

Table 6.6-4 shows offset printing abatement efficiency (η) by measure.

Table 6.6-4 Offset printing abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Impregnation with isopropanol and solvent-based cleaning agents. Fugitive emissions 45% of input. Secondary measure: thermal incineration	48
Reduced consumption of isopropanol and of cleaning agents. Fugitive emissions 30% of input. No secondary measure	26
Reduced consumption of isopropanol and of cleaning agents with high flash points. Fugitive emissions 30% of input. Secondary measure: thermal incineration	72
Reduced consumption of isopropanol and of cleaning agents with high flash points. Fugitive emissions 25% of input. No secondary measure	30
Reduced consumption of isopropanol and of cleaning agents with high flash points. Fugitive emissions 25% of input. Secondary measure: thermal incineration	76

Source: EMEP/EEA Guidebook

Table 6.6-5 shows publication gravure abatement efficiency by measure (η).

Table 6.6-5 Publication gravure abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Activated carbon adsorption, fugitive emission 10% of input	33
Activated carbon adsorption, fugitive emission (?)[1] % of input	67

[1]: The value is unknown due a typo.

Source: EMEP/EEA Guidebook

Table 6.6-6 shows small flexography abatement efficiency by measure (η).

Table 6.6-6 Small flexography abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Water-based flexography (5wt% solvent); no secondary measure	95
UV curing inks(0wt% solvent); no secondary measure	100
Conventional solvent products (90wt% solvent); secondary measure: incineration	76

Source: EMEP/EEA Guidebook

Table 6.6-7 shows Rotogravure abatement efficiency by measure (η)

Table 6.6-7 Rotogravure abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Water-based products (5wt% solvent); no secondary measure	94
60% of products used replaced by 2 components adhesives (0wt% solvent); no secondary measure	60
Conventional solvent products (80wt% solvent); secondary measure: incineration	76
Conventional solvent products (80wt% solvent); secondary measure: absorption and solvent recovery	76
60% of products used replaced by 2 components adhesives (0wt% solvent); secondary measure: incineration	90
60% of products used replaced by 2 components adhesives (0wt% solvent); secondary measure: absorption and solvent recovery	90

Source: EMEP/EEA Guidebook

6.6.2.5 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

6.7 House hold solvent use

6.7.1 Simple method

6.7.1.1 Outline of emission estimation method

Emissions are calculated by multiplying activity data by an emission factor. The activity data is product consumption. When the product consumption is not available, it can be substituted with the result of the following equation: the quantity of a product produced + the quantity of the product imported - the product stock volume. The emission factor is an emission per the consumption of a product. The calculation equation for emissions is shown below.

$$\mathrm{Emissions} = \mathrm{AD} \times \mathrm{EF} \quad \cdots\cdots (6.7\text{-}1)$$

Where:

Emissions: NMVOC emissions

AD: Activity data for solvent use (Product volume of an industrial product)

EF: Emission factor for solvent use

6.7.1.2 Estimation of activity data

The activity data are basic statistics of national population.

6.7.1.3 Setting of emission factors

Table 6.7-1 shows emission factor for household solvent use.

Table 6.7-1 Emission factor for household solvent use (NMVOC)

Subcategory	Technology identification	Emission factor	Unit
Household solvent use including fungicide	Default value	1	kg/person/year

Source: EMEP/EEA Guidebook

6.7.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

6.7.2 Detailed method

6.7.2.1 Outline of emission estimation method

Emissions are estimated by person and added together. When abatement measure is not taken, emissions from each population can be approximated by the following equation.

> Emissions = the amount of solvent and other product used × the content rate of the relevant material [1] - chemicals contained in wastewater
>
> [1]: Chemical composition of the product is required. (See MSDS and others)

When the content rate of a solvent and its chemical composition are not available, activity data corresponding to an existing emission factor may be calculated from statistics and surveys, and multiply by an emission factor. If an emission abatement measure is implemented, emissions may be calculated by multiplying the efficiency of the emission abatement measure with the emission factor. The equation to calculate emissions is as follows.

$$\text{Emissions} = \sum \text{AD} \times (1-\eta) \times \text{EF} \quad \cdots\cdots (6.7\text{-}2)$$

Where:

Emissions: Emissions of air pollutants and Greenhouse gas

AD: Activity data for the solvent and other product use (production volume of industrial products)

EF: Emission factor for solvent and other product use

η: Removal rate by emission abatement

6.7.2.2 Estimation of activity data

The activity data are national population. Table 6.7-2 shows the activity data of NMVOC emissions from household solvent use.

Table 6.7-2 Solvent and other product use (household solvent use) activity data

Subcategory	activity data	Source of activity data	Note
Household use	National population	Statistics of each country, UN statistics	

6.7.2.3 Setting of emission factors

The household solvent use includes sprays and glues. Household use of coatings is estimated in the coating category. An emission factor is annual emissions on a per-person basis. But the emission factors are from the United States, Canada, and UK, and the emission factor should be applied to East Asia region with caution. Table 6.7-3 shows emission factors for household solvent use.

Table 6.7-3 Emission factors for Household

Subcategory	Technology identification	Emission factor	Unit
Fungicides, cosmetics and toiletries	Region: USA	1	kg/person/year
Fungicides, cosmetics and toiletries (non aerosol)	Region: UK	0.2	kg/person/year
	Region: Canada	0.4	kg/person/year
Fungicides, cosmetics and toiletries (Aerosol)	Region: UK	0.5	kg/person/year
	Region: Canada	0.4	kg/person/year
Fungicides, household products	Region: USA	0.4	kg/person/year
Fungicides, household products (non aerosol)	Region: UK, Canada	0.2	kg/person/year
Fungicides, household products (Aerosol)	Region: UK	0.05	kg/person/year
	Region: Canada	0.3	kg/person/year
Fungicides, car care products	Region: USA	0.6	kg/person/year
Fungicides, car care products (non aerosol)	Region: UK	0.3	kg/person/year
	Region: Canada	0.6	kg/person/year
Car care products (Aerosol)	Region: UK	0.1	kg/person/year
	Region: Canada	0.3	kg/person/year
Fungicides, DIY/buildings, adhesives	Region: UK	0.07	kg/person/year
	Region: Canada	0.05	kg/person/year
	Region: USA	0.3	kg/person/year
Fungicides, DIY/buildings, other	Region: USA	0.2	kg/person/year
Fungicides, aerosol propellant	Region: UK	0.8	kg/person/year

Source: EMEP/EEA Guidebook

*The use of cosmetics may vary by country due to differences in lifestyle. These emission factors may be too large for East Asia region.

6.7.2.4 Temporal change and spatial distribution

1. *Temporal change*

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. *Spatial distribution*

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

6.8 Other product use

6.8.1 Simple method

6.8.1.1 Outline of emission estimation method

Emissions are calculated by multiplying activity data by an emission factor. The activity data is product consumption. When the product consumption is not available, it can be substituted with the result of the following equation: the quantity of a product produced + the quantity of the product imported - the product stock volume. The emission factor is an emission per the consumption of a product. The calculation equation for emissions is shown below.

$$\text{Emissions} = \text{AD} \times \text{EF} \quad \cdots\cdots\cdots \quad (6.8\text{-}1)$$

Where:

Emissions: NMVOC emissions

AD: Activity data for solvent use (Product volume of an industrial product)

EF: Emission factor for solvent use

6.8.1.2 Estimation of activity data

The activity data is total quantity of solvents and products used. Possible sources for the activity data are as follows:

1) Statistics of the county
2) UN Industrial Commodity Statistics Yearbook
3) Monthly Bulletin of Statistic (http://unstats.un.org/unsd/mbs/app/DataSearchTable.aspx)
4) Food and Agriculture Organization of the United Nations (FAOSTAT: http://faostat.fao.org/)
5) International Iron and Steel Institute (IISI: http://www.worldsteel.org/pictures/publicationfiles/SSY%202010.pdf)
6) United States Geographical Survey (USGS) International Minerals Statistics Information (http://minerals.usgs.gov/minerals/pubs/country)
7) Monthly Bulletin of Statistic: http://unstats.un.org/unsd/mbs/app/DataSearchTable.aspx
8) International Trade Statistics Yearbook
   v.1 Trade by Country: total import/export value (long term), total trade index(long term), import rate by economic category field and export rate by industry, trade value by major producing countries, trade volume and amount by commodities.
   v.2 Trade by Commodities: foreign trade amount by counties.

6.8.1.3 Setting of emission factors

Table 6.8-1 shows emission factor for other product use.

Table 6.8-1 Emission factor for other product use (NMVOC)

Subcategory	Technology identification	Emission factor	Unit
Other product use	Default value	2	kg/Mg product used

Source: EMEP/EEA Guidebook

6.8.1.4 Temporal change and spatial distribution

1. *Temporal change*

Temporal change is shown in Table 2.5-1 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

2. *Spatial distribution*

Spatial distribution is shown in Table 2.5-2 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

6.8.2 Detailed method

6.8.2.1 Outline of emission estimation method

Emissions are estimated by chemical product manufacturing plant and business facility and added together. When abatement measure is not taken, emissions from each business facility can be approximated by the following equation.

Emissions = the amount of solvent and other product used × the content rate of the relevant material[1] - chemicals contained in wastewater

[1]: Chemical composition of the product is required. (See MSDS and others)

When the content rate of a solvent and its chemical composition are not available, activity data corresponding to an existing emission factor may be calculated from statistics and surveys, and multiply by an emission factor. If an emission abatement measure is implemented, emissions may be calculated by multiplying the efficiency of the emission abatement measure with the emission factor. The equation to calculate emissions is as follows.

$$\text{Emissions} = \sum \text{AD} \times (1-\eta) \times \text{EF} \quad \cdots\cdots (6.8\text{-}2)$$

Where:

Emissions: Emissions of air pollutants and Greenhouse gas
AD: Activity data for the solvent and other product use (production volume of industrial products)
EF: Emission factor for solvent and other product use
η: Removal rate by emission abatement

6.8.2.2 Estimation of activity data

The activity data includes total quantities of solvents used and products produced, and the number of car users. For plants of a certain scale and larger, data on product consumption should be collected by a questionnaire survey or fieldwork. For other facilities, data may be estimated by subtracting the portion of the large-scale facilities from the statistic data by sector.

Table 6.8-2 shows active data on air pollutant emissions from other product use.

Table 6.8-2 Solvent and other product use (other product use) activity data

Subcategory	activity data	Source of activity data	Note
Fat, edible and non-edible oil extraction	Consumption (kg)	Statistics of each country	
Preservation of wood	Use amount of creosote wood preservatives or preservative agents (kg)	Statistics of each country	
Underseal treatment and conservation of vehicles	Number of car owners	Statistics of each country	
Vehicle dewaxing	Number of car production	Statistics of each country, UN statistics	
Industrial application of adhesives	Use amount of adhesives (kg)	Statistics of each country	
Tobacco combustion	Tobacco consumption (ton)	Statistics of each country, UN statistics	

6.8.2.3 Setting of emission factors

Emission factors for coatings, metal and other surface treatment, dry cleaning, chemical product manufacturing, printing, household solvent use, and other product use are set as follows. The default values are average values in Europe and North America and the values should be applied with care. In addition, when an emission factor is obtained from actual estimation, that factor should be prioritized.

Table 6.8-3 shows emission factor for other product use.

Table 6.8-3 Emission factors for other product use

Subcategory	Technology identification	Emission factor	Unit
Fat, edible and non-edible oil extraction	NMVOC	3	g/kg seed
	TSP	1.1	g/kg seed
	PM_{10}	0.9	g/kg seed
	PM	0.6	g/kg seed
Preservation of wood	NMVOC	110	g/kg creosote
	Benzo(a)pyrene	0.5	mg/kg creosote
	Benzo(b)fluoranthene	0.25	mg/kg creosote
	Benzo(k)fluoranthene	0.25	mg/kg creosote
	Indeno(1,2,3-cd)pyrene	0.25	mg/kg creosote
Organic solvent borne preservatives	NMVOC	900	g/kg preservative
Water borne preservatives	NMVOC	0	g/kg preservative
Dewaxing of new vehicles following storage/transport	NMVOC	1	kg/car
Treatment of vehicles	NMVOC	0.2	kg/person/year
Industrial application of adhesives	NMVOC	780	g/kg adhesives
Tobacco combustion	NOx	3.5	g/ton tobacco
	CO	122	g/ton tobacco
	NMVOC	4.8	g/ton tobacco
	TSP	40	g/ton tobacco
	PM_{10}	40	g/ton tobacco
	$PM_{2.5}$	40	g/ton tobacco

Source: EMEP/EEA Guidebook

6.8.2.4 Emission abatement efficiency

Table 6.8-4 shows other product use (preservation of wood: creosote preservative type) abatement efficiency (η) by measure.

Table 6.8-4 Other product use (preservation of wood: creosote preservative type) abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Solvent management plan, good housekeeping - type controls	3
Enclosure of drying and other areas and venting through end-of-pipe controls such as condensation or incineration [1]	67

[1]: Assumes that solvent management plan/good housekeeping-type measures are also used.

Source: EMEP/EEA Guidebook

Table 6.8-5 shows other product use (preservation of wood: organic solvent borne preservatives) abatement efficiency (η) by measure.

Table 6.8-5 Other product use (Preservation of wood- organic solvent bourn preservative) abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Solvent management plan, good housekeeping - type controls	5
Enclosure of drying booth, venting through end-of-pipe controls such as condensation or incineration [1]	69

[1]: Assumes that solvent management plan/good housekeeping-type measures are also used.

Source: EMEP/EEA Guidebook

Table 6.8-6 shows other product use (fat, edible and non-edible oil extraction) abatement efficiency (η) by measure.

Table 6.8-6 Other product use (fat, edible and non-edible oil extraction) abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Traditional desolventiser with old hexane recovery section	73
Schumacher type desolventiser-toaster-dryer-cooler with old hexane recovery section	80
Schumacher type desolventiser-toaster-dryer-cooler with old hexane recovery section and process optimizations	83

Source: EMEP/EEA Guidebook

Table 6.8-7 shows abatement efficiency by measure (η) for other product use (industrial application of adhesives).

Table 6.8-7 Other product use (industrial application of adhesives) abatement efficiency by measure

Emission abatement technology	Efficiency (%)
Traditional solvent based adhesives (65% solvent, 35% solid), with activated carbon adsorption or condensation	76
Traditional solvent based adhesives (65% solvent, 35% solid), with thermal or catalytic incineration	76
Emulsions (2% solvent, 50% solid) without secondary abatement	98
Hot melts or UV cross-linking acrylates or electron beam curing systems (100% solid) without secondary abatement	100

6.8.2.5 Temporal change and spatial distribution

1. <u>Temporal change</u>

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. <u>Spatial distribution</u>

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

7 Estimating emissions of air pollutants coming from agriculture activities (livestock, agricultural waste, fertilizer)

7.1 Targets of estimation

Emission sources of air pollutants in agricultural activities can be classified as below by using 2006 IPCC Guidelines as reference. These categories are classified by emission source of a pollutant. For example, the emission of CH_4 from rice cultivation is considered to be in the agricultural land (land use) category because the emission is caused by activities of anaerobic methane bacterium.

1) Emissions of air pollutants from livestock
2) Emissions of air pollutants from agricultural land (land use)
3) Emissions of air pollutants from agricultural crops

These categories are classified into more detailed subcategories. In this guideline, the category in which only so-called greenhouse gases emit is not included in the calculation. The subcategories in the emission inventories from agricultural activities can be listed as in Table 7.1-1. For categories not included in the calculation, 2006 IPCC Guidelines, EMEP/EEA Guidebook, EMEP/CORINAIR Guidebook and AP-42 should be referred to.

Specifically, air pollutants from livestock manure management are NH_3, CH_4 and N_2O. Whereas, particulate matters take place from livestock housing. Land spreading of manures is a source of NO_x and NH_3 due to Nitrogen contained in manures. Also, land spreading of urea is a source of NH_3 and CO_2. Field burning in the Savanna and field burning of crop residues emit similar air pollutants: NO_x, SO_x, NH_3, CO, NMVOC, PM_{10}, $PM_{2.5}$, BC, OC, CH_4, and N_2O. The emission of CO_2 is not accounted for in these categories because the net emission of CO_2 for one year in this category is deemed zero.

Generally, emissions of air pollutants from the agriculture sector are calculated by multiplying the activity data with the relevant emission factor. The activity data include the total number of livestock, the amount of manure applied to land, the total area of field burning, the amount of crops harvested (estimated amount of crop residues burnt in the field based on the amount harvested), and the total area of agricultural land. For these activity data, relevant statistics of the country should be used in the calculation. However, these activity data can be obtained online from the FAOSTAT database.

The emission factors are listed from the results of the existing studies. Since many of these existing studies are based on the data on western countries, care should be taken in the application of such data to developing countries due to large uncertainty. In general, the western countries and Japan are in warm climates. When climate conditions are different, emission factors might be largely different. For this reason, when emission factors obtained in the country are available, those emission factors should be preferentially used.

Table 7.1-1 Categories of the air pollutant emission inventories from agricultural activities

Category	Subcategory	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Livestock	Manure Management					○							○	○
	Livestock housing						○	○	○					
	Enteric Fermentation												IPCC a)	
Land use (agricultural soils, savanna, grassland)	Fertilization		○			○						○		
	Field burning of savanna	○	○	○	○	○	○	○	○	○	○		○	○
	Land use without conversion											IPCC b)		
	Land use with conversion											IPCC b)		
	Emission of CH_4 in rice cultivation												IPCC a)	
	CO_2 emission from application of limestone											IPCC b)		
Crops	Field burning of crop residues	○	○	○	○	○	○	○	○	○	○		○	○

Note: “IPCC” is not included in calculation in this guideline and it is a subcategory that should be calculated referring to 2006 IPCC Guidelines.

a) Emission category only for CH_4, b) Emission category only for CO_2

7.2 Estimating emissions of air pollutants coming from livestock

This chapter covers the calculation of emissions coming from livestock feeding. These emissions can be classified into two main categories. That is, the emissions of ammonia, methane and nitric oxide from livestock manure management, and the emissions of particulate matters from livestock feeding. Emissions of CO_2 are not taken into consideration because the net amount of CO_2 emissions coming from livestock for one year is considered zero. For those who would like to further understand in detail the calculation method of CH_4 and N_2O, please refer to “Chapter 10: Emissions from livestock and manure management” in the volume 4 of 2006 IPCC Guidelines.

The emissions from livestock manure management are ones from the storage and disposal of excreta from the category of 10 species of livestock (dairy cows, other cattle, buffalo, pig, sheep, goats, and horses (mules and asses), poultry (broilers, ducks, and gooses), fur animals, and camels). The emission of ammonia is calculated by multiplying the number of livestock with an emission factor.

PM_{10} and $PM_{2.5}$ emissions from ventilated housing systems into the atmosphere are the main source of PM emissions from livestock feeding. The PM emissions from grazing animals are not included in this guideline because the emission factors are not reported. There are several sources of PM in buildings of housing animals: feed, feeding process, bedding materials such as straw or wood shavings, skin particles, faces, feathers, manure and re-suspension of previously settled dust by animal activity.

The most important air pollutant to be covered in this subcategory is NH_3, in addition to this, NO, particulate matters (PM_{10}, $PM_{2.5}$), and NMVOC. GHG such as CH_4 and N_2O are also emitted. The calculation method of these air pollutants are based on EMEP/EEA Guidebook, the calculation method of GHG is based on 2006 IPCC Guidelines.

7.2.1 Simple method

7.2.1.1 Outline of emission estimation method

Below are the procedures to calculate air pollutants from livestock.

Step 1 is to define main live stock categories in the targeted area and obtain the annual average population (AAP) of each category.

Step 2 is to find out the main manure management system for each livestock category.

Step 3 is the calculation of the pollutant emissions ($E_{\mathrm{pollutant\_animal}}$, kg yr^{-1}) using the respective annual average population of each category and a relevant emission factor (Table 7.2-1) of each manure management system.

$$E_{\mathrm{pollutant\_animal}} = AAP_{animal} \times EF_{\mathrm{pollutant\_animal}} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(7.2-1)}$$

$$AAP_{animal} = NAPA \times \left(Days\_alive/365\right) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(7.2-2)}$$

NAPA : number of animals produced annually

For example, when 60,000 broilers are fed annually and the average feeding period before slaughter is 60 days, the AAP is 60,000x60/365=9,863.

Emissions of greenhouse gases include direct and indirect emissions of N_2O and emissions of CH_4.

Direct N_2O emissions take place by combination of nitrification and denitrification of the bacterial processes in livestock manures. First, a precondition of N_2O generation is for nitrogen to be oxidized under an aerobic condition to generate nitrate. Then, Nitrate and nitrite are denitrified under an anaerobic condition and are emitted as N_2O and N_2.

Indirect N_2O emissions are emissions of N_2O formed from NH_3 and NO; NH_3 and NO are emitted into atmosphere through the volatilization during manure management processes and are deposited into soils and water; then NH_3 and NO form N_2O through denitrification after deposited into soils and water.

Direct N_2O emission E_{N2O_Direct} is calculated as follows:

$$E_{N2O\_Direct} = \sum_{system}\left[\sum_{animal} AAP_{animal} \times X_{animal,system} \times Nex_{animal}\right] \times EF_{N2O\_1,system} \quad \cdots\cdots\cdots\cdots\cdots(7.2\text{-}3)$$

Indirect N_2O emission $E_{N2O\_Indirect}$ is calculated as follows:

$$E_{N2O\_Indirect} = N_{volatalization} \times EF_{N2O\_2} \quad \cdots\cdots\cdots\cdots\cdots(7.2\text{-}4)$$

Here, NH_3-N+NO-N ($N_{volatilization}$), which is volatilized into the atmosphere during manure management processes, is expressed as follows:

$$N_{volatilization} = \sum_{system}\left[\sum_{animal} AAP_{animal} \times X_{animal,system} \times Nex_{animal} \times \frac{Frac_{volatil,animal,system}}{100}\right] \quad \cdots\cdots(7.2\text{-}5)$$

The parameters for these equations are as follows:

$X_{animal,\ system}$: proportion of livestock type "animals" and manure management system "system" (the total should be 1.)

Nex_{animal}: N-excretion rate of the livestock type "animals" (kg-N AAP^{-1} $year^{-1}$)

$EF_{N2O\_1,\ system}$: emission factor for direct N_2O emission from the manure management system "system" (kg-N_2O AAP^{-1} $year^{-1}$)

EF_{N2O_2} : N_2O emission factor for volatized N

(kg-N_2O (kg-NH_3-N+kg-NO-N)$^{-1}$; the default value is 0.0157.)

$Frac_{volatil,\ animal,\ system}$: fraction of volatile N (%) from manure management processes of the livestock type "animals" and manure management system "system" (Table 7.2-3)

CH_4 emissions are calculated as follows:

$$E_{CH4} = \sum_{animal} AAP_{animal} \times EF_{CH4,animal,temp} \quad \cdots\cdots\cdots\cdots\cdots(7.2\text{-}6)$$

$EF_{CH4,\ animal,\ temp}$: CH_4 emission factor (kg-CH_4 AAP^{-1} $year^{-1}$) of livestock type "animal" (Table 7.2-4 to Table 7.2-6)

7.2.1.2 Estimation of activity data

As already explained, the activity data are the annual average populations (AAP).

If available, inventory compilers should use the statistic information on the number of livestock animals from the official national statistics or relevant organizations. If the national data is not available, statistic information from the Food and Agriculture Organization of the United Nation (FAO) can be used.

7.2.1.3 Setting of emission factors

The emission factors of the air pollutants (Table 7.1-1) are mostly cited from EMEP/EEA Guidebook and the emission factors for greenhouse gases (Table 7.2-2 to Table 7.2-6) are cited from 2006 IPCC Guidelines.

Upon citing, the values from the Asia region were selected as much as possible, and the values in the Asia region were used for the N- excretion rate of livestock animals, which influence N spices pollutants.

Table 7.2-1 Emission factors for livestock manure management

Livestock	N Excretion Rate (kg-N AAp^{-1} yr^{-1}) [a]	Manure Type	NH_3 (kg AAP^{-1} yr^{-1}) [a]	NO (kg AAP^{-1} yr^{-1}) [a]	PM_{10} (kg AAP^{-1} yr^{-1})	$PM_{2.5}$ (kg AAP^{-1} yr^{-1})	NMVOC (kg AAP^{-1} yr^{-1})
Dairy cows	60.0	Slurry	22.4	0.004	0.36	0.23	13.6
	60.0	Solid	16.4	0.088	0.36	0.23	13.6
Other cattle (including young cattle,. beef cattle and suckling cows)	39.6	Slurry	10.5	0.002	0.24	0.16	7.4
	39.6	Solid	7.20	0.074	0.24	0.16	7.4
Fattening pigs	5.11	Slurry	2.76	0.0004	0.5	0.08	3.9
	5.11	Solid	2.68	0.019	0.5	0.08	3.9
Sows	5.11	Slurry	1.64	0.0004	0.58	0.09	13.3
	5.11	Solid	1.89	0.014	0.58	0.09	13.3
	5.11	Outdoor	0.76	0.000	NA	NA	NA
Sheep (and goats)	12.0	Solid	1.11	0.004	NE	NE	0.2
Horses (and mules, asses)	40.0	Solid	16.5	0.146	0.18	0.12	NE
Laying hens (laying hens and parents)	0.539	Solid	0.41	0.0026	0.017	0.002	0.3
	0.539	Slurry	0.41	0.0001	0.017	0.002	0.3
Broilers (broilers and parents)	0.361	Litter	0.22	0.001	0.052	0.007	0.1
Other poultry (ducks)	0.818	Litter	0.68	0.004	NA	NA	NA
Other poultry (geese)	NA	Litter	0.35	0.001	NA	NA	NA
Other poultry (turkeys)	1.837	Litter	0.95	0.005	0.032	0.004	0.9
Fur animals	4.59	Solid	0.02	0.0002	NA	NA	NA
Camels	36.4	Solid	12.72	NA	NA	NA	NA
Buffalo	44.4	Solid	NE	0.043	NE	NE	NE

Source: EMEP/EEA Guidebook

a: For the emission factors for NH_3 and NO, the emission factors based on N-excretion rate in Western Europe are adjusted with values in Asia.

Table 7.2-2 N_2O Emission factors for livestock manure management (direct emission)

Manure Management Category	Manure Management Sub-category	N_2O-N (kg-N AAP^{-1} yr^{-1})	N_2O (kg-N_2O AAP^{-1} yr^{-1})
Daily spread		0	0
Solid storage		0.005	0.008
Dry lot		0.02	0.03
Liquid/Slurry	With natural crust cover	0.005	0.008
	Without natural crust cover	0	0
Uncovered anaerobic lagoon		0	0
Pit storage below animal confinements		0.002	0.003
Anaerobic digester		0	0
Cattle and swine deep bedding	No mixing	0.01	0.02
	Mixing	0.07	0.11
Composting In-Vessel		0.006	0.009
Composting Static Pile		0.006	0.009
Composting Intensive Windrow		0.1	0.16
Composting Passive Windrow		0.01	0.02
Poultry manure with litter		0.001	0.002
Poultry manure without litter		0.001	0.002
Aerobic treatment	Natural aeration system	0.01	0.02
	Forced aeration system	0.005	0.008

Source: 2006 IPCC Guidelines, Volume 4, p10.62 to p10.64, Table 10.21

Table 7.2-3 N volatilization fraction from processes of livestock manure management

Animal type	Manure management system	N volatilization fraction as NH_3-N and NO-N (%)
Swine	Anaerobic lagoon	40
	Pit storage	25
	Deep bedding	40
	Liquid/slurry	48
	Solid storage	45
Dairy Cow	Anaerobic lagoon	35
	Liquid/Slurry	40
	Pit storage	28
	Dry lot	20
	Solid storage	30
	Daily spread	7
Poultry	Poultry without litter	55
	Anaerobic lagoon	40
	Poultry with litter	40
Other Cattle	Dry lot	30
	Solid storage	45
	Deep bedding	30
Other including sheep, horses, and fur-bearing animals	Deep bedding	25
	Solid storage	12

Source: 2006 IPCC Guidelines, Volume 4, p10.65, Table 10.22

Table 7.2-4 CH_4 Emission factors for livestock excreta management (Part 1)

Region	**Livestock Type**	**CH_4 emission factors by annual average temperature with degree C (kg-CH_4 animal^{-1} year^{-1})**																		
		Cool					**Temperate**											**Warm**		
		<=10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28<**
Asia	Dairy Cow	9	10	10	11	12	13	14	15	16	17	18	20	21	23	24	26	28	31	31
	Other Cattle	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Swine	2	2	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6	7	7
	Buffalo	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Source: 2006 IPCC Guidelines, Volume 4, p10.39, Table 10.14

*Except of Asia region only

Table 7.2-5 CH_4 Emission factors for livestock manure management (Part 2)

Livestock	**CH_4 emission factors by annual average temperature with degree C (kg-CH_4 animal^{-1} year^{-1})**		
	Cool (< 15°C)	**Temperate (15 to 25 °C)**	**Warm (25°C<)**
Sheep	0.10	0.15	0.20
Goats	0.11	0.17	0.22
Camels	1.28	1.92	2.56
Horses	1.09	1.64	2.19
Mules and Asses	0.60	0.90	1.20
Poultry	0.01	0.02	0.02

Source: 2006 IPCC Guidelines, Volume 4, p10.40, Table 10.15

*Excerpt of the section of developing countries

Table 7.2-6 CH_4 Emission factors for livestock manure management (Part 3)

Livestock type	CH_4 emission factor (kg-CH_4 anumal^{-1} year^{-1})
Deer	0.22
Reindeer	0.36
Rabbits	0.08
Fur-bearing animals like fox, mink etc.	0.68

Source: 2006 IPCC Guidelines, Volume4, p10.41, Table 10.16

7.2.1.4 Temporal change and spatial distribution

1. Temporal change

Basically, the emissions are evenly distributed to each time of the year. When the number of livestock is available over a period shorter than a year, the emissions are evenly distributed according to that temporal change. In doing so, attention must be paid to the fact that the above emission factors and the activity data are the figures per year.

2. Spatial distribution

The activity data for the calculation of air pollutants from livestock management is the annual average population (AAP) of livestock, and in general should be distributed based on the classified areas in the statistics on the number of livestock (by province and by municipality).

Article 7.2-1 Example of the estimation of air pollutants emission from livestock in Vietnam

The numbers of livestock (water buffalo, cows, pigs, poultry, horse, sheep and goats) in Vietnam are reported by province, district and nation. The number of dairy cows in 2005 is set at 107,609 heads according to "http://www.aphca.org/reference/Workshops_chiangmai_25-29-08/Presentation/Day1/3_Smallholder%20Dairy%20in%20Vietnam-Gautier.pdf#search='dairy cattle Vietnam". The number of other cattle in 2005 is set as 5,433.1 (thousand heads) after the deduction of the number of the dairy cattle from the number of total cattle, 5540.7 (thousand). Provided that this ratio between the dairy cattle and other cattle, 107.6: 5,433.1, does not change for the period from 2006 to 2008, the numbers of the dairy cattle and the other cattle were estimated by dividing the total number of cattle for the period from 2006 to 2008 using this ratio.

Table 7.2-7 shows the national figures on the numbers of livestock.

Table 7.2-7 Number of livestock fed in Vietnam

Livestock type	Unit	2005	2006	2007	2008
Water buffalo	1000 heads	2,922.2	2,921.1	2,996.4	2,897.7
Total cattle	1000 heads	5,540.7	6,510.8	6,724.7	6,337.7
Dairy cattle	1000 heads	107.6	126.5	130.6	123.1
Other cattle	1000 heads	5,433.1	6,384.4	6,594.1	6,214.6
Pigs	1000 heads	27,435.0	26,855.3	26,560.7	26,701.6
Poultry	1000 heads	219,911.0	214,565.0	226,027.0	247,310.0
Horse	1000 heads	110.5	87.3	103.5	121.0
Sheep and goats	1000 heads	1,314.1	1,525.3	1,777.7	1,483.5

NH_3 emission amount of Vietnam in 2008 is estimated as follows.

Emission factors in Table 7.2-1 are used. Pig and poultry are assumed fattening pig and laying hens, and manure type for dairy cattle, other cattle, and fattening pig are slurry.

Table 7.2-8 shows the result of the emission calculation for NH3 coming from livestock of Vietnam in 2008 based on the above conditions.

Table 7.2-8 Results of emission calculation for air pollutants from livestock in Vietnam

	Activity data 2008 (thosand head)	N Excretion Rate (kg-N AAp^{-1} yr^{-1})	Manure Type	NH_3 emission factor (kg AAP^{-1} yr^{-1})	NH_3 emission (ton/year)
Buffalo	2,897.70	44.4	Solid	NE	-
Dairy cows	123.09	60	Slurry	22.4	2,757.17
Other cattle (including young cattle,. beef cattle and suckling cows)	6,214.61	39.6	Slurry	10.5	65,253.43
Fattening pigs	26,701.60	5.11	Slurry	2.76	73,696.42
Laying hens (laying hens and parents)	248,320.00	0.539	Litter	0.41	101,811.20
Horses (and mules, asses)	121.20	40	Solid	16.5	1,999.80
Sheep (and goats)	1,483.40	12	Solid	1.11	1,646.57

7.2.2 Detailed method

7.2.2.1 Outline of emission estimation method

The detailed method is a bottom-up calculation method where: categories of livestock are refined into more detailed categories; locations of each livestock are identified; and the emissions of all subcategories are added up. The detailed method for CH_4 and N_2O emissions are Tier 2 or Tier 3 in 2006 IPCC Guidelines. For more detail, please refer to “Chapter 10: Emissions from livestock and manure management” in the volume 4 of 2006 IPCC Guidelines.

Tier 2 method in EMEP/EEA Guidebook is adopted as a detailed method for estimating emissions of air pollutants. Below are its processes:

Step 1 is the definition of categories and subcategories with regards to types of livestock and manure management system, and the respective number of the animals has to be obtained.
Step 2 is the calculation of the total annual N-excretion by the livestock type. (N_{ex}).
Step 3 is to calculate the amount of the annual N excreted that is deposited in buildings in which livestock are housed, on uncovered yards and during grazing. This is based on the total annual N excretion (N_{ex}) and the proportions of excreta deposited at these locations (x_{build}, x_{yard}, and x_{graz}). Total of x_{build}, x_{yard}, and x_{graz} should be always 1.0.

$$m_{graz\_N} = x_{graz} \times N_{ex} \quad \cdots (7.2\text{-}7)$$

$$m_{yard\_N} = x_{yard} \times N_{ex} \quad \cdots (7.2\text{-}8)$$

$$m_{build\_N} = x_{build} \times N_{ex} \quad \cdots (7.2\text{-}9)$$

Step 4 is to use the proportion of the N excreted as TAN (total ammoniac nitrogen) to calculate the amount of TAN deposited during gazing, on yards, or in buildings.

$$m_{graz\_TAN} = x_{TAN} \times m_{graz\_N} \quad \cdots (7.2\text{-}10)$$

$$m_{yard\_TAN} = x_{TAN} \times m_{yard\_N} \quad \cdots (7.2\text{-}11)$$

$$m_{build\_TAN} = x_{TAN} \times m_{build\_N} \quad \cdots (7.2\text{-}12)$$

Step 5 is to calculate the amounts of TAN and total-N deposited in buildings handled as liquid slurry ($m_{build\_slurry\_TAN}$) or as solid ($m_{build\_solid\_TAN}$). Here, x_{slurry} is the proportion of livestock manure handled as slurry.

$$m_{build\_slurry\_TAN} = x_{slurry} \times m_{build\_TAN} \quad \cdots (7.2\text{-}13)$$

$$m_{build\_slurry\_N} = x_{slurry} \times m_{build\_N} \quad \cdots (7.2\text{-}14)$$

$$m_{build\_solid\_TAN} = (1 - x_{slurry}) \times m_{build\_TAN} \quad \cdots (7.2\text{-}15)$$

$$m_{build\_solid\_N} = (1 - x_{slurry}) \times m_{build\_N} \quad \cdots (7.2\text{-}16)$$

Step 6 is to calculate the NH_3-N losses, E_{build}, from the livestock building and from the yards, by multiplying the amount of TAN m_{build_TAN} with the emission factor EF_{build} (NH_3-N) for both slurry and farmyard manure (FYM).

$$E_{build\_slurry} = m_{build\_slurry\_TAN} \times EF_{build\_slurry} \quad \cdots (7.2\text{-}17)$$

$$E_{build\_solid} = m_{build\_solid\_TAN} \times EF_{build\_solid} \quad \cdots (7.2\text{-}18)$$

$$E_{yard} = m_{yard\_TAN} \times EF_{yard} \quad \cdots (7.2\text{-}19)$$

S***tep 7*** is only applied to solid manure. When manure in buildings is managed as solid, the fraction of TAN in the manure is immobilized in organic matter. On the other hand, N in straw used for bedding for the animals is added. By adding these two processes to the amount of the NH_3-N losses, the amounts of total-N applied as fertilizer after the solid processing and TAN are calculated. Where, f_{imm} is the fraction of TAN immobilized, and the default value is 0.0067 (kg kg^{-1}).

$$m_{ex\text{-}build\_solid\_TAN} = (m_{build\_solid\_TAN} - E_{build\_solid}) \times (1 - f_{imm}) \quad \cdots (7.2\text{-}20)$$

$$m_{bedding\_N} = AAP \times Straw \times N_{Straw} \quad \text{(7.2-21)}$$

$$\mathrm{m}_{\text{ex-build\_solid\_N}} = \left\lfloor \mathrm{m}_{\text{build\_solid\_N}} + \mathrm{m}_{\text{bedding\_N}} - \mathrm{E}_{\text{build\_solid}} \right\rfloor \quad \text{(7.2-22)}$$

Table 7.2-9 Default values for length of housing period, annual straw use in litter-based manure management systems and the N content of straw

Livestock	Housing period Days	Straw amount kg AAP^{-1} year^{-1}	N added in straw kg AAP^{-1} year^{-1}
Dairy cows	180	1500	6.00
Other cattle	180	500	2.00
Finishing pigs	365	200	0.80
Sows	365	600	2.40
Sheep and goats	30	20	0.08
Horses etc.	180	500	2.00
Buffalos	225	1500	6.00

Source: EMEP/EEA Guidebook, p22, Table 3-6

Step 8 is to calculate the amounts of total-N and TAN stored before application to land. Not all manures are stored before spreading; some will be applied to fields direct from buildings. Here, $\mathrm{x}_{\text{sotre\_slurry}}$ and $\mathrm{x}_{\text{store\_solid}}$ are proportions of “slurry” and “solid” stored before application to land.

For slurry:

$$\mathrm{m}_{\text{storage\_slurry\_TAN}} = \left\lfloor \left(\mathrm{m}_{\text{build\_slurry\_TAN}} - \mathrm{E}_{\text{build\_slurry}}\right) + \left(\mathrm{m}_{\text{yard\_TAN}} - \mathrm{E}_{\text{yard}}\right)\right\rfloor \times \mathrm{x}_{\text{store\_slurry}} \quad \text{(7.2-23)}$$

$$\mathrm{m}_{\text{storage\_slurry\_N}} = \left\lfloor \left(\mathrm{m}_{\text{build\_slurry\_N}} - \mathrm{E}_{\text{build\_slurry}}\right) + \left(\mathrm{m}_{\text{yard\_N}} - \mathrm{E}_{\text{yard}}\right)\right\rfloor \times \mathrm{x}_{\text{store\_slurry}} \quad \text{(7.2-24)}$$

$$\mathrm{m}_{\text{spread\_direct\_slurry\_TAN}} = \left\lfloor \left(\mathrm{m}_{\text{build\_slurry\_TAN}} - \mathrm{E}_{\text{build\_slurry}}\right) + \left(\mathrm{m}_{\text{yard\_TAN}} - \mathrm{E}_{\text{yard}}\right)\right\rfloor \times \left(1 - \mathrm{x}_{\text{store\_slurry}}\right) \quad \text{(7.2-25)}$$

$$\mathrm{m}_{\text{spread\_direct\_slurry\_N}} = \left\lfloor \left(\mathrm{m}_{\text{build\_slurry\_N}} - \mathrm{E}_{\text{build\_slurry}}\right) + \left(\mathrm{m}_{\text{yard\_N}} - \mathrm{E}_{\text{yard}}\right)\right\rfloor \times \left(1 - \mathrm{x}_{\text{store\_slurry}}\right) \quad \text{(7.2-26)}$$

For solid:

$$\mathrm{m}_{\text{storage\_solid\_TAN}} = \mathrm{m}_{\text{ex-build\_solid\_TAN}} \times \mathrm{x}_{\text{store\_solid}} \quad \text{(7.2-27)}$$

$$\mathrm{m}_{\text{storage\_solid\_N}} = \mathrm{m}_{\text{ex-build\_solid\_N}} \times \mathrm{x}_{\text{store\_solid}} \quad \text{(7.2-28)}$$

$$\mathrm{m}_{\text{spread\_direct\_solid\_TAN}} = \mathrm{m}_{\text{ex-build\_solid\_TAN}} \times \left(1 - \mathrm{x}_{\text{store\_solid}}\right) \quad \text{(7.2-29)}$$

$$\mathrm{m}_{\text{spread\_direct\_solid\_N}} = \mathrm{m}_{\text{ex-build\_solid\_N}} \times \left(1 - \mathrm{x}_{\text{store\_solid}}\right) \quad \text{(7.2-30)}$$

Step 9 is only applied to slurries and its function is to calculate the amount of TAN from slurry stores. When slurries are stored, a fraction of the organic N is mineralized to TAN. $f_{\min}$ is the ratio of mineralization and the default value is o0.1.

$$mm_{\mathrm{storage\_slurry\_TAN}} = m_{\mathrm{storage\_slurry\_TAN}} + \left\lfloor \left(m_{\mathrm{storage\_slurry\_N}} - m_{\mathrm{storage\_slurry\_TAN}} \right) \times f_{\min} \right\rfloor \cdots\cdots\cdots\cdots (7.2\text{-}31)$$

Step 10 is to calculate the emissions of NH_3, N_2O, NO and N_2 from stored slurries and solids. The emission factors for these are emission proportions of each air pollutant to TAN. (Table 7.2-10 to Table 7.2-12)

For slurry:

$$\begin{aligned} E_{\mathrm{storage\_slurry}} &= E_{\mathrm{storage\_slurry\_NH3}} + E_{\mathrm{storage\_slurry\_N2O}} + E_{\mathrm{storage\_slurry\_NO}} + E_{\mathrm{storage\_slurry\_N2}} \\ &= mm_{\mathrm{strage\_slurry\_TAN}} \times \left(EF_{\mathrm{storage\_slurry\_NH3}} + EF_{\mathrm{storage\_slurry\_N2O}} + EF_{\mathrm{storage\_slurry\_NO}} + EF_{\mathrm{storage\_slurry\_N2}} \right) \end{aligned} \cdots\cdots\cdots\cdots (7.2\text{-}32)$$

For solid:

$$\begin{aligned} E_{\mathrm{storage\_solid}} &= E_{\mathrm{storage\_solid\_NH3}} + E_{\mathrm{storage\_solid\_N2O}} + E_{\mathrm{storage\_solid\_NO}} + E_{\mathrm{storage\_solid\_N2}} \\ &= mm_{\mathrm{strage\_solid\_TAN}} \times \left(EF_{\mathrm{storage\_solid\_NH3}} + EF_{\mathrm{storage\_solid\_N2O}} + EF_{\mathrm{storage\_solid\_NO}} + EF_{\mathrm{storage\_solid\_N2}} \right) \end{aligned} \cdots\cdots\cdots\cdots (7.2\text{-}33)$$

Step 11 is to calculate the total-N and TAN that is applied the field ($m_{\mathrm{applic\_N}}$ and $m_{\mathrm{applic\_TAN}}$).

Fro slurry

$$m_{\mathrm{applic\_slurry\_TAN}} = m_{\mathrm{spread\_direcr\_slurry\_TAN}} + mm_{\mathrm{storage\_slurry\_TAN}} - E_{\mathrm{storage\_slurry}} \cdots\cdots\cdots\cdots (7.2\text{-}34)$$

$$m_{\mathrm{applic\_slurry\_N}} = m_{\mathrm{spread\_direcr\_slurry\_N}} + mm_{\mathrm{storage\_slurry\_N}} - E_{\mathrm{storage\_slurry}} \cdots\cdots\cdots\cdots (7.2\text{-}35)$$

For solid:

$$m_{\mathrm{applic\_solid\_TAN}} = m_{\mathrm{spread\_direct\_solid\_TAN}} + mm_{\mathrm{storage\_solid\_TAN}} - E_{\mathrm{storage\_solid}} \cdots\cdots\cdots\cdots (7.2\text{-}36)$$

$$m_{\mathrm{applic\_solid\_N}} = m_{\mathrm{spread\_direct\_solid\_N}} + mm_{\mathrm{storage\_solid\_N}} - E_{\mathrm{storage\_solid}} \cdots\cdots\cdots\cdots (7.2\text{-}37)$$

Step 12 is to calculate the emission of NH_3-N during and immediately after field application.

For slurry:

$$E_{\mathrm{applic\_slurry}} = m_{\mathrm{appric\_slurry\_TAN}} \times EF_{\mathrm{applic\_slurry}} \cdots\cdots\cdots\cdots (7.2\text{-}38)$$

For solid:

$$E_{\mathrm{applic\_solid}} = m_{\mathrm{appric\_solid\_TAN}} \times EF_{\mathrm{applic\_solid}} \cdots\cdots\cdots\cdots (7.2\text{-}39)$$

Step 13 is to calculate the net amount of N returned to soil from manure ($m_{\mathrm{returned\_N}}$ and $m_{\mathrm{returned\_TAN}}$).

For slurry:

$$m_{\mathrm{returned\_slurry\_TAN}} = m_{\mathrm{appric\_slurry\_TAN}} - E_{\mathrm{applic\_slurry}} \cdots\cdots\cdots\cdots (7.2\text{-}40)$$

$$m_{\mathrm{returned\_slurry\_N}} = m_{\mathrm{appric\_slurry\_N}} - E_{\mathrm{applic\_slurry}} \cdots\cdots\cdots\cdots (7.2\text{-}41)$$

For solid:

$$m_{\mathrm{returned\_solid\_TAN}} = m_{\mathrm{appric\_solid\_TAN}} - E_{\mathrm{applic\_solid}} \cdots\cdots\cdots\cdots (7.2\text{-}42)$$

$$m_{\mathrm{returned\_solid\_N}} = m_{\mathrm{appric\_solid\_N}} - E_{\mathrm{applic\_solid}} \quad \cdots\cdots (7.2\text{-}43)$$

Step 14 is to calculate the NH_3-N emissions from grazing

$$E_{\mathrm{graz}} = m_{\mathrm{graz\_TAN}} \times EF_{\mathrm{grazing}} \quad \cdots\cdots (7.2\text{-}44)$$

Step 15 is to sum all the emissions from the manure management system and convert them to the amounts of NH_3 and NO.

$$E_{\mathrm{MMS\_NH3}} = \begin{pmatrix} E_{\mathrm{yard}} + E_{\mathrm{build\_slurry}} + E_{\mathrm{build\_solid}} + \\ E_{\mathrm{storage\_NH3\_slurry}} + E_{\mathrm{storage\_NH3\_solid}} + E_{\mathrm{applic\_slurry}} + E_{\mathrm{applic\_solid}} \end{pmatrix} \times \frac{17}{14} \quad \cdots\cdots (7.2\text{-}45)$$

$$E_{\mathrm{MMS\_NO}} = \left(E_{\mathrm{storage\_NO\_slurry}} + E_{\mathrm{storage\_NO\_solid}} \right) \times \frac{30}{14} \quad \cdots\cdots (7.2\text{-}46)$$

7.2.2.2 Estimation of activity data

When the detailed method is applied, it is necessary to obtain detailed input data on livestock and the manure management system such as the grazing period (x_{graz}), the length of housing period (x_{build}), and the length spend on yards (x_{yard}) of each type of livestock, the ratio of the manure stored as slurry. Such data needs to be obtained by fieldwork such as interviews in the local areas.

7.2.2.3 Setting of emission factors

Table 7.2-10 to Table 7.2-12 show the default emission factors used in the detailed methods.

Table 7.2-10 NH_3 emission factors in detailed method

Livestock	Housing period (day year^{-1})	N_{ex} (kg N AAP^{-1} year^{-1})	Proportion of TAN	Manure type	EF housing	EF Yard	EF Storage	EF Spreading	EF grazing/ outdoor
Dairy cow	180	105	0.6	Slurry	0.20	0.30	0.20	0.55	0.10
				Solid	0.19	0.30	0.27	0.79	0.10
Other cattle (young cattle, beef cattle and suckling cows)	180	41	0.6	Slurry	0.20	0.53	0.20	0.55	0.06
				Solid	0.19	0.53	0.27	0.79	0.06
Fattening pig (8-110 kg)	365	12.1	0.7	Slurry	0.28	0.53	0.14	0.40	
				Solid	0.27	0.53	0.45	0.81	
Sows (and piglets to 8 kg)	365	34.5	0.7	Slurry	0.28	0.53	0.14	0.40	
				Solid	0.27	0.53	0.45	0.81	
	0			Outdoor	NA	NA	NA	NA	0.25
Sheep (and goats)	30	15.5	0.5	Solid	0.22	0.75	0.28	0.90	0.09
Horses (and mules, asses)	180	47.5	0.6	Solid	0.22	NA	0.35	0.90	0.35
Laying hens (laying hens and parents)	365	0.77	0.7	Solid, can be stacked	0.41	NA	0.14	0.69	
Laying hens (laying hens and parents)	365	0.36	0.7	slurry, can be pumped	0.41	NA	0.14	0.69	
Broilers (broilers and parents)	365	1.64	0.7	Solid	0.28	NA	0.17	0.66	
Other poultry (turkeys)	365	1.64	0.7	Solid	0.35	NA	0.24	0.54	
Other poultry (ducks)	365	1.26	0.7	Solid	0.24	NA	0.24	0.54	
Other poultry (geese)	365	0.55	0.7	Solid	0.57	NA	0.16	0.45	
Fur animals	365	0.08	0.6	Solid	0.27	NA	0.09	NA	
Buffalo	140	82.0	0.5	Solid	0.20	NA	0.17	0.55	0.13

Source: EMEP/EEA Guidebook, p26, Table 3-8

Table 7.2-11 NO, N_2 emission factors in detailed method

	Proportion to TAN
$EF_{storage\_slurryNO}$	0.0001
$EF_{storage\_slurryN2}$	0.0030
$EF_{storage\_solidNO}$	0.0100
$EF_{storage\_solidN2}$	0.3000

Source: EMEP/EEA Guidebook, p27, Table 3-9

Table 7.2-12 N_2O emission factor in detailed method

	EF kg N_2O-N (kg TAN entering store)$^{-1}$
Cattle Slurry without natural crust	0
Cattle slurry with natural crust	0.01
Pig slurry without natural crust	0
Cattle manure heaps, solid	0.08
Pig manure heaps, solid	0.05
Sheep and goat manure heaps, solid	0.07
Horse (mules and asses) manure heaps, solid	0.08
Layer manure heaps, solid	0.04
Broiler manure heaps, solid	0.03
Turkey and duck manure heaps, solid	0.03
Goose manure heaps, solid	0.03
Buffalo manure heaps, solid	0.08

Source: EMEP/EEA Guidebook, p24, Table 3-7

7.2.2.4 Temporal change and spatial distribution

1. *Temporal change*

If the hourly and seasonal information on livestock grazing, feeding on yards and in buildings, the hourly and seasonal information of manure management are available along with the emission calculation using the detailed method, the temporal change can be made more detailed.

2. ***Spatial distribution***

If statistics on the numbers of animals for each region, the accurate locations of and numbers of animals at large-scale livestock farms can be obtained, more detailed spatial distribution can be set.

7.3 Estimating emissions of air pollutants from agricultural soils

A fraction of N contained in various fertilizers is mostly emitted into the atmosphere as NH_3 and NO. The emissions of ammonia from such source are influenced by the types and amounts of the fertilizers, methods and timing of fertilizer application, types of soils where fertilizers are applied to, and climate factors. The missions of nitrogen oxide (NO) can be easily calculated as a fraction of the total amount of nitrogen fertilizers applied.

Emissions caused by livestock excreta including emissions of N-spices air pollutants such as NH_3 and NO are calculated in “7.2 Estimating emissions of air pollutants from livestock”. Nitrogen emissions caused by the application of manures to agricultural lands including fruit farms are calculated in this section, and nitrogen emissions from other natural soils are calculated in “10.3 Estimating emissions of NH_3 and NOx from soils.”

According to the above, the nitrogen emission from grassland is dealt in 7.2, and cropland in 7.3, other land use in 10.3.

NMVOC emissions from crops in cropland are calculated in “10.1 Estimating NMVOC emissions from vegetation.”

7.3.1 Simple method

7.3.1.1 Outline of emission estimation method

There are two simple methods for NH_3 and NO, and PM.

Below is the equation for NH_3 and NO:

$$\mathrm{Emissions} = \mathrm{AD}_{\mathrm{afertiliser\_applied}} \times \mathrm{EF}_{\mathrm{pollutant}} \quad \cdots\cdots(7.3\text{-}1)$$

Where:

$\mathrm{Emissions}$: Amount of pollutant (NH_3 or NO) emissions (kg yr^{-1})

$\mathrm{AD}_{\mathrm{afertiliser\_applied}}$: Amount of N applied as fertilizer (kg yr^{-1})

$\mathrm{EF}_{\mathrm{pollutant}}$: Emission factor of pollutant (kg ha^{-1} yr^{-1})

Below is the equation for PM:

$$\mathrm{Emissions} = \mathrm{AD}_{\mathrm{area}} \times \mathrm{EF}_{\mathrm{pollutant}} \quad \cdots\cdots(7.3\text{-}2)$$

Where:

$\mathrm{Emissions}$: Amount of pollutant (PM) emissions (kg yr^{-1})

$\mathrm{AD}_{\mathrm{area}}$: Activity data (area size of cropland) (ha)

$\mathrm{EF}_{\mathrm{pollutant}}$: Emission factor of pollutant (kg ha^{-1} yr^{-1})

7.3.1.2 Estimation of activity data

The activity data for NH_3 and NO is the amount of N applied as fertilizer, and the activity data for PM_{10} and $PM_{2.5}$ is area size of cropland. These statistics for the activity data should be collected according to Table 7.3-1.

Table 7.3-1 Source candidates of activity data

Activity data item	Examples of relevant organizations for activity data source
Amount of nitrogen fertilizers and cropland area size	1) Statistics of the country 2) Questionnaire survey to relevant organizations in the country 3) International statistics (Ex: FAOSTAT)

Note: FAOSTAT: http://faostat.fao.org./site/575/default.aspx

7.3.1.3 Setting of emission factors

Table 7.3-2 shows emission factors for the simple method.

Table 7.3-2 Emission factors for air pollutants from use of fertilizer

Pollutant	Emission factor	Unit
NH_3	0.084	kg kg^{-1} fertilizer-N applied
NO	0.026	kg kg^{-1} fertilizer-N applied
PM_{10}	1.56	kg/ha
$PM_{2.5}$	0.06	kg/ha

Source: Table 3-1 in “4.D. Crop production and agricultural soils”, EMEP/EEA Guidebook

7.3.1.4 Temporal change and spatial distribution

1. *Temporal change*

NH_3 and NO are distributed based on the time of application of fertilizers containing nitrogen, and PM is distributed based on the time of soil cultivation and harvesting.

2. *Spatial distribution*

NH_3, NO and PM are both distributed to cropland.

7.3.2 Detailed method

7.3.2.1 Outline of emission estimation method

Tier 2 method in EMEP/EEA Guidebook is adopted as detailed method for estimating emissions of NH_3 and PM.

1. NH_3

Below are the procedures for estimating NH_3 emissions:

Step 1 is to partition the total area to which N fertilizer is applied into three regions according to mean spring air temperature (t_s). Three region partitions are: a region with the mean spring air temperature of 6°C and below, a region with the mean spring temperature between 6°C and 13°C, and a region with the mean spring temperature over 13.

Step 2 is to use the following equation to estimate emissions from each type of N fertilizer in each of the regions and sum up. Here, the emission factor is a function of a fertilizer type and the mean spring air temperature. Furthermore, when the pH of soil is over 7.0, the emission factor is multiplied by a multiplier. (Table 7.3-3)。

$$E_{fert\_NH3} = \sum_{i=1}^{I}\sum_{j=1}^{J}\left\{m_{fert\_i\_j} \times EF_{i\_j} \times \left[1 - p_{alk\_j} \times \left(1 - c_i\right)\right]\right\} \cdots\cdots (7.3\text{-}3)$$

E_{fert_NH3} : NH_3 emissions (kg-NH_3 year^{-1})

$m_{fert\_i\_j}$: mass of fertilizer-N applied as type i in region j (kg-N year^{-1})

EFi_j : Emission factor for fertilizer type i in region j (kg-NH_3 (kg-N)$^{-1}$)

p_{alk_j} : proportion of region j where the soil pH is over 7.0

c_i : soil pH multiplier for fertilizer type i when the soil pH is over 7.0

2. PM

As shown in the following equation, emissions should be calculated by multiplying the cultivated area of each crop by an EF for each crop and agricultural operation. For each agricultural operation, the number of times that each operation is carried out should be taken into account.

$$E_{PM} = \sum_{i=1}^{I}\sum_{n=0}^{N_{i\_k}} EF_{PM\_i\_k} \times A_i \times n \cdots\cdots (7.3\text{-}4)$$

E_{PM} : annual amount of emission of PM10 or PM2.5 from crop i (kg year^{-1})

I : number of crops grown

A_i : annual cropped area of crop i (ha)

N_{i_k} : number of times operation k is performed on crop i (year^{-1})

$EF_{PM\_i\_k}$: PM emission factor for operation k of the crop i (kg ha^{-1})

7.3.2.2 Estimation of activity data

1. NH_3

One of necessary activity data to estimate detailed NH_3 emissions is the amount of each fertilizer applied, which should be collected from the official country statistic of the country. The statistics may include sales, domestic production and imports of fertilizers. Also, the data from IFIA (International Fertilizer Industry Association) and FAO (the Food and Agriculture Organization of the United Nations) can be used.

In order to classify croplands by mean spring air temperature, the GIS data of cropland distribution and meteorological observation data may be used. Each cropland can be classified by allocating the mean spring air temperature of a nearby meteorological observation point to see the cropland is included in that region.

It is desirable to use GIS data on geological distribution (for example, calcareous soil) regarding pH level of soils.

In addition, it is effective to investigate by interviews and questionnaire surveys whether there is any relation among crops and cropland and fertilizers used.

2. PM

Necessary activity data to estimate more detailed PM emissions is the area covered by each crop, and statistics on area covered by each crop in each regions and GIS data on the distribution of agricultural lands may be used.

On the other hand, the times of each crop operation for each crop carried out in a year need to rely on interviews and questionnaire surveys.

7.3.2.3 Setting of emission factors

1. NH_3

Table 7.3-3 shows Emission factor estimation equation and multipliers for NH_3.

Table 7.3-3 Emission factor estimation equation and multipliers for NH_3

Fertilizer type	Emission factor estimation equation for NH_3 EF (kg-NH_3 (kg-N)$^{-1}$) ts: average temperature in spring (°C)	Multiplier $^{1)}$ c_i
Ammonium sulphate	EF=0.0107+0.0006 ts	10
Ammonium nitrate	EF=0.0080+0.0001 ts	1
Calcium ammonium nitrate	EF=0.0080+0.0001 ts	1
Anhydrous ammonia	EF=0.0127+0.0012 ts	4
Urea	EF=0.1067+0.0035 ts	1
Nitrogen solutions	EF=0.0481+0.0025 ts	1
Ammonium phosphates	EF=0.0107+0.0006 ts	10
Other NK and NPK	EF=0.0080+0.0001 ts	1

1) When the pH level of solid is over 7.0, a multiplier is applied.

Source: EMEP/EEA Guidebook “4.D Crop production and agricultural soils”, Table 3-2

2. PM

Table 7.3-4 to Table 7.3-7 show PM emission factors for each crop and agricultural operation. Drying climate means Mediterranean climate and other climates belong to wet climate.

Table 7.3-4 PM_{10} emission factors for agricultural crop operations (kg ha^{-1}) (wet climate)

Crop type	Soil cultivation	Harvesting	Cleaning	Drying
Wheat	0.25	0.49	0.19	0.56
Rye	0.25	0.37	0.16	0.37
Barley	0.25	0.41	0.16	0.43
Oat	0.25	0.62	0.25	0.66
Other Arable	0.25	NA	NA	NA
Grass(1)	0.25	0.25	0	0

Table 7.3-5 PM_{10} emission factors for agricultural crop operations (kg ha^{-1}) (dry climate)

Crop type	Soil cultivation	Harvesting	Cleaning	Drying
Wheat	2.25	2.45	0.19	0
Rye	2.25	1.85	0.16	0
Barley	2.25	2.05	0.16	0
Oat	2.25	3.10	0.25	0
Other Arable	2.25	NA	NA	NA
Grass(1)	2.25	1.25	0	0

Table 7.3-6 $PM_{2.5}$ emission factors for agricultural crop operations (kg ha^{-1}) (dry climate)

Crop type	Soil cultivation	Harvesting	Cleaning	Drying
Wheat	0.15	0.020	0.009	0.168
Rye	0.15	0.015	0.008	0.111
Barley	0.15	0.016	0.008	0.129
Oat	0.15	0.025	0.0125	0.198
Other Arable	0.15	NA	NA	NA
Grass(1)	0.15	0.010	0	0

Table 7.3-7 $PM_{2.5}$ emission factors for agricultural crop operations (kg ha^{-1}) (wet climate)

Crop type	Soil cultivation	Harvesting	Cleaning	Drying
Wheat	0.12	0.098	0.0095	0
Rye	0.12	0.074	0.008	0
Barley	0.12	0.082	0.008	0
Oat	0.12	0.125	0.0125	0
Other Arable	0.12	NA	NA	NA
Grass(1)	0.12	0.05	0	0

1) Grass includes hay making only.

Source: Tables 3-3 to 3-6, in "4.D Crop production and agricultural soils", EMEP/EEA Guidebook

7.3.2.4 Temporal change and spatial distribution

1. *Temporal change*

NH_3 is distributed based on the time of the application of fertilizers, and PM is distributed based on the time of each agricultural operation.

2. *Spatial distribution*

NH_3 is assigned based on area classification by cropland and mean spring temperature and the distribution of alkaline soils and PM is assigned based on the distribution of cropland by crop.

7.4 Estimating emissions of air pollutants from field burning in savanna

In savanna, fire is opened on purpose mostly for agricultural reasons in dry season. The agricultural reasons include removal of weeds and pest, facilitation of nutrient cycling, and growth promotion of grass for glazing. Field burning in savanna, which occur an average of once in one to four years, are potential combustion source of CO, NO_x, NMVOC, PM, SO_2, and NH_3. In order to estimate the emissions from this source, area of field burning, load of biomass fuel, ratio of fuel in filed burning, and emission factor of each pollutant need to be taken into consideration.

7.4.1 Simple method

7.4.1.1 Outline of emission estimation method

In this guideline, the annual emissions from field burning in savanna are estimated as in the following steps:

1) Estimate the amount of biomass combustion based on the area of savanna burnt in the inventory year, fuel load biomass (different from total above ground biomass), and proportion of biomass burnt (dry matter)
2) Estimate the emission of each pollutant by multiplying the amount of combusted biomass with the emission factors of each pollutant (CO, NO_x, SO_2, NMVOCs, particulate matter (PM_{10} and $PM_{2.5}$), NH_3 and greenhouse gases)

Blow is the general equation to estimate each air pollutant and greenhouse gases from field burning in savanna.

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3} \cdots\cdots (7.4\text{-}1)$$

Where:

L_{fire}: emissions from field burning in savanna (for each pollutant, tons per year)

A: area burnt (ha)

M_B: mass of fuel actually combusted (tones ha^{-1}). This includes biomass, underground litter and dead wood.

C_f: combustion factor (dimensionless) (default values in Table 7.4-2)

G_{ef}: emission factor (g/kg dry matter burnt) (default values in Table 7.4-3)

Note: Where data for M_B and C_f are not available, a default value for the amount of fuel actually burnt (the product of M_B and C_f) can be used (Table 7.4-1).

7.4.1.2 Estimation of activity data

For the calculation process for the activity data, the following equation by IPCC is adopted.

$$AD_{fire} = A \times M_B \times C_f \cdots\cdots (7.4\text{-}2)$$

Where:

AD_{fire}: activity data on field burning in savanna

A: area burnt (ha)

M_B: mass of fuel for combustion (tones ha^{-1}). This includes biomass, underground litter and dead wood.

C_f: Combustion factor (dimensionless) (default values in Table 7.4-2)

Note: Where data for M_B and C_f are not available, a default value for the amount of fuel actually burnt (the product of M_B and C_f) can be used (Table 7.4-1).

The amount of fuel that can be burnt is given by the area burnt and the density of fuel present on that area. The fuel density can include biomass, dead wood and litter. The type of fire is also affected by the amount of fuel available for combustion.

The combustion factor is a measure of the proportion of the fuel that is actually combusted, which varies as a function of the size and architecture of the fuel load (i.e., a smaller proportion of large, coarse fuel such as tree stems will be burnt compared to fine fuels, such as grass leaves), the moisture content of the fuel and the type of fire (i.e., intensity and rate of spread which is markedly affected by climatic variability and regional differences as reflected in Table 7.4-2).

Table 7.4-1 Fuel biomass consumption in field burning on Savanna (Unit: tones dry Matter/ha)

Vegetation Type	Subcategory	Factor
Savanna woodlands (early dry season burns)	Savanna woodland	2.5
	Savanna parkland	2.7
All savanna woodlands (early dry season burns)		2.6
Savanna woodlands (mid/late dry season burns)	Savanna woodland	3.3
	Savanna parkland	4.0
	Tropical savanna	6
	Other savanna woodlands	5.3
Savanna Grassland /Pastures (mid/late dry season burns)		4.6
Savanna Grasslands/ Pastures (early dry season burns)	Tropical/ sub-tropical grassland	2.1
	Grassland	-
All savanna grassland (early dry season burns)		2.1
Savanna Grasslands/ Pastures (mid/late dry season burns)	Tropical/ sub-tropical grassland	5.2
	Grassland	4.1
	Tropical pasture	23.7
	Savanna	7.0
All savanna grasslands (mid/late dry season burns)		10.0

Excerpt of surface only

Source: 2006 IPCC Guidelines, Volume 4, Chapter 2, Table 2.4

Table 7.4-2 Ratio of fuel in field burning in Savanna (dimensionless)

Vegetation Type	Subcategory	Mean
Savanna woodlands (early dry season burns)	Savanna woodland	0.22
	Savanna parkland	0.73
	Other savanna woodlands	0.37
All savanna woodlands (early dry season burns)		0.40
Savanna woodlands (mid/late dry season burns)	Savanna woodland	0.72
	Savanna parkland	0.82
	Tropical savanna	0.73
	Other savanna woodlands	0.68
Savanna Grassland /Pastures (mid/late dry season burns)		0.74
Savanna Grasslands/ Pastures (early dry season burns)	Tropical/ sub-tropical grassland	0.74
	Grassland	-
All savanna grassland (early dry season burns)		0.74
Savanna Grasslands/ Pastures (mid/late dry season burns)	Tropical/ sub-tropical grassland	0.92
	Tropical pasture	0.35
	Savanna	0.86
All savanna grasslands (mid/late dry season burns)		0.77

Surface layer combustion only

Source: 2006 IPCC Guidelines, Volume 4, Chapter 2, Table 2.6

7.4.1.3 Setting of emission factors

Table 7.4-3 show the emission factors for field burning in savanna. The values for these emission factors are based on the comprehensive review by Andreae and Merlet (2001). 2006 IPCC Guidelines also adopted these values.

Table 7.4-3 Emission factors of the air pollutants and GHS from field burning in savanna

Unit: kg-pollutant/ton-Dry weight

Air pollutant / GHG	EF
CO	65
NO_x as NO	3.9
SO_2	0.35
NMVOC	3.4
NH_3	0.6
TSP	8.3
$PM_{2.5}$	5.4
OC	3.4
BC	0.48
CO_2	1613
CH_4	2.3
N_2O	0.21

Source: Andreae and Merlet, Emission of trace gases and aerosols from biomass burning, 2001

7.4.1.4 Temporal change and spatial distribution

1. Temporal change

Basically, the temporal change of field burning in savanna is obtained through fieldwork. The fieldwork may include study of existing references, hearings of relevant ministries and offices and interviews of relevant organizations.

If the temporal change cannot be obtained through fieldwork, the temporal change is set as below.

When only the annual total area of field burning in savanna is obtained, the emissions are evenly distributed to each hour of the year. Assumed each hour is a day 24 hours and a year 365 days.

When a monthly total area of field burning on savanna is obtained, the emissions are evenly distributed to each hour of the month. Each hour is assumed to be the same as above.

When a seasonal total area of field burning on savanna is obtained, the emissions are evenly distributed to each hour of the season. Each hour is assumed to be the same as above

When a daily total area of field burning on savanna is obtained, the emissions are evenly distributed over 24 hours when field burning in savanna was carried out.

2. Spatial distribution

For the spatial distribution of field burning in savanna, fieldwork such as reference collection of the data from existing studies and interviews with relevant organizations should be carried out. When the information of spatial distribution can not be obtained, it can be set as follows.

When only the national total area burnt in savanna is available, the following two methods may be used to calculate spatial distribution.

1) Using the total area of savannas in each mesh as distribution index, the total emissions of air pollutants from field burning in savanna should be evenly distributed.
2) Using the total area of savanna, which is at the level of an administrative district more specific than provincial, prefectural and national levels, as distribution index, the total emissions of air pollutants from field burning in savanna should be evenly distributed.

When the area of savanna more specific than those at province/prefecture and national levels is available, any of the following three methods may be used to calculate spatial distribution.

3) The total emissions of air pollutants from field burning in savanna in each province and each prefecture are evenly distributed according to the area of savanna in each mesh.
4) The total emissions of air pollutants from field burning in savanna in each province and each prefecture are evenly distributed according to the area of savanna in each province and prefecture.
5) When more detailed information of area of savanna (city or district), using the area of savanna from such information as distribution index, the total emissions of air pollutants from field burning in savanna are evenly distributed.

7.4.2 Detailed method

7.4.2.1 Outline of emission estimation method

The detailed method is a bottom-up emission estimation method.

The requirements to estimate emissions are: (1) the incineration point can be identified by satellite image data; (2) land use classification data for each mesh in savanna is available.

Emissions are calculated in the following steps.

1) Extract fire points from the satellite image data (data A).
2) Obtain land use classification data of each mesh in savanna in the area (country, province and other) (data B).
3) Overlay the data A and the data B to identify fire points in the area where the land use is savanna. Only these points are deemed as field burning in savanna (data C).
4) These analyses are carried out during the period subject to the inventory. Based on the data C, annual total of area burnt in savanna is calculated for each country or province. (data D)
5) Estimate the area burnt in savanna from other national statistics (data E).
6) Cross-check the data D using the data E. The data D tend to underestimate compared to the data E because satellite imaging normally can not observe all the ground surfaces for 24 hours a day for 365

days of a year due to clouds and intervals in observation by the satellite. The area burnt in savanna that are underestimated should be evenly distributed to the hours and areas that could not be observed due to clouds and other reasons.

7) When the data D overestimates compared with the data E, the overestimated area burnt in savanna should be uniformly eliminated from the data D. In such case, it is considered that during the hours and in areas that were not observed due to clouds and other reasons field burning did not occur in savanna.

8) Using the total area of savanna burnt calculated above as activity data, emissions are calculated by multiplying the activity data with an emission factor.

7.4.2.2 Estimation of activity data

The activity data is the total area of each field burning in savanna obtained from satellite image and total area of field burning in savanna obtained through correction.

7.4.2.3 Setting of emission factors

The emission factors are the same as in the simple method (7.4.1).

7.4.2.4 Temporal change and spatial distribution

1. Temporal change

The temporal change relies on temporal change of satellite image data.

In general, the start time and end time of field burning in savanna in each hotspot in satellite image are checked and used as inventory. When the start and end times are not known due to clouds, the middle of the hours before and after that can be specified are used as the start and end times.

As a simpler method, a sample survey may be carried out for each hotspot to obtain average duration of field burning in savanna, and the average duration may be applied to each hotspot.

When the area burnt in savanna, which is obtained from satellite image, is underestimated and area burnt in other savanna (area burnt in savanna other than the area burnt in savanna obtained from the satellite image) needs to be calculated, the temporal change is evenly distributed to each hour of the year.

2. Spatial distribution

The spatial distribution relies on spatial resolution of the satellite image data and the land use classification data for each mesh.

The spatial distribution of the areas burnt in savanna is identified based on the location information of hotspots that are classified as savanna in land use for each mesh. Unlike temporal change, there is no simpler method to calculate station distribution.

When it is assumed that field burning in savanna is taking place in the area much larger than the area burnt in savanna obtained from the satellite image, the spatial distribution is to be appropriately distributed to points that can not be observed due to clouds but field burning might take place.

But when the area burnt in savanna confirmed in the satellite image is underestimated and the area burnt in other savanna needs to be calculated, the spatial distribution may be evenly distributed to the total area of a country, province or prefecture.

7.5 Estimating emissions of air pollutants from burning of agricultural wastes

Open burning of agricultural wastes leads to the emission of CO, NOx, NMVOCs, SO_2, NH_3, $PM_{10}/PM_{2.5}$, BC, OC, CO_2, CH_4 and N_2O. To estimate emission of these matters, crop production, dry matter content of residue burnt per production of a crop, and estimation of emission factors are necessary.

7.5.1 Simple method

7.5.1.1 Outline of emission estimation method

A method in GAP Forum Manual is adopted as a simple method to estimate emissions from burning of agricultural wastes. This method is based on the method of 1996 IPCC Guidelines with additional data of the developing countries, and consists of the following steps:

1) Dry mater content of agricultural wastes burnt are estimated based on production of each crop (rice, wheat, cereals, soy, corn, potato, jute, cotton, peanut, sugar cane, rapeseed and mustard seed), residue ratio per production of each crop, dry matter content of each residue, proportion of each residue burnt in the field, and the fraction of burnt material that is oxidized during combustion.
2) Emission factors are listed as emission of pollutant per dry matter of burnt agricultural wastes.
3) Emissions from burning of agricultural wastes are estimated by multiplying dry matter of burnt agricultural wastes with an emission factor.

$$E_{pollu\tan t} = AR_{residue\_burnt} \times EF_{pollu\tan t} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (7.5\text{-}1)$$

$E_{pollutant}$: emission of pollutant (kg)

$AR_{residue\_burnt}$: dry matter of burnt agricultural wastes (activity data) (dry matter ton)

$EF_{pollutant}$: emission factor (kg/Dry weight ton)

4) CO emission factor is a product of the fraction of carbon in the burnt agricultural wastes, the fraction of carbon emitted as CO, and CO to C ratio of molecular weight.
5) NOx emission factor (as NO_2) is a product of the fraction of carbon in the burnt agricultural wastes, C to N ratio, the fraction of nitrogen emitted as NOx, and NO_2 to N ratio of the molecular weight.
6) Emission factors for NMVOCs, SO_2, NH_3, $PM_{10}/PM_{2.5}$, BC, OC, CO_2, CH_4 and N_2O are separately calculated.

7.5.1.2 Estimation of activity data

The activity data is estimation of dry matter of agricultural wastes actually burnt. The estimation equation is as below.

$$AR_{residue\_burnt,i} = CP_i \times RC_i \times DM_i \times Bi_l \times OX_i \cdots\cdots\cdots\cdots\cdots\cdots (7.5\text{-}2)$$

Where:

AD_i : dry matter of agricultural wastes burnt of crop i (activity data) (dry matter ton)

i : crop type i

CP_i : amount of crop i produced (amount harvested containing moisture) (ton)

RC_i : residue to crop ratio of crop I (dimensionless) (”Residue to crop ratio” inTable 7.5-1)

DM_i : dry matter fraction in residues of crop i (dimensionless) (”Dry matter fraction” inTable 7.5-1)

BF_i: fraction of residue burnt in fields of crop i (dimensionless) (”Fraction burned in fields” in Table 7.5-1)

OX_i: fraction oxidized during combustion of crop i (”Fraction oxidized during combustion” in Table 7.5-1)

“Fraction of residues burnt in fields (BF_i)” is a fraction of agricultural wastes actually burnt in field, after the deduction of fractions of wastes that are incorporated in the soil, consumed by livestock on the field or removed from the field for use elsewhere. Fraction oxidized during combustion is a fraction of agricultural wastes that are completely burnt and cause of air pollutant emissions.

Amount produced of each crop can be obtained from statistics such as below.

1) Statistics of each country
2) FAOSTAT (URL; http://faostat.fao.org/site/567/DesktopDefault.aspx#ancor)

Table 7.5-1 shows the default parameters to estimate the dry matter (activity data) of burnt residues from production amount of each crop

Table 7.5-1 Parameter for activity data estimation

Parameter / Crop type	Residue to Crop Ratio [a]	Dry Matter Fraction [a]	Fraction Burnt in Fields [a, b]	Fraction Oxidized during Combustion [a]
Rice	1.4	0.83	0.25	0.9
Wheat	1.5 [d]	0.80 [c]	0.25	0.9
Millet	1.2 [d]	0.80 [c]	0.25	0.9
Soya	2.1	0.80 [c]	0.25	0.9
Maize	0.33 [d]	0.4	0.25	0.9
Potatoes	0.4	0.45	0.25	0.9
Jute	2.15 [d]	0.80 [c]	0.25	0.9
Cotton	3.0 [d]	0.80 [c]	0.25	0.9
Groundnut	2.0 [d]	0.80 [c]	0.25	0.9
Sugarcane	0.1 [e]	0.80 [c]	0.25	0.9
Rapeseed and mustard	1.8 [e]	0.80 [c]	0.25	0.9

a: IPCC (1996) default values. Use locally determined factors where available.
b: The average proportion, between 0 (none) and 1 (all), of the residue burned in the fields.
c: Bhattacharya and Mitra (1998)
d: TIFAC (1991)
e: Tyagi (1989)
* Table and notes are cited from GAP Forum Manual.

7.5.1.3 Setting of emission factors

Table 7.5-2 to Table 7.5-4 show emission factors and parameters for the emission factors. When original values of each country are available, those values should be used.

CO_2 is calculated if emissions that get out of the annual balance, occur.

Table 7.5-2 Emission factors for burning of agricultural residues (Part 1) (CO, NO_2, NMVOC, SO_2, NH_3)

Unit: kg/burnt dry matter ton

Parameter / Crop type	CO [a]	NO_2 [a]	NMVOC [f]	SO_2 [g]	NH_3 [j]
Rice [h]	58.9	2.4	6.3	0.3	2.4
Wheat [h]	66.7	2.3	5.5 [i]	0.5	2.4
Millet	63.0	2.9	9	0.48	1.3
Soya	63.0	8.9	9	0.48	1.3
Maize [h]	38.8	1.8	4.5	0.2	2.4
Potatoes	59.2	6.7	9	0.48	1.3
Jute	63.0	2.7	9	0.48	1.3
Cotton	63.0	2.7	9	0.48	1.3
Groundnut	63.0	2.7	9	0.48	1.3
Sugarcane	63.0	2.7	9	0.48	1.3
Rapeseed and mustard	63.0	2.7	9	0.48	1.3
Barley [h]	98.7	2.7	11.7	0.1	2.4

a: IPCC (1996) default values. Use locally determined factors where available.
f: US EPA (1995) default for unspecified crops unless otherwise indicated
g: Reddy and Venkataraman (2002) unless otherwise indicated
h : EMEP/EEA Guidebook, emission factors for the crop
i: Mean of US EPA (1995) defaults for headfire burning (6.5 kg NMVOC/Tons) and backfire burning (4.5 kg NMVOC/Tons)
j: Value given by Andeae and Merlet (2001) for agricultural residues unless otherwise indicated

* Table and notes are cited from GAP Forum Manual, and the emission factors for CO and NO_2 are calculated using the default values.
The emission factors for SO_2 and NMVOC were modified because they were not correct. The emission factors for Rice, Wheat and Maize are changed to the latest figure in EMEP/EEA Guidebook. The emission factor for Barley is added.

Table 7.5-3 Emission factors for burning of agricultural residues (Part 2) (TSP, PM_{10}, $PM_{2.5}$, BC, OC)

Unit: kg/burnt dry matter ton

Parameter / Crop type	TSP [k]	PM_{10} [k]	$PM_{2.5}$ [k]	BC [l]	OC [l]
Rice [h]	5.8	5.8	5.5	0.69	3.3
Wheat [h]	5.8	5.7	5.4	0.69	3.3
Millet	4.85	4.85	3.88	0.69	3.3
Soya	4.85	4.85	3.88	0.69	3.3
Maize [h]	6.3	6.2	6.0	0.69	3.3
Potatoes	4.85	4.85	3.88	0.69	3.3
Jute	4.85	4.85	3.88	0.69	3.3
Cotton	4.85	4.85	3.88	0.69	3.3
Groundnut	4.85	4.85	3.88	0.69	3.3
Sugarcane	4.85	4.85	3.88	0.69	3.3
Rapeseed and mustard	4.85	4.85	3.88	0.69	3.3
Barley [h]	7.8	7.7	7.4	0.69	3.3

h: EMEP/EEA Guidebook, emission factors for the crop

k: Values from Reddy and Venkataraman (2002) and $PM_{2.5}$/TSP ratio of 0.80 is used and $PM_{2.5}/PM_{10}$ ratio of 1.0 is assumed

l: Tami C. Bond et al. (2004)

Table 7.5-4 Emission factors for burning of agricultural residues (Part 3) (CO_2, CH_4, N_2O)

Unit: kg/burnt dry matter ton

	CO_2	CH_4	N_2O
Agricultural Residues	1515±177	2.7	0.07

Source: 2006 IPCC Guidelines

7.5.1.4 Temporal change and spatial distribution

1. Temporal change

It can be assumed that burning of agricultural residues is carried out after harvesting in general. Hence, the harvest period needs to be identified through interview survey and the emissions are basically distributed to that period.

2. Spatial distribution

The estimation method for activity data on burning of agricultural residues is based on crop production. Therefore, the basic policy is to distribute the amount produced of each crop in each province or country to cropland.

Article 7.5-1 Results of calculation of emissions of air pollutants from field burning of agricultural wastes in Vietnam

The emissions of air pollutants from field burning of agricultural wastes in Vietnam are calculated as below.
First, annual production of each crop is obtained from statistics in Vietnam as in Table 7.5-5.

Table 7.5-5 Annual production of agricultural crops in Vietnam

Annual production	Unit	2004	2005	2006	2007	2008
Rice	1000 tons	36,149	35,833	35,850	35,943	38,725
Soya	1000 tons	246	293	259	275	269
Maize	1000 tons	3,431	3,787	3,855	4,303	4,531
Jute	1000 tons	13	13	11	26	9
Cotton	1000 tons	28	34	29	16	7
Groundnut	1000 tons	469	489	463	510	534
Sugarcane	1000 tons	115,649	14,949	16,720	17,397	16,128

Source: Vietnam statistical yearbook

NH_3 emission amount of Vietnam in 2008 is estimated as follows.

Various parameters to calculate amounts of agricultural residues from annual production of each crop used in Table 7.5-1.

The emission factors for field burning of agricultural wastes used are shown in Table 7.5-2.

Table 7.5-6 shows the result of the emission calculation for NH_3 coming from field burning of agricultural wastes of Vietnam in 2008 based on the above conditions.

Table 7.5-6 Results of calculation of emissions of NH_3 from field burning of agricultural wastes in Vietnam

	activity data 2008 (thousand tons)	Residue to Crop Ratio	Dry Matter Fraction	Fraction Burned in Fields	Fraction Oxidized during Combustion	NH_3 emission factor (kg/ton biomass burned)	NH_3 emission (ton/year)
Rice	38,725.1	1.4	0.83	0.25	0.9	2.4	24,299.23
Soya	268.6	2.1	0.8	0.25	0.9	1.3	131.99

Maize	4,531.2	0.33	0.4	0.25	0.9	2.4	322.98
Jute	8.8	2.15	0.8	0.25	0.9	1.3	4.43
Cotton	6.9	3	0.8	0.25	0.9	1.3	4.84
Groundnut	533.8	2	0.8	0.25	0.9	1.3	249.82
Sugarcane	16,128.0	0.1	0.8	0.25	0.9	1.3	377.40

7.5.2 Detailed method

7.5.2.1 Emission estimation method outline

The emission estimation method itself is the same as in the simple method. The main points for refinement are explained below.

7.5.2.2 Activity data estimation

The activity data is “dry matter of burnt agricultural residues by crop.” The data is estimated from annual production of each crop using parameter for each crop shown in Table 7.5-1.

“Fraction of residue burnt in fields (BF_i)” is assumed to the most uncertain among the parameters. It is effective to carry out interview surveys on whether a specific crop is used for a specific purpose other than being cleared by burning in fields.

7.5.2.3 Setting of emission factor

Emission factors described in many manuals, guidelines, and documents are listed as emission of air pollutant per dry matter of burnt residues of each crop. For that reason, use of emission factor for crop type actually produced leads to refinement of emission factor.

In particular, USEPA AP-42 lists emission factors of many crop types and differences in burning techniques for certain crops are taken into consideration.

The burning technique here means Headfire Burning and Backfire Burning. The Headfire Burning is a technique in which fire is opened in the windward of a field where burning operation is to be conducted and burning proceeds in the leeward direction. In the Backfire Burning, fire is opened in the leeward of the field and burning is forcefully moved in the windward direction.

Table 7.5-7 to Table 7.5-9 show emission factors in USEPA AP-42.

Table 7.5-7 Emission factors for burning of agricultural residues (Part 4)

Unit: kg/burnt dry matter ton

	TSP	CO	CH_4	NMVOC
Field Crops (Unspecified)	11	58	2.7	9
Burning techniques not significant				
Asparagus	20	75	10	33
Barley	11	78	2.2	7.5
Corn	7	54	2	6
Cotton	4	88	0.7	2.5
Grasses	8	50	2.2	7.5
Pineapple	4	56	1	3
Rice	4	41	1.2	4
Safflower	9	72	3	10
Sorghum	9	38	1	3.5
Sugar cane	2.3 - 3.5	30 - 41	0.6 - 2	2 - 6

Source: AP-42

Table 7.5-8 Emission factors for burning of agricultural residues (Part 5)

Unit: kg/burnt dry matter ton

	TSP	CO	CH_4	NMVOC
Headfire Burning				
Alfalfa	23	53	4.2	14
Bean (red)	22	93	5.5	18
Hay (wild)	16	70	2.5	8.5
Oats	22	68	4	13
Pea	16	74	4.5	15
Wheat	11	64	2	6.5
Backfire Burning				
Alfalfa	14	60	4.5	14
Bean (red)	7	72	3	10
Hay (wild)	8	75	2	6.5
Oats	11	68	2	7
Wheat	6	54	1.3	4.5
Vine Crops	3	26	0.8	3
Weeds				
Unspecified	8	42	1.5	4.5
Russian thistle (tumbleweed)	11	154	0.2	0.8
Tales (wild reeds)	3	17	3.2	10

Source: AP-42

Table 7.5-9 Emission factors for burning of agricultural residues (Part 6)

Unit: kg/burnt dry matter ton

	TSP	CO	CH_4	NMVOC
Orchard Crops				
Unspecified	3	26	1.2	4
Almond	3	23	1	3
Apple	2	21	0.5	1.5
Apricot	3	24	1	3
Avocado	10	58	3.8	12
Cherry	4	22	1.2	4
Citrus (orange, lemon)	3	40	1.5	5
Date palm	5	28	0.8	3
Fig	4	28	1.2	4
Nectarine	2	16	0.5	1.5

Source: AP-42

7.5.2.4 Temporal change and spatial distribution

1. Temporal change

The temporal change can be made more detailed through the implementation of interview surveys to find out months and times in which agricultural wastes from harvesting are cleared.

2. Spatial distribution

Statistics on total amount produced by crop at a more local level (municipal level rather than province or national level) help to refine the spatial distribution. But actually the most effective information for refinement of spatial distribution may be the GIS data on agricultural land. It is valid to distribute emissions of air pollutants at national level or province level to cropland in the region.

Regarding forest fires described hereinafter, use of satellite data has been tested due to large fire spreading area, but field burning of agricultural residues is too small a size to use the satellite data.

8 Estimating emissions of air pollutants coming from forest fires

8.1 Simple method

8.1.1 Outline of emission estimation method

This chapter covers emissions of SO_2, NOx, CO, NMVOC, NH_3, PM (TSP, PM_{10}, $PM_{2.5}$, BC, and OC), CH_4 and N_2O from vegetation fires caused by change in land use, forest management, or accidental factors. Conversions of forestry, forestland and grassland into cropland, intentional burn for fire management or forest management and other vegetation fires that occur naturally due to man-induced accident or lightening are included in this chapter. Savanna burnings are not included in this chapter because it is included as agricultural operation in Chapter 7 “Estimating emissions of air pollutants coming from agriculture activities.”

Many wood types, in particular, conifers, are important source of specified NMVOC. These are estimated in Chapter 10 “Estimating emissions of air pollutants from natural sources”.

The emissions are calculated by multiplying the annual or monthly total area of forests burnt at national, provincial or prefectural level with the biomass consumption and the emission factor.

8.1.2 Estimation of activity data

The activity data is the annual or monthly total area of forests burnt at national, provincial or prefectural level.

The activity data should be obtained from statistics of the country. If the national statistic is not available, UN statistics (for example, FAO State of the world’s forests 2003) may be used.

The general equation for estimating emission of each air pollutant and greenhouse gas from forest fires is as follows:

$$AD_{\text{wildfire}} = A \times M_B \times C_f \quad \cdots\cdots (8.1\text{-}1)$$

Where:

AD_{wildfire}: activity data on wildfire (biomass combustion in wildfire) (tons)

A: area of wildfire (ha)

M_B: mass of fuel for combustion (tones ha^{-1}). This includes biomass, underground litter and dead wood.

C_f: Combustion factor (dimensionless) (default values in Table 8.1-2)

Note: Where data for M_B and C_f are not available, the default value for the amount of fuel actually burnt (the product of M_B and C_f) can be used (Table 8.1-1).

The amount of fuel that can be burnt is given by the area burnt and the density of fuel present on that area. The fuel density can include biomass, dead wood and litter. The amount of fuel available for combustion also affects the type of fire.

The combustion factor is a measure of the proportion of the fuel that is actually combusted, which varies as a function of the size and architecture of the fuel load (i.e., a smaller proportion of large, coarse fuel such as tree stems will be burnt compared to fine fuels, such as grass leaves), the moisture content of the fuel and the type of fire (i.e., intensity and rate of spread which is markedly affected by climatic variability and regional differences as reflected in Table 8.1-2).

The estimation of the total area of forest fires is necessary. There are international databases for the annual total area burnt by fires, but these databases do not provide reliable data on the area annually burnt in a managed criteria in each country. It is good practice to develop assessment of national total area burnt and the nature of fires.

If the data on the total area burnt is not available from the national information sources, international data such as “FAO State of the worlds forests 2003 Annex 2: Table 2” should be used. In the application of such data, it should be assumed that “Mean annual forest cover change” is equal to “total forest area burnt.”

(URL: http://www.fao.org/DOCREP/005/Y7581E/y7581e00.htm)

Table 8.1-1 Fuel biomass consumption in forest fires (Unit: tones dry matter/ha)

Vegetation	Subcategory	Factor
Primary tropical forest (slash and burn)	Primary tropical forest	83.9
	Primary open tropical forest	163.6
	Primary tropical moist forest	160.4
	Primary tropical dry forest	-
All primary tropical forests		119.6
Secondary tropical forest (slash and burn)	Young secondary tropical forest (3-5 years)	8.1
	Intermediate secondary tropical forest (6-10 years)	41.1
	Advanced secondary tropical forest (14-17 years)	46.4
All secondary tropical forests		42.2
All Tertiary tropical forest		54.1
Boreal forest	Wildfire (general)	52.8
	Crown fire	25.1
	Surface fire	21.6
	Post logging slash burn	69.6
	Land clearing fire	87.5
All boreal forest		41.0
Eucalypt forests	Wildfire	53.0
	Prescribed fire - (surface)	16.0
	Post logging slash burn	168.4
	Land clearing fire	132.6
All Eucalypt forests		69.4
Other temperate forests	Wildfire	19.8
	Post logging slash burn	77.5
	Felled and burned (land-clearing fire)	48.4
All “other” temperate forest		50.4

Source: 2006 IPCC Guidelines, Volume 4, Chapter 2, Table 2.4

Table 8.1-2 Combustion factor values for forest fires (dimensionless)

Vegetation	Subcategory	Factor
Primary tropical forest (slash and burn)	Primary tropical forest	0.32
	Primary open tropical forest	0.45
	Primary tropical moist forest	0.50
	Primary tropical dry forest	-
All primary tropical forests		0.36
Secondary tropical forest (slash and burn)	Young secondary tropical forest (3-5 years)	0.46
	Intermediate secondary tropical forest (6-10 years)	0.67
	Advanced secondary tropical forest (14-17 years)	0.50
All secondary tropical forests		0.55
All Tertiary tropical forest		0.59
Boreal forest	Wildfire (general)	0.40
	Crown fire	0.43
	Surface fire	0.15
	Post logging slash burn	0.33
	Land clearing fire	0.59
All boreal forest		0.33
Eucalypt forests	Wildfire	-
	Prescribed fire - (surface)	0.61
	Post logging slash burn	0.68
	Land clearing fire	0.49
All Eucalypt forests		0.63
	Post logging slash burn	0.62
	Felled and burned (land-clearing fire)	0.51
All “other” temperate forest		0.45

Source: 2006 IPCC Guidelines, Volume 4, Chapter 2, Table 2.6

8.1.3 Setting of emission factors

The emission factors give the amount of a specific air pollutant and GHG per dry matter burnt which varies as a function of carbon content of biomass and completeness of combustion. Due to high nitrogen density, emissions of nitrogen oxide and N_2O from fires vary as a function of nitrogen content of fuel.

Table 8.1-4 to Table 8.1-6 show the emission factors for forest fires. The emission factors are based on Andreae and Merlet (2001), and allocated to each vegetation according to the procedure in GAP Forum Manual (Table 8.1-3).

Table 8.1-3 Allocation of emission factor to each vegetation

Vegetation type	Vegetation type by Andreae and Merlet
Tropical/subtropical forest (primary)	Tropical Forest
Tropical/subtropical forest (secondary)	Tropical Forest
Tropical/subtropical grassland (excluding savanna burning)	Savanna and Grassland
Tropical pasture	Savanna and Grassland
Eucalypt forests	Extratropical Forest
Other temperate forest	Extratropical Forest
Scrubland (general)	Savanna and Grassland
Temperate grasslands	Savanna and Grassland
Boreal forest	Extratropical Forest
Peatland	Extratropical Forest
Boreal grasslands/ Tundra	Savanna and Grassland

Source: GAP Forum Manual, Table 7-1

Table 8.1-4 List of emission factors for air pollutants from forest fires (Part 1)

Unit: g/kg dry matter burnt

Vegetation	CO	SO_2	NO_x as NO	NMVOC	NH_3
Tropical/subtropical forest (primary)	104	0.57	1.6	8.1	1.3
Tropical/subtropical forest (secondary)	104	0.57	1.6	8.1	1.3
Tropical/subtropical grassland (excluding savanna burning)	65	0.35	3.9	3.4	1.5
Tropical pasture	65	0.35	3.9	3.4	1.5
Eucalypt forests	107	1.0	3.0	5.7	1.4
Other temperate forest	107	1.0	3.0	5.7	1.4
Scrubland (general)	65	0.35	3.9	3.4	1.5
Temperate grasslands	65	0.35	3.9	3.4	1.5
Boreal forest	107	1.0	3.0	5.7	1.4
Peatland	107	1.0	3.0	5.7	1.4
Boreal grasslands/ Tundra	65	0.35	3.9	3.4	1.5

Source: Andreae and Merlet, Emission of trace gases and aerosols from biomass burning, 2001

Table 8.1-5 List of emission factors for air pollutants from forest fires (Part 2)

Unit: g/kg dry matter burnt

Vegetation type	TSP	$PM_{2.5}$	BC	OC
Tropical/subtropical forest (primary)	10.5	9.1	0.66	5.2
Tropical/subtropical forest (secondary)	10.5	9.1	0.66	5.2
Tropical/subtropical grassland (excluding savanna burning)	8.3	5.4	0.48	3.4
Tropical pasture	8.3	5.4	0.48	3.4
Eucalypt forests	17.6	13	0.56	8.6
Other temperate forest	17.6	13	0.56	8.6
Scrubland (general)	8.3	5.4	0.48	3.4
Temperate grasslands	8.3	5.4	0.48	3.4
Boreal forest	17.6	13	0.56	8.6
Peatland	17.6	13	0.56	8.6
Boreal grasslands/ Tundra	8.3	5.4	0.48	3.4

Source: Andreae and Merlet, Emission of trace gases and aerosols from biomass burning, 2001

Table 8.1-6 List of emission factors for GHG from forest fires

Unit: g/ kg dry matter burnt

Vegetation type	CO_2	CH_4	N_2O
Tropical/subtropical forest (primary)	1580	6.8	0.20
Tropical/subtropical forest (secondary)	1580	6.8	0.20
Tropical/subtropical grassland (excluding savanna burning)	1613	2.3	0.21
Tropical pasture	1613	2.3	0.21
Eucalypt forests	1569	4.7	0.26
Other temperate forest	1569	4.7	0.26
Scrubland (general)	1613	2.3	0.21
Temperate grasslands	1613	2.3	0.21
Boreal forest	1569	4.7	0.26
Peatland	1569	4.7	0.26
Boreal grasslands/ Tundra	1613	2.3	0.21

Source: Andreae and Merlet, Emission of trace gases and aerosols from biomass burning, 2001

8.1.4 Temporal change and spatial distribution

8.1.4.1 Temporal change

When the annual total area of forest fires is obtained, the emissions are evenly distributed to each hour of the year.

When the monthly total area of forest fires, the emissions are evenly distributed to each hour of the month.

When the daily total area of forest fires is obtained, the emissions are evenly distributed each hour of 24 hours in a day.

When the hourly total area of forest fires, the emissions are evenly distributed to each hour according to it.

8.1.4.2 Spatial distribution

When only the national total area burnt in savanna is available, the following two methods may be used to calculate spatial distribution.

1) Using the total area of forests in each mesh as distribution index, the national total area of forest fires should be evenly distributed.
2) Using the total area of forests, which is at a level of administrative district more specific than provincial, prefectural and national levels, as distribution index, the total area of forest fires should be evenly distributed.

When the total area of forest fires is available at more specific level than province/prefecture and national levels, either of the following two methods may be used to calculate spatial distribution.

3) Using the total area of forests in each mesh as distribution index, the provincial or prefectural total area of forest fires should be evenly distributed.
4) When the total area of forests, which is at a level of administrative district more specific than provincial, prefectural and national levels, using that total area of forests as distribution index, the total area of forest fires is distributed.

Article 8.1-1 Calculation example of emissions of air pollutant from forest fires in Vietnam

An example of the emission calculation for air pollutants from forest fires in Vietnam is shown below.

The data of total area of forest fires are obtained from Vietnam's statistics as below. In Vietnam, the total areas of forest fires in each province are available. From the statistics as of 2009, the data on the period from 1995 to 2008 were available. The values for 2008 are the values for quick estimation.

Table 8.1-7 Total area of forest fires in Vietnam

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Prel. 2008
WHOLE COUNTRY	**7457**	**4198.4**	**1750.2**	**19943.3**	**4817**	**1045.9**	**1523.4**	**12333.5**	**5510.6**	**4787**	**6829.3**	**2386.7**	**5136.4**	**1677.3**
Red River Delta	***0***	***68.6***	***11.4***	***170.1***	***433.5***	***59.4***	***48.5***	***95.5***	***499.8***	***460.1***	***195.7***	***441.8***	***979.2***	***166.3***
Hà Nội		23.6		36	47.5	11		14.2	73	91	7.7	32	10	54.1
Hà Tây		24.4			1			3	2	12.6	6	0.5	1.1	
Vĩnh Phúc			8.5	78.7	77	15.1	4	78.3	52.4	42.6	11.5	22.5	24.9	7.8
Bắc Ninh											0.9			17
Quảng Ninh			2.9		263	29.5	41.7		355.6	295.3	162.7	363.1	916	76
Hải Dương		2.4		50.3	41	1.5			1.5	11.5	4	21.5	24	8.2
Hải Phòng		18.2		3.5	4	2.3	2.8		15.3	2	1.7	2.2	0.7	3.2
Hà Nam										1.2				
Ninh Bình				1.6						3.9	1.2		2.5	
Northern midlands and mountain areas	***679***	***2909.3***	***193.7***	***5051***	***3282.5***	***507.9***	***270***	***563***	***2814.5***	***1590.2***	***1980.4***	***1097.6***	***3059***	***425.3***
Hà Giang	20	68	73	193	243	6	2	15.6	113.7	8.8	66.5	335.3	97.8	16.3
Cao Bằng	2	163	19	177	30	47	15	132.6	190.3	144.3	64.9	73.9	75.8	28.4
Bắc Kạn			1	30	260	10.2		21.7	14.5	37	3.4	9.7	4.9	12
Tuyên Quang	1	59.4			387	2.1	0.2	16	97.1	58.2	32.1	51.9	82.6	20.4
Lào Cai	30	598			44	92.6		26.4	110	6.5	28.7	8.9	43	2.9
Yên Bái	250	415	19.5	258.7	20	3.4	8.5	9.5	274.1	27.9	190.1	149.3	709.2	26.7
Thái Nguyên	12	161	1.6	6.7	2.8	2.7	3.7	3.7	5	45.7	3.5	30	21	11.1
Lạng Sơn		58.1	21.3	78.4	240	268.2	10	68.2	544	163.9	85.8	137.6	251.8	208.4
Bắc Giang		22.8	3	2.1	40.7	5.8		40.8	34.2	20.1	17.2	48.4	59	8.8
Phú Thọ		9		16	12	2	0.3	20.6	332	6.1	8.9	22.7	13.9	2.5
Điện Biên									236.6	839.2	876.9	34.2	151.8	3.2
Lai Châu	}328.0	1080	23	377.7	333	47.3	117.3	162.4	77	114.1	156.4	153.7	360.2	84.4
Sơn La	31		28.3	3784	1625	20.5	113	45.5	71	72	238	40	1188	0.2
Hoà Bình	5	275	4	127.4	45	0.1			715	46.4	208	2		
North Central area and Central coastal area	***1842***	***208.9***	***737.9***	***1195.1***	***418.9***	***157.9***	***488.1***	***943***	***948.7***	***503.6***	***1285.4***	***461.8***	***328.9***	***593.7***
Thanh Hoá	1	20.2	48	50	33.5	30		2.1	165.2	37.9	24	13.8		17.8
Nghệ An		36.5	10.9	156	52	7.6		15.4	39.2	23.3	126.5	108.5	27.9	34.2
Hà Tĩnh	28	16		74	6	1	2	12.1	57	31	132	63	65	100
Quảng Bình	2		7	39			90.7	22.3	17	2.8	80.9	5.7	17.1	16.6
Quảng Trị	32	16.5	154	202.8	35.2	6.2	84.2	206.4	121	33.3	282.1	26.4	137.1	162
Thừa Thiên Huế	31	38.7	27.5	95	13.2	12		22.1	20.8	223	50.7	53.4	6.6	70
Đà Nẵng			34				6		22.4	48.2	136	33	7	0.9
Quảng Nam	38	0.1	24.7	76.7	10			157	65	6	7	19.5	25	27
Quảng Ngãi	2	10	45		4	2.9	1.5	93.6	95.2	19.7	62	62	8.2	13.7
Bình Định	8	1.6	23.8	19.6	17	16.7	15.7	202	9	23	80	70	23.6	11.2
Phú Yên	26	10	107	310	147	22	237	98	17	25.8	45	5.5	9.4	125.3
Khánh Hoà	31	18.9	23	120	36	12.8	51	104	26.9	10.6	259.2		2	
Ninh Thuận	1584		190		33				293	19		1		15
Bình Thuận	59	40.4	43	52	32	46.7		8		524	1612.7	232.6	420.7	98.2
Central Highlands	***2344***	***618.3***	***179.4***	***1246.1***	***211.4***	***98***	***301.5***	***348.6***	***187.2***	***367.6***	***1483.3***	***178.4***	***249.9***	***24***
Kon Tum	58		45.7	373.5	108	33	126.8	144.8	62.6	22.2		27.4	158.6	62.9
Gia Lai	475	408.3	42.9	481.6	33	6	104.1	130	103.6	25.2	52.4		2	3.9
Đắk Lắk	}513.0	16	34.8	52	14.4	23	18.6	62		83	9	9		
Đắk Nông														
Lâm Đồng	1298	194	56	339	56	36	52	11.8	21	26	68	17.8	10.2	7.4
South East	***520***	***373.7***	***313.6***	***2067.7***	***458.4***	***124.2***	***127.7***	***246.3***	***121***	***97.6***	***355.8***	***38.3***	***22.2***	***86.9***
Bình Phước	25	3.7	35.6	613	362	20.2		16	42	7	58	23	3	65
Tây Ninh	202	51	32	207.2	6	1.5	23.3	52	11.4	55.1	263.4	6	17.2	14.7
Bình Dương			31			11	5	23	15	11	19	2	2	1
Đồng Nai	235	251	57	1106	40	19.5	52	119	24.3	18.5	9.3	6.7		
Bà Rịa - Vũng Tàu	58	68	158	141.5	50.4	72	47.4	36.3	24.8	5	5.8	0.5		5.6
TP.Hồ Chí Minh									3.5	1	0.3	0.1		0.6
Mekong River Delta	***2072***	***19.6***	***314.2***	***10213.3***	***12.3***	***98.5***	***287.7***	***10137.1***	***939.4***	***1611.5***	***1399.3***	***114.6***	***326.4***	***306.9***
Long An	205	2		224		31		1485	102.2	484.6	553.5	24	107	28
Tiền Giang								150		50	272.2		25.2	
Bến Tre							0.1							
Đồng Tháp	37	10	12	9.3	2	4	0.4	7.8		4.9	6.2	0.3	2.4	179.8
An Giang	79	7.3	3.7	29	10.3	63	0.2	0.5	16.2	13.6	41.2		25	87
Kiên Giang			243	8653				4069	726	1058	446	85	86.8	
Cần Thơ	}	0.3	0.5	31				1.8		0.2				
Hậu Giang											2.3	0.3		0.1
Sóc Trăng	8		5.5	57							0.9			
Bạc Liêu							287							
Cà Mau	1743		49.5	1210		0.5		4423	95	0.2	77	5	80	12

Table 8.1-8 Total area of forest fires in Vietnam (biomass burnt)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Prel. 2008
WHOLE COUNTRY	**372850**	**209920**	**87510**	**997165**	**240850**	**52295**	**76175**	**616675**	**275530**	**247170**	**347935**	**122045**	**265360**	**87575**
Red River Delta	*0*	*3430*	*570*	*8505*	*21675*	*2970*	*2425*	*4775*	*24990*	*23005*	*9785*	*22090*	*48960*	*8315*
Hà Nội	0	1180	0	1800	2375	550	0	710	3650	4550	385	1600	500	2705
Hà Tây	0	1220	0	0	50	0	0	150	100	630	300	25	55	0
Vĩnh Phúc	0	0	425	3935	3850	755	200	3915	2620	2130	575	1125	1245	390
Bắc Ninh	0	0	0	0	0	0	0	0	0	0	45	0	0	850
Quảng Ninh	0	0	145	0	13150	1475	2085	0	17780	14765	8135	18155	45800	3800
Hải Dương	0	120	0	2515	2050	75	0	0	75	575	200	1075	1200	410
Hải Phòng	0	910	0	175	200	115	140	0	765	100	85	110	35	160
Hà Nam	0	0	0	0	0	0	0	0	0	60	0	0	0	0
Ninh Bình	0	0	0	80	0	0	0	0	0	195	60	0	125	0
Northern midlands and mountain areas	*33950*	*145465*	*9685*	*252550*	*164125*	*25395*	*13500*	*28150*	*140725*	*79510*	*99020*	*54880*	*152950*	*21265*
Hà Giang	1000	3400	3650	9650	12150	300	100	780	5685	440	3325	16765	4890	815
Cao Bằng	100	8150	950	8850	1500	2350	750	6630	9515	7215	3245	3695	3790	1420
Bắc Kạn	0	0	50	1500	13000	510	0	1085	725	1850	170	485	245	600
Tuyên Quang	50	2970	0	0	19350	105	10	800	4855	2910	1605	2595	4130	1020
Lào Cai	1500	29900	0	0	2200	4630	0	1320	5500	325	1435	445	2150	145
Yên Bái	12500	20750	975	12935	1000	170	425	475	13705	1395	9505	7465	35460	1335
Thái Nguyên	600	8050	80	335	140	135	185	185	250	2285	175	1500	1050	555
Lạng Sơn	0	2905	1065	3920	12000	13410	500	3410	27200	8195	4290	6880	12590	10420
Bắc Giang	0	1140	150	105	2035	290	0	2040	1710	1005	860	2420	2950	440
Phú Thọ	0	450	0	800	600	100	15	1030	16600	305	445	1135	695	125
Điện Biên	0	0	0	0	0	0	0	0	11830	41960	43845	1710	7590	160
Lai Châu	16400	54000	1150	18885	16650	2365	5865	8120	3850	5705	7820	7685	18010	4220
Sơn La	1550	0	1415	189200	81250	1025	5650	2275	3550	3600	11900	2000	59400	10
Hoà Bình	250	13750	200	6370	2250	5	0	0	35750	2320	10400	100	0	0
North Central area and Central coastal area	*92100*	*10445*	*36895*	*59755*	*20945*	*7895*	*24405*	*47150*	*47435*	*51380*	*144905*	*34720*	*37480*	*34595*
Thanh Hoá	50	1010	2400	2500	1675	1500	0	105	8260	1895	1200	690	0	890
Nghệ An	0	1825	545	7800	2600	380	0	770	1960	1165	6325	5425	1395	1710
Hà Tĩnh	1400	800	0	3700	300	50	100	605	2850	1550	6600	3150	3250	5000
Quảng Bình	100	0	350	1950	0	0	4535	1115	850	140	4045	285	855	830
Quảng Trị	1600	825	7700	10140	1760	310	4210	10320	6050	1665	14105	1320	6855	8100
Thừa Thiên Huế	1550	1935	1375	4750	660	600	0	1105	1040	11150	2535	2670	330	3500
Đà Nẵng	0	0	1700	0	0	0	300	0	1120	2410	6800	1650	350	45
Quảng Nam	1900	5	1235	3835	500	0	0	7850	3250	300	350	975	1250	1350
Quảng Ngãi	100	500	2250	0	200	145	75	4680	4760	985	3100	3100	410	685
Bình Định	400	80	1190	980	850	835	785	10100	450	1150	4000	3500	1180	560
Phú Yên	1300	500	5350	15500	7350	1100	11850	4900	850	1290	2250	275	470	6265
Khánh Hoà	1550	945	1150	6000	1800	640	2550	5200	1345	530	12960	0	100	0
Ninh Thuận	79200	0	9500	0	1650	0	0	0	14650	950	0	50	0	750
Bình Thuận	2950	2020	2150	2600	1600	2335	0	400	0	26200	80635	11630	21035	4910
Central Highlands	*117200*	*30915*	*8970*	*62305*	*10570*	*4900*	*15075*	*17430*	*9360*	*7820*	*6470*	*2710*	*8540*	*3710*
Kon Tum	2900	0	2285	18675	5400	1650	6340	7240	3130	1110	0	1370	7930	3145
Gia Lai	23750	20415	2145	24080	1650	300	5205	6500	5180	1260	2620	0	100	195
Đắk Lắk	25650	800	1740	2600	720	1150	930	3100	0	4150	450	450	0	0
Đắk Nông	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lâm Đồng	64900	9700	2800	16950	2800	1800	2600	590	1050	1300	3400	890	510	370
South East	*26000*	*18685*	*15680*	*103385*	*22920*	*6210*	*6385*	*12315*	*6050*	*4880*	*17790*	*1915*	*1110*	*4345*
Bình Phước	1250	185	1780	30650	18100	1010	0	800	2100	350	2900	1150	150	3250
Tây Ninh	10100	2550	1600	10360	300	75	1165	2600	570	2755	13170	300	860	735
Bình Dương	0	0	1550	0	0	550	250	1150	750	550	950	100	100	50
Đồng Nai	11750	12550	2850	55300	2000	975	2600	5950	1215	925	465	335	0	0
Bà Rịa - Vũng Tàu	2900	3400	7900	7075	2520	3600	2370	1815	1240	250	290	25	0	280
TP.Hồ Chí Minh	0	0	0	0	0	0	0	0	175	50	15	5	0	30
Mekong River Delta	*103600*	*980*	*15710*	*510665*	*615*	*4925*	*14385*	*506855*	*46970*	*80575*	*69965*	*5730*	*16320*	*15345*
Long An	10250	100	0	11200	0	1550	0	74250	5110	24230	27675	1200	5350	1400
Tiền Giang	0	0	0	0	0	0	0	7500	0	2500	13610	0	1260	0
Bến Tre	0	0	0	0	0	0	5	0	0	0	0	0	0	0
Đồng Tháp	1850	500	600	465	100	200	20	390	0	245	310	15	120	8990
An Giang	3950	365	185	1450	515	3150	10	25	810	680	2060	0	1250	4350
Kiên Giang	0	0	12150	432650	0	0	0	203450	36300	52900	22300	4250	4340	0
Cần Thơ	0	15	25	1550	0	0	0	90	0	10	0	0	0	0
Hậu Giang	0	0	0	0	0	0	0	0	0	0	115	15	0	5
Sóc Trăng	400	0	275	2850	0	0	0	0	0	0	45	0	0	0
Bạc Liêu	0	0	0	0	0	0	14350	0	0	0	0	0	0	0
Cà Mau	87150	0	2475	60500	0	25	0	221150	4750	10	3850	250	4000	600

Emission factors for forest fires in Vietnam are set as in Table 8.1-9

Table 8.1-9 Emission factors set in Vietnam for forest fires

	SO_2	NO_x	CO	NMVOC	TSP	PM_{10}	$PM_{2.5}$	NH_3
Other temperate forest	1	4.6	107	5.7	17.6	17.6	13	1.4

Below is an example of the results of calculation of air pollutant emissions from forest fires in Vietnam. In Vietnam, the provincial total area of forest fires (Table 8.1-7 and Table 8.1-8) has been reported in the statistics. Using the total amount of biomass burnt per unit area in Table 8.1-3 and the emission factors (Table 8.1-9), emissions during the period of 1995 to 2008 are calculated (Table 8.1-10 to Table 8.1-12).

Table 8.1-10 Air pollutant emissions from forest fires in Vietnam

National total in Vietnam	1995	1996	1997	1998	1999
Biomass burnt (ton/year)	372,850	209,920	87,510	997,165	240,850
SOx emissions (ton/year)	372.85	209.97	87.58	997.22	240.87
NOx emissions (ton/year)	1,715.11	965.64	402.58	4,586.97	1,107.92
CO emissions (ton/year)	39,894.95	22,461.49	9,363.64	106,696.71	25,770.97
NMVOC emissions (ton/year)	2,125.32	1,196.59	498.89	5,683.91	1,372.91
PM_{10} emissions (ton/year)	6,562.16	3,694.59	1,540.17	17,550.12	4,238.96
$PM_{2.5}$ emissions (ton/year)	4,847.05	2,729.01	1,137.70	12,963.20	3,131.07
NH_3 emissions (ton/year)	521.99	293.90	122.54	1,396.05	337.20

Table 8.1-11 Air pollutant emissions from forest fires in Vietnam

National total in Vietnam	2000	2001	2002	2003	2004
Biomass burnt (ton/year)	52,295	76,175	616,675	275,530	247,170
SOx emissions (ton/year)	52.37	76.23	616.73	275.58	247.26
NOx emissions (ton/year)	240.59	350.41	2,836.70	1,267.47	1,137.03
CO emissions (ton/year)	5,595.64	8,150.78	65,984.28	29,481.76	26,447.28
NMVOC emissions (ton/year)	298.15	434.23	3,515.09	1,570.61	1,408.92
PM_{10} emissions (ton/year)	920.41	1,340.69	10,853.47	4,849.34	4,350.21
$PM_{2.5}$ emissions (ton/year)	679.91	990.33	8,016.83	3,581.94	3,213.30
NH_3 emissions (ton/year)	73.24	106.66	863.38	385.74	346.02

Table 8.1-12 Air pollutant emissions from forest fires in Vietnam

National total in Vietnam	2005	2006	2007	2008
Biomass burnt (ton/year)	347,935	122,045	265,360	87,575
SOx emissions (ton/year)	348.05	122.15	265.41	87.64
NOx emissions (ton/year)	1,600.54	561.44	1,220.67	402.86
CO emissions (ton/year)	37,229.16	13,058.92	28,393.57	9,370.59
NMVOC emissions (ton/year)	1,983.27	695.68	1,512.58	499.20
PM_{10} emissions (ton/year)	6,123.67	2,147.99	4,670.35	1,541.33
$PM_{2.5}$ emissions (ton/year)	4,523.27	1,586.69	3,449.73	1,138.54
NH_3 emissions (ton/year)	487.12	170.90	371.50	122.60

8.2 Detailed method

8.2.1 Outline of emission estimation method

The detailed method uses a bottom-up emission estimation method.

Emissions are calculated using satellite data as below:

1) Extract fire points from the satellite image data (data A).
2) Obtain land use classification data by mesh and etc. in the relevant area (nation, province and other) (data B).
3) Overlay the data A and the data B to identify fire points in the area where the land use is forest. Only these points are deemed as forest fire and the total area of forest fires is calculated.
4) These analyses are carried out during the period subject to the inventory. Annual total of area of forest fires is calculated for each country or province. (data C)
5) Estimate the area of forest fires from other national statistics and so on (data D).
6) Cross-check the data C using the data D. The data C tend to underestimate compared to the data D because satellite imaging normally can not observe all the ground surfaces for 24 hours a day for 365 days of a year due to clouds and intervals in observation by the satellite. The area of forest fires that is underestimated should be uniformly distributed to the hours and areas that could not be observed due to clouds and other reasons.

7) When the data C overestimates compared with the data D, the overestimated area of forest fires should be uniformly eliminated from the data C. In such case, it is considered that fires did not occur during the hours and in areas that were not observed due to clouds and other reasons forest.
8) Using the total area of forest fires calculated above as activity data, emissions are calculated by multiplying the activity data with an emission factor.

8.2.2 Estimation of activity data

The activity data are the total area of each forest fire obtained from satellite image and the total area of forest fires obtained through correction.

8.2.3 Setting of emission factors

The emission factors from US-EPA are refined by phase of fire and other factors (Table 8.2-1).

Table 8.2-1 Emission factors for air pollutants from forest fires (Part 3)

Unit: kg / dry matter burned

Fire/Fuel Configuration	Phase[1)]	CO	CH_4	NMVOC	TSP	PM_{10}	$PM_{2.5}$	Mix Ratio
Broadcast logging slash								
Hardwood	F	44	2.1	3.8	13	7	6	0.33
	S	146	8.0	7.7	20	14	13	0.67
	Fire	112	6.1	6.4	18	12	11	-
Conifer								
Short needle	F	72	2.3	2.1	12	8	7	0.33
	S	226	7.2	4.2	19	15	14	0.67
	Fire	175	5.6	3.5	17	13	12	-
Long needle	F	45	1.5	1.7	9	6	6	0.33
	S	166	7.7	5.4	25	17	16	0.67
	Fire	126	5.7	4.2	20	13	13	-
Logging slash debris								
Dozer piled conifer No mineral soil	F	28	1.0	ND	5	4	4	0.90
	S	116	8.7	ND	14	7	6	0.10
	Fire	37	1.8	ND	6	4	4	-
10 to 30 % Mineral soil	S	200	ND	ND	25	ND	ND	ND
25 % organic soil	S	250	ND	ND	35	ND	ND	ND
Range fire								
Juniper slash	Fire[2)]	82	6.0	5.2	14	10	9	-
Sagebrush	Fire[2)]	103	6.2	6.9	23	15	13	-
Chaparral shrub communities	F	56	1.7	8.2	16	8	7	42
	S	133	6.4	15.6	23	13	12	58
	Fire	101	4.5	12.5	20	11	10	-
Line fire Conifer								
Long needle (pine)	Heading	200	ND	ND	50	40	ND	-
	Backing	125	ND	ND	20	20	ND	-
Palmetto/gallberry	Heading	150	ND	ND	17	15	ND	-
	Backing	100	ND	ND	15	15	ND	-
	Fire	ND	ND	ND	ND	8 - 22	ND	-
Chaparral	Heading	62	2.8	3.5	15	9	8	62
Grasslands	Fire	75	ND	0	10	10	ND	75

1) F: flaming, S: smoldering, Fire: weighted average of mix ratio of F and S

2) The values for Fire are used because of uncertain weighted average rate due to short and severe combustion phase.

Source: AP-42, 13.1 Wildfire and Prescribed Burning, Table 13.1-3

8.2.4 Temporal change and spatial distribution

8.2.4.1 Temporal change

The temporal change relies on temporal change of the satellite data.

In general, the start time and end time of a forest fire in each hotspot in the satellite image are checked and used as inventory. When the start and end times are not known due to clouds, the hour in the middle of the hours before and after that can be specified are used as the start and end times.

As a simpler method, a sample survey may be carried out for each hotspot to obtain average duration of forest fire, and the average duration may be applied to each hotspot.

When the area of a forest fire, which is obtained from the satellite image, is underestimated and the area of other forest fires (area of forest fire other than the area of forest fire obtained from the satellite image) needs to be calculated, the temporal change is evenly distributed to each hour of the year.

8.2.4.2 Spatial distribution

The spatial distribution relies on spatial resolution of satellite image data and land use classification data for each mesh.

The spatial distribution of the area of forest fires is identified based on the location information of hotspots that are classified as forest in land use for each mesh. Unlike temporal change, there is no simpler method to calculate spatial distribution.

When it is assumed that forest fires are taking place in the areas much larger than the areas of forest fires obtained from the satellite image, the spatial distribution is to be appropriately distributed to points that can not be observed due to clouds but field burning might take place.

But when the total area of forest fires confirmed in the satellite image is underestimated and the other area of forest fires needs to be calculated, the spatial distribution the other area may be evenly distributed to the total area of a country, province or prefecture.

9 Estimating emissions of air pollutants from the treatment and disposal of waste

9.1 Targets of estimation

The category of the estimation in the treatment and disposal of waste sector is classified into the following categories using 2006 IPCC Guidelines as reference: “Solid waste disposal”, “Biological treatment”, “Incineration”, “Wastewater treatment” and “Others.” Each of these categories is further classified into subcategories of solid waste disposal (landfill and etc. at a waste disposal site), biological treatment (composting and etc.), incineration by incinerators and open burning, waste water treatment, and others (man-made source and wild animals).

Among these, generation sources that are sources of the air pollutants (SO_2, NO_x, CO, NMVOC, NH_3 and PM) are estimated. That is, main emission sources are incineration of municipal solid waste (MSW), other industrial waste and commercial waste, and other burning (open burning in several countries in particular).

The targets of estimation include the above air pollutants and greenhouse gases (CO_2, CH_4, N_2O).

Landfill of wastes and waste water treatment both generate greenhouse gases such as CH_4 and N_2O, but are not important emission source of other air pollutants. For calculation of CH_4 and N_2O emissions from these sources, 2006 IPCC Guidelines should be referred. Storage of excreta in toilets (outside portable toilets) is often an important emission source of NH_3.

Table 9.1-1 Emission source category of air pollutants in the waste sector and the subject material

category	Subcategory	SO_x	NO_x	CO	NMVOC	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	CH_4	N_2O
Solid waste disposal		NA	NA	NA	○	NE	NE	NE	NE	NE	NE	NE	IPCC	IPCC
Biological treatment	Compost	NE	NA	NA	NE	○	NE	NE	NE	NE	NE	NE	IPCC	IPCC
	Sludge	NE	NA	NA	NE	○	NE	NE	NE	NE	NE	NE	IPCC	IPCC
Incineration	Incinerators	○	○	○	○	○	○	○	○	○	○	○	○	○
	Open burning	○	○	○	○	○	○	○	○	○	○	○	○	○
	Small incinerators and others	○	○	○	○	○	○	○	○	○	○	○	○	○
Waste water treatment		NA	NA	NA	○	NE	NE	NE	NE	NE	NE	NE	IPCC	IPCC
Others	Man-induced source	NA	NA	NA	NE	○	NE	NE	NE	NE	NE	NE	○	NE
	Wild animal	NA	NA	NA	NE	○	NE	NE	NE	NE	NE	NE	○	NE

Note: “IPPC” indicates categories that the emissions must be calculated in 2006 IPCC Guidelines.

“NE” is “Not Estimated”, “NA” is “Not Applicable.”

9.2 Solid waste disposal

9.2.1 Simple method

9.2.1.1 Outline of emission estimation method

Landfill gas from landfill sites contains NMVOC. CH_4 from solid waste landfills shall be estimated using 2006 IPCC Guidelines. N_2O from solid waste landfill is not estimated according to 2006 IPCC Guidelines.

9.2.1.2 Estimation of activity data

For landfill sites, the amount of landfill gas is required. This can be obtained from national statistics and statistics on waste. 2006 IPCC Guidelines specify detailed estimation method of the activity data and this guideline comply with them.

9.2.1.3 Setting of emission factors

The emission factor is shown in Table 9.2-1.

Table 9.2-1 Emission factor for landfill site

Subcategory	Technology identification	Air pollutant	emission factor	Unit
Landfill site	Landfill gas	NMVOC	5.65	g/m^3 landfill gas

Source: EMEP/EEA Guidebook

9.2.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

9.2.2 Detailed method

This category has no detailed method.

9.3 Biological treatment

9.3.1 Simple method

9.3.1.1 Outline of emission estimation method

NH_3 is emitted from compost production and sludge.

9.3.1.2 Estimation of activity data

For compost, the amount of organic wastes composted is comprehended. For sludge, the amount of sludge is used. These data are collected from national statistics and waste statistics. 2006 IPCC Guidelines specify detailed calculation procedures of the activity data, and the procedures of this guideline comply with them.

9.3.1.3 Setting of emission factors

The emission factors are shown inTable 9.3-1 .

Table 9.3-1 Emission factors for biological treatment

Subcategory	Technology identification	Air pollutant	Emission factor	Unit
Compost	Compost production	NH_3	0.24	kg/Mg organic waste
Sludge	Sludge spreading	NH_3	0.50	g/kg NH_3 in the sludge

Source: EMEP/EEA Guidebook

9.3.1.4 Temporal change and spatial distribution

1. ***Temporal change***

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. ***Spatial distribution***

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

9.3.2 Detailed method

This category has no detailed method.

9.4 Incineration

9.4.1 Simple method

9.4.1.1 Outline of emission estimation method

The simple method covers wastes such as “municipal waste”, “Industrial waste”, and “medical waste.”

Below are the calculation procedures for air pollutants from waste incineration:

1) Collect the activity data and data on the emission factors.
2) The activity data is the amount of wastes incinerated. 9.4.1.2 describes the calculation procedures for activity data.
3) Set an emission factor for each waste type and incinerator type. 9.4.1.3 shows the default emission factors.

4) Estimate the emissions of a pollutant by multiplying the total amount of incinerated wastes by incinerator type (including open burning) with the emission factor.

The calculation formula is the equation below. Attention should be paid that the activity data is the total amount of wastes incinerated.

$$\mathrm{Emissions} = \sum_{\mathrm{i}} \left(\mathrm{IW_i} \times \mathrm{EF_i}\right) \cdots\cdots\cdots (9.4\text{-}1)$$

Where:

Emissions are the emissions of air pollutant during the inventory calculation period;

i is the type of waste and incinerator;

$\mathrm{IW_i}$ is the total amount of type *i* waste incinerated (Gg/year);

$\mathrm{EF_i}$ is the emission factor for type *i* (kg per ton waste incinerated).

The emissions from other small-scale incineration of wastes (ex. Incineration of various biomass residues and fires) are calculated in “9.4.2 Detailed method”.

Article 9.4-1 Results of the estimation of air pollutant emissions from wastes in Vietnam

Table 9.4-1 shows the results of the estimation of air pollutant emissions from wastes in Vietnam. The emissions were calculated by multiplying the activity data with the emission factor. The activity data and the emission factors are shown in the below article.

Table 9.4-1 Results of emission calculation of waste disposal

Unit (ton/year)	2003	2004	2005	200	2007	2008
SO_x emission	396	401	407	412	417	423
NO_x emission	2,313	2,343	2,374	2,405	2,437	2,469
CO emission	32,205	32,629	33,059	33,495	33,937	34,384
NMVOC emission	11,499	11,650	11,804	11,959	12,117	12,277
NH_3 emission						
TSP emission	6,162	6,243	6,325	6,409	6,493	6,579
PM_{10} emission						
$PM_{2.5}$ emission						
BC emission	3,253	3,296	3,339	3,383	3,428	3,473
OC emission	344	348	353	358	362	367

9.4.1.2 Estimation of activity data

The activity data, which is the total amounts of incinerated waste, are estimated as follows;

Table 9.4-2 Calculation procedures for total amount of waste incinerated

Calculation process	Note
1) Collect data on the amount of waste.	Wastes are municipal waste, industrial waste, and medical waste.
2) If no data on the amount of municipal waste is available, the amount of municipal waste is estimated from the population of the country.	The estimation is a product of MSW generation rate per person (the default value for each country is in Annex 2A.1 of the 5th volume “Waste” in 2006 IPCC Guidelines) and the population.
3) Estimate the proportion of the municipal waste incinerated.	Annex2A.1 in 2006 IPCC Guidelines shows data on several countries, but for majority of the developing countries, for which there are no data by country, 5% is considered to be appropriate as

	the default value.
4) If no data is available for the amounts of industrial waste and medical waste, use 2006 IPCC Guidelines for estimation.	The estimation should be conducted according to ”2.2.3 Industrial waste” in Waste section of 2006 IPCC Guidelines.
5) Estimate the proportion of the industrial waste incinerated.	In this guideline, the default value is set as 5%, which is the default value for municipal waste.
6) Estimate the amount of waste incinerated for each incineration type.	Estimate the amount of waste incinerated for each processing type. There is no default value because the values are unique to the relevant country and region.
7) Estimate the amount of waste incinerated by open burning.	When appropriate incinerators seem to be unavailable, all the waste incinerated and considered burnt by open burning.

Article 9.4-2 Data on total waste amount in Vietnam

As the data on total waste amounts in Vietnam, only the figures for 2003 were available as below.

Table 9.4-3 Activity data for waste disposal

		2003
Municipal waste	**Municipal**	6,400,000
	Province	6,400,000
	Total	12,800,000
Non-toxic industrial waste	**Municipal**	1,740,000
	Province	770,000
	Total	2,510,000
Toxic industrial waste	**Municipal**	126,000
	Province	2,400
	Total	128,400
Hospital waste	**Municipal**	
	Province	
	Total	21,500

Source: The World Bank: "Vietnam Environment Monitor 2004 Solid Waste"

Article 9.4-3 Estimation of the total waste amount in Vietnam

Only the figures in 2003 are available for data on the total amount of wastes in Vietnam. Therefore, the total waste amounts of other years were calculated using the population increase rate as index. The data on the population of Vietnam is as below.

Table 9.4-4 Data on demographic change in Vietnam

		2003	2004	2005	2006	2007	2008
National population of Vietnam	Population	80,746,369	81,810,818	82,889,300	83,981,998	85,089,10	86,210,800
		Statistical value	Statistical value	Statistical value	Statistical value	Statistical value	Statistical value

Source: Vietnam statistics yearbook

Assuming the increase rate of the population as the increase rate of total amount of wastes, the totals of wastes are estimated as below.

Table 9.4-5 Activity data on waste disposal

		2003	2004	2005	2006	2007	2008
Municipal waste	**Municipal**	6,400,000	6,484,369	6,569,850	6,656,458	6,744,207	6,833,114
	Province	6,400,000	6,484,369	6,569,850	6,656,458	6,744,207	6,833,114
	Total	12,800,000	12,968,738	13,139,700	13,312,916	13,488,414	13,666,228
Non-toxic industrial waste	**Municipal**	1,740,000	1,762,938	1,786,178	1,809,724	1,833,581	1,857,753
	Province	770,000	780,151	790,435	800,855	811,412	822,109
	Total	2,510,000	2,543,089	2,576,613	2,610,579	2,644,993	2,679,862
Toxic industrial waste	**Municipal**	126,000	127,661	129,344	131,049	132,777	134,527
	Province	2,400	2,432	2,464	2,496	2,529	2,562
	Total	128,400	130,093	131,808	133,545	135,306	137,089
Hospital wastes	**Municipal**						
	Province						
	Total	21,500	21,783	22,071	22,362	22,656	22,955

Assumed that 5% of total amount of generated municipal wastes and non-toxic industrial wastes are burnt by open burning; toxic wastes are not burnt; 50% of hospital wastes are incinerated according to The World Bank: "Vietnam Environment Monitor 2004 Solid Waste."

9.4.1.3 Setting of emission factors

Table 9.4-6 shows emission factors for each waste type and each incinerator type.

Table 9.4-6 List of emission factors for waste disposal

	Emission factors (kg per ton waste incinerated)						
Waste/Incinerator Type	**SO_2**	**NOx**	**CO**	**NMVOC**	**NH_3 [d]**	**PM_{10}[c]**	**$PM_{2.5}$**
Municipal Wastes:							
--Mass burn refractory wall	1.73	1.23	0.685	0.02 [e]	0	12.6	-
--Modular excess air	1.73	1.24	-	-	0	12.6	-
--Modular starved air	1.61	1.58	0.15	-	0	1.72	-
--Refuse-derived fuel-fired	1.95	2.51	0.96	-	0	34.8	-
--Trench	1.25	-	-	-	0	18.5	-
--Open burning	0.5	3	42	3.34	0	19	17.4
Industrial/commercial:							
--Multiple chamber	1.25	1.5	5	1.5 [b]	0	3.5	-
--Single chamber	1.25	1	10	75 [b]	0	7.5	-

Source: GAP Forum Manual

[a] US EPA (1995) uncontrolled defaults unless otherwise indicated

[b] Includes methane

[c] Factors for PM_{10} not given by US EPA (1995); for default assume = TSP factor

[d] EMEP/CORINAIR (2004) - assume negligible

[e] EMEP/CORINAIR (2004) uncontrolled default

- No factor available

For emission factors of greenhouse gases such as CO_2, CH_4 and N_2O, Table 5.2 (CO_2) (Table 9.4-7 of this guideline), Table 5.3 (CH_4) (Table 9.4-8 of this guideline) and Tables 5.4 to 5.6 (N_2O) (Table 9.4-9 to Table 9.4-11 of this guideline) in Chapter 5 of "Volume 5: Waste" in 2006 IPCC Guidelines are used.

Table 9.4-7 CO_2 emission factors for waste incineration and open burning (Default value)

Parameters	Management practice	MSW	Industrial waste (%)	Clinical Waste (%)	Sewage Sludge (%)	Fossil liquid waste (%)
Dry matter content in % of wet weight			NA	NA	NA	NA
Total carbon content in % of dry weight			50	60	40 - 50	80
Fossil carbon fraction in % of total carbon content			90	40	0	100
Oxidation factor in % of carbon input	Incineration	100	100	100	100	100
	Open-burning	58	NO	NO	NO	NO

Source: 2006 IPCC Guidelines

Note: NA (Not Available), NO (Not Occurring)

Table 9.4-8 CH_4 emission factors for municipal solid waste incineration (Default value)

Type of incineration	Type of technology	CH_4 Emission Factors (kg/Gg waste incinerated on a wet weight basis
Continuous incineration	Stoker	0.2
	Fluidized bed	~0
Semi-continuous incineration	Stoker	6
	Fluidized bed	188
Batch type incineration	Stoker	60
	Fluidized bed	237

Source: 2006 IPCC Guidelines

Table 9.4-9 N_2O emission factors for municipal solid waste incineration (Default value)

Country	Type of Incineration	Type of Technology	Emission Factor for MSW (gN_2O/t MSW incinerated)	Weight basis
Japan	Continuous incineration	Stocker	47	Wet weight
		Fluidized bed	67	Wet weight
	Semi-continuous incineration	Stocker	41	Wet weight
		Fluidized bed	68	Wet weight
	Batch type incineration	Stocker	56	Wet weight
		Fluidized bed	221	Wet weight
Germany			8	Wet weight
Netherland			20	Wet weight
Austria			12	Wet weight

Source: 2006 IPCC Guidelines

Table 9.4-10 N_2O emission factors for industrial waste incineration (default value)

Country	Type of Waste	Type of Incineration/ Technology	Emission Factor for Industrial Waste (gN_2O/t waste)	Weight basis
Japan	Waste paper, waste wood		10	Wet weight
	Waste oil		9.8	Wet weight
	Waste plastic		170	Wet weight
	Sludge (except sewage sludge)		450	Wet weight
	Dehydrated sewage sludge		900	Wet weight
	High molecular weight flocculent	Fluidized bed incinerator at normal temperature	1508	Wet weight
		Fluidized bed incinerator at high temperature	645	Wet weight
		Multiple hearth	882	Wet weight
	Other flocculent		882	Wet weight
	Lime sludge		294	Wet weight
Germany	Sewage sludge		990	Dry weight
	Industrial waste		420	Wet weight

Source: 2006 IPCC Guidelines

Table 9.4-11 N_2O emission factors for other wastes and waste management (default value)

Type of waste	Technology/Management practice	Emission Factor (g N_2O/t waste)	Weight basis
MSW	Continuous us and semi-continuous incinerators	50	Wet weight
MSW	Batch-type incinerators	60	Wet weight
MSW	Open burning	150	Dry weight
Industrial waste	All type of incineration	100	Wet weight
Sludge (except sewage sludge)	All type of incineration	450	Wet weight
Sewage sludge	Incineration	990	Dry weight
		900	Wet weight

Source: 2006 IPCC Guidelines

Article 9.4-4 Emission factors for waste used in Vietnam

Emission factors for wastes in Vietnam are set as below.

Table 9.4-12 Emission factors for waste disposal in Vietnam (kg / ton waste incinerated)

Waste/Incinerator Type	SO_2	NOx	CO	NMVOC	TSP	PM_{10}	$PM_{2.5}$	BC	OC
Municipal Wastes: (no data on PM_{10} and $PM_{2.5}$)									
- Open burning	0.5	3	42	15	8			4.2	0.4
Industrial/commercial: (set as the same as Municipal Waste Open burning)									
- Open burning	0.5	3	42	15	8			4.2	0.4
Medical Waste Incineration: (BC and OC are set as the same as Municipal Waste Open burning.)									
Default value	0.5	3	42	0.7	8			4.2	0.4

9.4.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of "2.5 Temporal change and spatial distribution" of "2 Basic policy in estimating emission inventory of air pollutants".

9.4.2 Detailed method

9.4.2.1 Outline of emission estimation method

The detailed method for air pollutant emissions from waste incineration deals with waste incinerators. The emissions from open burning are dealt in "9.4.1 Simple method". In addition, the emission procedures for incineration of biomass related residues other than agricultural residues, cremation and other fires, which are minor emission sources related to waste incineration, are described.

In these calculation methods, as the same with large point source in "3 Estimating emissions of air pollutants from fuel consumption", similar questionnaire surveys will be required. That is, the basic survey format does not change with the fuel seed being changed to incinerated waste and with a different emission factor. As a result, the following information needs to be collected to estimate the emissions of the air pollutants.

1) Identification of the locations of domestic waste incinerators
2) Data on the total annual amount of wastes incinerated in the domestic incinerators
3) Data on hourly patterns of operations of the domestic incinerators

The estimation formula is the equation below as the same in "9.4.1 Simple method". The activity data is the total amount of waste incinerated, but it should be noted that the unit might differ for each waste type.

$$\mathrm{Emissions} = \sum_{i} \left(\mathrm{IW_i} \times \mathrm{EF_i} \right) \cdots\cdots\cdots (9.4\text{-}2)$$

Where:

Emissions are the emissions of air pollutant during the inventory estimation period;

i is the type of waste and incinerator;

$\mathrm{IW_i}$ is the total amount of type *i* waste incinerated;

$\mathrm{EF_i}$ is the emission factor for type *i*.

The activity data for waste incinerators is the total amount of waste incinerated by each type of waste incinerator (Mg waste/year) and each type of waste incinerator has its own emission factor (kg/Mg waste).

The activity data for small-scale waste incineration is the total amount of each incinerated waste (leaf burning, forest residues, orchard crop, weeds, and vine crops, backfire burning and headfire burning) (Mg waste/year). Simplified total amount of waste incinerated can be calculated by multiplying the total area of each agricultural land with the default value of 25 (kg/hectare). Each waste type has its own emission factor (kg/Mg waste).

The activity data for cremation is the number of cremations (body/year) and the total weight of animals cremated (Mg waste/year), and emission per unit for these activity data (kg/body and kg/Mg waste) is used as emission factor.

The activity data for car fires is the number of car fires. The emission factor is emission per car fire. The number of car fires is equal to the number of cars in car fire. For house fire, the number of house fires is required.

Emissions from open burning and greenhouse gases are calculated in "9.4.1 Simple method".

9.4.2.2 Estimation of activity data

The activity data for emissions from waste incinerators is the total amount of waste incinerated at each incinerator. The activity data is collected from the national statistics, relevant offices and ministries, related local government, questionnaire survey and interview survey.

Among the waste incinerated at incinerators, the amount of waste, for which the applicable waste incinerator cannot be identified, is considered an area source. This is equivalent to the case where: when the national total amount of incinerated wastes and the individual total amount of waste processed at several waste incinerators are available, the remaining of the national total of waste after subtraction of the total amounts of waste at individual facilities is deemed as an area source. If the specific (technical) incineration method used for these wastes can be identified, these can be estimated in "9.4.2 Detailed method". If the identification is not possible, the emissions can be estimated using "9.4.1 Simple method".

The activity data for cremation is the number of cremations (body/year) and the total weight of animals cremated (Mg waste/year), and this information is available from the national statistics agencies, crematorium associations, or may be obtained through direct contact with crematorium operators.

The activity data for small-scale waste incineration is the total amount of each incinerated waste (leaf burning, forest residues, orchard crop, weeds, and vine crops, backfire burning and headfire burning) (Mg waste/year). Simplified total amount of waste incinerated can be calculated by multiplying the total area of each agricultural land with the default value of 25 (kg/hectare). The activity data can be obtained from the national statistics and written surveys to related ministries and offices.

The activity data for car fires is the number of car fires. The emission factor is emission per car fire. The number of car fires is equal to the number of cars in car fire. For house fire, the number of house fires is required. This information can be obtained from the national statistics, questionnaire survey to relevant organizations, and interview survey.

The activity data for wild animals is estimated figures of the growth number. This information can be obtained through written survey to relevant organizations and expert judgment. The activity data for the air pollutants from human breath and perspiration is the population. The population available in the national statistics may be used.

9.4.2.3 Setting of emission factors

The priority should be to apply the waste incinerator emission factor of each waste incinerator. If appropriate emission factor is not available, the following emission factors may be used.

Table 9.4-13, Table 9.4-15 and Table 9.4-16 show the emission factors for the incineration of municipal waste. Table 9.4-14 shows abatement efficiencies for waste incineration.

Table 9.4-13 Emission factors for municipal waste incineration (kg/Mg waste)

Technology type	NO_x	CO	NMVOC	SO_x	TSP	PM_{10}	$PM_{2.5}$
Default value	1.8	0.7	0.02	0.4	0.3	0.23	0.15
Incineration of domestic or municipal wastes (except energy recovery) (uncontrolled)	1.8	0.7	0.02	1.7	18.3	13.7	9.2

Source: EMEP/EEA Guidebook (6.C.c Municipal waste incineration)

Table 9.4-14 Abatement efficiencies for municipal waste incineration (%)

Subcategory	Technology	Abatement efficiency
Acid gas abatement	SO_2	76 %
Particle abatement only	TSP	98 %
	PM_{10}	98 %
	$PM_{2.5}$	98 %
Particle and acid gas abatement	TSP	99.99 %
	PM_{10}	99.99 %
	$PM_{2.5}$	99 %
EU Waste Incineration Directive (WID) compliant plant	TSP	97 %
	PM_{10}	61 %
	$PM_{2.5}$	99 %

Source: EMEP/EEA Guidebook (6.C.c Municipal waste incineration)

Table 9.4-15 Emission factors for municipal waste incineration (Part 1) (kg/Mg waste)

Technology	NO_x	CO	NMVOC	SO_x	TSP	PM_{10}	$PM_{2.5}$
Mass Burn and Modular Excess Air Combustors							
Uncontrolled	1.83	0.232		3.2	12.6		
ESP	1.83	0.232		ND	0.105		
DSI/ESP				0.139	0.0295		
SD/ESP	1.83	0.232		0.079	0.0352		
DSI/FF	1.83	0.232		0.319	0.0895		
SD/FF	1.83	0.232		0.106	0.0311		
Mass Burn Waterwall Combustors							
Uncontrolled	1.83	0.233					
ESP	1.83	0.233					
DSI/FF	1.83	0.233					
SD/FF	1.83	0.233					
Mass Burn Rotary Waterwall Combustors							
Uncontrolled	1.13	0.383					
ESP	1.13	0.383					
DSI/FF	1.13	0.383					
SD/FF	1.13	0.383					

Source: AP-42

Note: ESP = Electrostatic Precipitator, DSI/ESP = Duct Sorbent Injection/Electrostatic Precipitator, SD/ESP = Spray Dryer/Electrostatic Precipitator, DSI/FF = Duct Sorbent Injection/Fabric Filter, SD/FF = Spray Dryer/Fabric Filter

Table 9.4-16 Emission factors for municipal waste incineration (Part 2) (kg/Mg waste)

Technology	NO_x	CO	NMVOC	SO_x	TSP	PM_{10}	$PM_{2.5}$
Mass Burn Refractory Wall Combustors							
Uncontrolled	1.23	0.685					
ESP	1.23	0.685					
DSI/ESP	1.23	0.685					
Modular Excess Air Combustors							
Uncontrolled	1.24	ND					
ESP	1.24	ND					
DSI/FF	1.24	ND					
Refuse-derived Fuel-fired Combustors							
Uncontrolled	2.51	0.96		1.95	34.8		
ESP	2.51	0.96		ND	0.517		
SD/ESP	2.51	0.96		0.799	0.0482		
SD/FF	2.51	0.96		0.221	0.0664		
Modular Starved-Air Combustors							
Uncontrolled	1.58	0.15		1.61	1.72		
ESP	1.58	0.15		1.61	0.174		
Open Burning	3	42	15	0.5	8		

Source: AP-42

Note: ESP = Electrostatic Precipitator, DSI/ESP = Duct Sorbent Injection/Electrostatic Precipitator, SD/ESP = Spray Dryer/Electrostatic Precipitator, DSI/FF = Duct Sorbent Injection/Fabric Filter, SD/FF = Spray Dryer/Fabric Filter

Table 9.4-17 and Table 9.4-21 show emission factors for industrial waste incineration. Table 9.4-18 to Table 9.4-20 show abatement efficiencies for industrial waste incineration.

Table 9.4-17 Emission factors for industrial waste incineration (kg/Mg waste)

Technology	NO_x	CO	NMVOC	SO_x	TSP	PM_{10}	$PM_{2.5}$
Default value	0.87	0.07	7.4	0.047	0.01	0.007	0.004
Incineration of industrial wastes (except flaring) (uncontrolled)	2.5	0.13	7.4	0.07	2.3	1.5	1
Incineration of sludge from waste water treatment (uncontrolled)	2.5	15.5	0.84	14	52	33.7	22.5

Source: EMEP/EEA Guidebook (6.C.b Industrial waste incineration)

Table 9.4-18 Abatement efficiencies for industrial waste incineration (Incineration of industrial wastes, Part 1)

Subcategory	Technology	Abatement efficiency
Low energy scrubber / Fabric filter	particle > 10μm	80 %
	10μm > particle > 2.5μm	77 %
	2.5μm > particle	77 %
Medium energy scrubber / Fabric filter	particle > 10μm	97 %
	10μm > particle > 2.5μm	95 %
	2.5μm > particle	92 %
Fabric filter	particle > 10μm	96 %
	10μm > particle > 2.5μm	94 %
	2.5μm > particle	94 %

Source: EMEP/EEA Guidebook (6.C.b Industrial waste incineration)

Table 9.4-19 Abatement efficiencies for incineration of industrial wastes (Incineration of industrial wastes, Part 2)

Subcategory	Technology	Abatement efficiency
Low energy scrubber	particle > 10μm	38 %
	10μm > particle > 2.5μm	34 %
	2.5μm > particle	96 %
High energy scrubber	particle > 10μm	68 %
	10μm > particle > 2.5μm	65 %
	2.5μm > particle	98 %
Dry sorbent injection / Fabric filter	particle > 10μm	93 %
	10μm > particle > 2.5μm	89 %
	2.5μm > particle	83 %
Dry sorbent injection / Carbon injection / Fabric filter	particle > 10μm	98 %
	10μm > particle > 2.5μm	98 %
	2.5μm > particle	96 %
Dry sorbent injection / Fabric filter / Scrubber	particle > 10μm	42 %
	10μm > particle > 2.5μm	36 %
	2.5μm > particle	96 %
Dry sorbent injection / Electrostatic precipitator	particle > 10μm	84 %
	10μm > particle > 2.5μm	82 %
	2.5μm > particle	82 %

Source: EMEP/EEA Guidebook (6.C.b Industrial waste incineration)

Table 9.4-20 Abatement efficiencies for industrial waste incineration (Incineration of sludge from waste water treatment)

Subcategory	Technology	Abatement efficiency
Low energy scrubber / Fabric filter	TSP	96 %
	SO_x	80 %
	NMVOC	44 %
Cyclone / impingement	TSP	99 %
Cyclone / venture	TSP	100 %
	NMVOC	85 %
Cyclone / venture / impingement	TSP	99 %
ESP - Fabric filter	TSP	100 %
ESP - Impingement	TSP	99 %
ESP – Venturi	TSP	97 %
Venturi / impingement	TSP	98 %
	SO_x	99 %
Venturi / impingement / wet ESP	TSP	100 %
Impingement	SO_x	98 %
	NMVOC	48 %
Venturi	SO_x	84 %

Note: ESP: electrostatic precipitator

Source: EMEP/EEA Guidebook (6.C.b Industrial waste incineration)

Table 9.4-21 Emission factors for industrial waste incineration (kg/Mg waste)

Technology	NO_x	CO	NMVOC	SO_x	TSP	PM_{10}	$PM_{2.5}$
Industrial/ Commercial							
Multiple chamber	1.5	5.0		1.25	3.5		
Single chamber	1.0	10.0		1.25	7.5		
Trench							
Wood	2.00	ND		0.05	6.5		
Rubber tires	ND	ND		ND	69.0		
Municipal refuse	ND	ND		1.25	18.5		
Fuel-fed single chamber	1.5	10.0		0.25	15.0		
Fuel-fed (modified)	5.0	5.0		0.25	3.0		
Domestic single chamber							
Without primary burner	0.5	150		0.25	17.5		
With primary burner	1.0	Neg		0.25	3.5		

Source: AP-42

Note: Neg = Negligible

Table 9.4-22 shows emission factors for sewage sludge incineration.

Table 9.4-22 Emission factors for sewage sludge incineration (kg/Mg waste)

Technology	NO_x	CO	NMVOC	SO_x	TSP	PM_{10}	$PM_{2.5}$
Multiple Hearth Sewage Sludge Incinerators							
Uncontrolled	2.5	15.5	0.84	14	52		
Cyclone			1.5	2.8	2.0		
Cyclone/ impingement					0.40		
Cyclone/ venture			0.22		0.25		
Cyclone/ venture/ impingement					0.31		
Fabric filter					0.002		
Impingement			0.78	0.32	0.70		
Venturi				2.3	1.6		
Venturi/ impingement				0.1	1.1		
Venturi/ impingement/ Wet ESP					0.20		
Fluidized Bed Sewage Sludge Incinerators							
Uncontrolled	0.88	1.1		0.15	230		
Cyclone/ venture/ impingement					0.5		
Impingement				0.30	0.13		
Venturi				9.2	0.57		
Venturi/ impingement				0.40	0.27		
Venturi/ impingement/ Wet ESP					0.10		
Uncontrolled					3.7		
Cyclone/ venture					1.9		
Impingement					0.82		
Venturi/ impingement					0.95		

Source: AP-42

Note: ESP = Electrostatic Precipitator

Table 9.4-23 and Table 9.4-25 show emission factors for medical waste incineration, and Table 9.4-24 shows removal rate for medical waste incineration.

Table 9.4-23 Emission factors for medical waste incineration (kg/Mg waste)

Technology	NO_x	CO	NMVOC	SO_x	TSP
Default value	1.4	2.8	0.7	1.4	0.5
Controlled air incinerator (uncontrolled)	1.8	1.5	0.7	1.1	2.3
Rotary kiln incinerator (uncontrolled)	2.3	0.19	0.7	0.54	17
Small on-site facilities without abatement technology	1.4	2.8	0.7	1.4	0.5
Clinical waste incineration (particle abatement only (de-dusting))	1.4	2.8	0.7	1.4	0.5
Incineration of hospital wastes (BAT for compliance with HWID)	1.4	2.8	0.7	1.4	0.5

Source: EMEP/EEA Guidebook (6.C.a Clinical waste incineration)

Table 9.4-24 Abatement efficiencies for medical waste incineration (%)

Technology	NO_x	CO	NMVOC	SO_x	TSP
Controlled air incinerator				92%	90%
Rotary kiln	0%	88%		59%	99%

Source: EMEP/EEA Guidebook (6.C.a Clinical waste incineration)

Table 9.4-25 Emission factors for medical waste incineration (kg/Mg waste)

Technology	NO_x	CO	NMVOC	SO_x	TSP	PM_{10}	$PM_{2.5}$
Controlled Air Medical Waste Incinerators							
Uncontrolled	1.78	1.48		1.09	2.33	1.51	1.01
Low Energy Scrubber/FF					0.455		
Medium Energy Scrubber/FF				0.188	0.0803		
FF				0.422	0.0876		
Low Energy Scrubber				1.04	1.45		
High Energy Scrubber				0.0129	0.741		
DSI/FF				0.192	0.169		
DSI/Carbon Injection/FF				0.357	0.0361		
DSI/FF/Scrubber				0.00757	1.34		
DSI/ESP					0.367		
Rotary Kiln Medical Waste Incinerator							
Uncontrolled	2.31	0.191		0.543	17.3		
SD/ Fabric Filter	2.63	0.0194		0.324	0.154		
SD /Carbon Injection/FF	2.45	0.025		0.15	0.0378		
High Energy Scrubber	2.04	0.030			0.427		

Source: AP-42

Note: FF = Fabric Filter, DSI = Dry Sorbent Injection, ESP = Electrostatic Precipitator, SD = Spray Dryer

Table 9.4-26 shows emission factors for cremation.

Table 9.4-26 Emission factors for cremation

Subcategory	Technology	Air pollutant	Emission factor	Unit
Cremation	Default value	NO_x	0.309	kg/body
		CO	0.141	kg/body
		NMVOC	0.013	kg/body
		SO_x	0.544	kg/body
		TSP	14.6	g/body
	Sheep burn using an air curtain incinerator	NMVOC	2	kg/Mg waste
		NH_3	1.9	kg/Mg waste
		TSP	2.18	kg/Mg waste
		PM_{10}	1.53	kg/Mg waste
		$PM_{2.5}$	1.31	kg/Mg waste
	Cow burn using an air curtain incinerator	NMVOC	2	kg/Mg waste
		NH_3	1.9	kg/Mg waste
		TSP	0.897	kg/Mg waste
		PM_{10}	0.628	kg/Mg waste
		$PM_{2.5}$	0.538	kg/Mg waste

Source: EMEP/EEA Guidebook (6.C.d Cremation)

Table 9.4-27 and Table 9.4-28 show emission factors for small-scale waste incineration. These are small-scale open burning, which are not included in field burning of crop residues, savanna fires and forest fires. Municipal waste, industrial waste, and medical waste are not included.

Table 9.4-27 Emission factors for small-scale waste incineration (Part 1)

Subcategory	Technology	Air pollutant	Emission factor	Unit
Small-scale waste incineration	Default value	NMVOC	2	kg/Mg waste
		NH_3	1.9	kg/Mg waste
		TSP	1.4	kg/Mg waste
		PM_{10}	0.979	kg/Mg waste
		$PM_{2.5}$	0.839	kg/Mg waste
Small-scale waste incineration in agriculture and forestry (open burning)	leaf burning (open burning of agricultural wastes)	NMVOC	2	kg/Mg waste
		NH_3	1.9	kg/Mg waste
		TSP	15.2	kg/Mg waste
		PM_{10}	10.6	kg/Mg waste
		$PM_{2.5}$	9.1	kg/Mg waste
	Incineration of forest residues	NMVOC	2	kg/Mg waste
		NH_3	1.9	kg/Mg waste
		TSP	4	kg/Mg waste
		PM_{10}	2.8	kg/Mg waste
		$PM_{2.5}$	2.4	kg/Mg waste
	Incineration of residues in orchard crops	NMVOC	2	kg/Mg waste
		NH_3	1.9	kg/Mg waste
		TSP	4.47	kg/Mg waste
		PM_{10}	3.13	kg/Mg waste
		$PM_{2.5}$	2.68	kg/Mg waste

Source: EMEP/EEA Guidebook (6.C.d Cremation)

Table 9.4-28 Emission factors for small-scale waste incineration (Part 2)

Subcategory	Technology	Air pollutant	Emission factor	Unit
Small-scale waste incineration in agriculture and forestry (open burning)	Weed incineration	NMVOC	2	kg/Mg waste
		NH_3	1.9	kg/Mg waste
		TSP	5.74	kg/Mg waste
		PM_{10}	4.02	kg/Mg waste
		$PM_{2.5}$	3.45	kg/Mg waste
	Incineration of residues of vine crops	NMVOC	2	kg/Mg waste
		NH_3	1.9	kg/Mg waste
		TSP	3	kg/Mg waste
		PM_{10}	2.1	kg/Mg waste
		$PM_{2.5}$	1.8	kg/Mg waste
	Backfire burning	NMVOC	2	kg/Mg waste
		NH_3	1.9	kg/Mg waste
		TSP	9.17	kg/Mg waste
		PM_{10}	6.42	kg/Mg waste
		$PM_{2.5}$	5.5	kg/Mg waste
	Headfire burning	NMVOC	2	kg/Mg waste
		NH_3	1.9	kg/Mg waste
		TSP	15.9	kg/Mg waste
		PM_{10}	11.1	kg/Mg waste
		$PM_{2.5}$	9.54	kg/Mg waste

Source: EMEP/EEA Guidebook (6.C.d Cremation)

Table 9.4-29 shows the emission factors for BC (Black carbon) and OC (Organic Carbon) from waste. These are set as below according to “A technology-based global inventory of black and organic carbon emission from combustion” (Tami C. Bond, etc 2004).

$$EF_{BC} = EF_{PM} \times F_{1.0} \times F_{BC} \times F_{cont} \quad \cdots\cdots (9.4\text{-}3)$$

$$EF_{OC} = EF_{PM} \times F_{1.0} \times F_{OC} \times F_{cont} \quad \cdots\cdots (9.4\text{-}4)$$

Where:

EF_{PM}: the bulk PM emission factor (g/kg)

$F_{1.0}$: the fraction of the emissions with diameters smaller than one micrometer

F_{BC}: the fraction of the fine particulate matter that is black carbon

F_{OC}: the fraction of the fine particulate matter that is organic carbon

F_{cont}: the fraction of fine PM that penetrates the control device

The ratio between organic matter (OM) and organic carbon (OC), as R_{org}, is not considered here.

Table 9.4-29 Emission factors for BC and OC

Waste (Fuel)	BC	OC
Power	0.013 (g/kg dry matter)	0.002 (g/kg dry matter)
Industry	0.013 (g/kg dry matter)	0.002 (g/kg dry matter)
Residential	4.2 (g/kg dry matter)	0.4 (g/kg dry matter)
Transport and other End Uses	(open) 5.5 (g/kg dry matter)	(open) 5.5 (g/kg dry matter)

Source: “A technology-based global inventory of black and organic carbon emissions from combustion” Tami C. Bond, etc., (Journal of Geophysical Research Vol.109 2004)

Table 9.4-30 lists the emission factors for other waste.

Table 9.4-30 Emission factors for other wastes

Subcategory	Technology	Air pollutant	Emission factor	Unit
Car fire		TSP	2.3	kg/fire
		PM_{10}	2.3	kg/fire
		$PM_{2.5}$	2.3	kg/fire
House fire	Detached house	TSP	0.14	kg/fire
		PM_{10}	0.14	kg/fire
		$PM_{2.5}$	0.14	kg/fire
	Terrace house	TSP	0.06	kg/fire
		PM_{10}	0.06	kg/fire
		$PM_{2.5}$	0.06	kg/fire
	Complex housing	TSP	0.04	kg/fire
		PM_{10}	0.04	kg/fire
		$PM_{2.5}$	0.04	kg/fire
	Industrial building fire	TSP	0.03	kg/fire
		PM_{10}	0.03	kg/fire
		$PM_{2.5}$	0.03	kg/fire

Source: EMEP/EEA Guidebook

9.4.2.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

9.5 Wastewater treatment

9.5.1 Simple method

9.5.1.1 Outline of emission estimation method

NMVOC is emitted from waste water treatment. CH_4 and N_2O are also emitted from waste water treatment process, but 2006 IPCC Guidelines should be referred to for this emission.

$$\text{Emissions} = \text{AD} \times \text{EF} \quad \cdots\cdots (9.5\text{-}1)$$

Where:

Emissions are the emissions of air pollutant during the inventory estimation period.

AD is the amount of wastewater treatment. (m^3)

EF is the emission factor (mg/m^3 waste water)

9.5.1.2 Estimation of activity data

The activity data is the total amount of wastewater treatment (m^3).

9.5.1.3 Setting of emission factors

Table 9.5-1 shows the emission factor.

Table 9.5-1 Emission factor for Wastewater treatment

Subcategory	Technology	Air pollutant	Emission factor	Unit
Wastewater treatment	Wastewater treatment process	NMVOC	15	mg/m^3 waste water

Source: EMEP/EEA Guidebook

9.5.1.4 Temporal change and spatial distribution

1. *Temporal change*

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. *Spatial distribution*

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

9.5.2 Detailed method

This category has no detailed method.

9.6 Others

9.6.1 Simple method

9.6.1.1 Outline of emission estimation method

NH_3 emissions from outdoor portable toilets, emissions of CH_4 and NH_3 from wild animals and human breath and perspiration are included.

The calculation formula for the air pollutants from vital activities by wild animals and human is the below equation as in "9.4.1 Simple method". The activity data for wild animals is the estimated figure of the growth number. The emission factor is emission per the number of animals. The activity data for human breath and perspiration is the population and the emission factor is emission per population.

$$\mathrm{Emissions} = \sum_{\mathrm{i}} \left(\mathrm{IW_i} \times \mathrm{EF_i} \right) \cdots\cdots (9.6\text{-}1)$$

Where:

Emissions are emissions of air pollutant during the inventory calculation period,

i indicates a type of wild animal and human,

IW_i is the number of wild animals and human population,

EF_i is the emission factor for type *I*.

9.6.1.2 Estimation of activity data

The activity data for NH_3 emissions from latrines (simple outdoor non-flush toilets) can be set as below. For domestic non-flush toilets in house, the number of people in an average family in the same home is used as the activity data. For public latrines, the average of daily users is the activity data.

For wild animals, estimated values from existing investigation and statistics may be used.

9.6.1.3 Setting of emission factors

Table 9.6-1 and Table 9.6-2 show the emission factors.

Table 9.6-1 Emission factor for other wastes

Subcategory	Technology	Air pollutant	Emission factor	Unit
Human	latrines	NH_3	1.6	kg/person/year

Source: EMEP/EEA Guidebook

Table 9.6-2 Emission factors for emissions from wild animals

Subcategory	Technology	Air pollutant	emission factor	Unit
Wild animals	Deer (red deer and reindeer) (assumed life weight is 100kg)	CH_4	25	kg/animal year
		NH_3	1.1	kg/animal year
	Moose (assumed life weight is 350kg)	CH_4	50	kg/animal year
		NH_3	2.2	kg/animal year
	Red deer (assumed life weight is 15kg)	CH_4	4	kg/animal year
		NH_3	0.2	kg/animal year
	Boar	CH_4	1.5	kg/animal year
		NH_3	1	kg/animal year
	Bird (assumed life weight is 0.8kg)	NH_3	0.12	kg/animal year
	Large bird (assumed life weight is 2.4kg)	NH_3	0.36	kg/animal year
	Human (breath and perspiration)	CH_4	0.1	kg/person year
		NH_3	0.05	kg/person year

Source: EMEP/EEA Guidebook

9.6.1.4 Temporal change and spatial distribution

1. Temporal change

Temporal change is shown in Table 2.5-1 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

2. Spatial distribution

Spatial distribution is shown in Table 2.5-2 of “2.5 Temporal change and spatial distribution” of “2 Basic policy in estimating emission inventory of air pollutants”.

9.6.2 Detailed method

This category has no detailed method.

10 Estimating emissions of air pollutants from natural sources

10.1 Estimating NMVOC emissions from vegetation

10.1.1 Outline of emission estimation method

Using EMEP/EEA Guidebook[10] and US-EPA BEIS[11] as reference, a method for that data is commonly available in East Asia is selected.

ENVOC emissions from vegetation differ depending on species, are proportionate to biomass, and vary according to short-term temperature and solar radiation changes. (EMEP/EEA, 2009)

Methods to estimate the biomass of each species over a wide area are still under development, and there is no database encompassing the total biomass in the whole of East Asia. Also, since there are only a handful of measurement samples of NMVOC emission from the vegetation organisms in East Asia, there is no emission factor database encompassing species across East Asia.

Therefore, in this chapter, a method is selected in which calculation can be carried out using commonly available data for East Asia; that is, a method in which the total area of each land-use is multiplied by the emission factor for each land-use. For the land-use data, "Global Map Data/Global Land Cover (hereinafter, referred as GLCNMO)[12]", for the emission factors, the emission factors of BEIS by US-EPA is used respectively.

If any detailed local data[13] is available, it may be used for the calculation.

10.1.2 Estimation of activity data

Using a land-use map or land-use data, the national total area of each land-use and its distribution are calculated.

In the guidelines, "GLCNMO" is selected because of three reasons: its free public access (anyone can use it for free), its range (covering the entire East Asia), and its detailness (30 seconds of both latitude and longitude: equivalent of 1km).

First, download the land-use data from GLCNMO, and extract the area for emission estimation. Then, calculate the total area for each application range of the correction factor described hereinafter and for each unit of the spatial distribution analysis.

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[10] 11.C Other natural sources, EMEP/EEA emission inventory guidebook 2009
http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

[11] BEIS (Biogenic Emissions Inventory System, US-EPA)
http://www.epa.gov/AMD/biogen.html

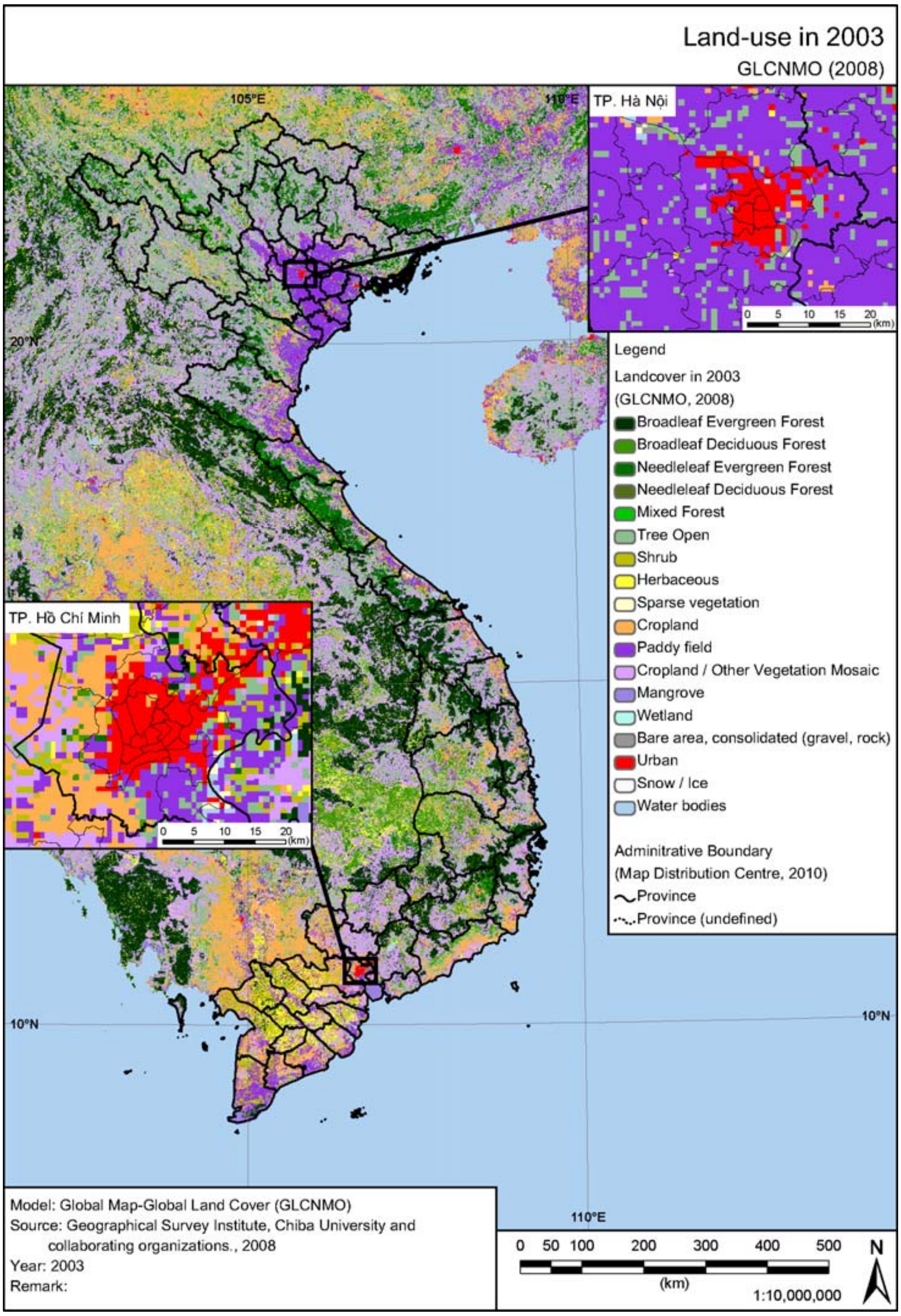
[12] "Geospatial Information Authority of Japan, Chiba University and collaborating organizations." The Global Land Cover by National Mapping Organizations (GLCNMO) is the data of 1km (30 arc seconds) grid with 20 land cover items. The data were created by using MODIS data observed in 2003 (TERRA Satellite). The classification is based on LCCS developed by FAO. Therefore, it is possible to compare and integrate GLCNMO with other land cover data products based on LCCS.
http://www.iscgm.org/browse.html

[13] Followings are potential data of detailed local data;

1) Land-use data developed by remote sensing using local control data
2) Emission factors developed by NMVOC emission measurement on local vegetation (it should be developed by database of huge samples since individual variation of variation of vegetation is not small.)

Article 10.1-1 Land-use data used for the calculation of emissions from Vietnam

Figure 10.1-1 shows the land-use map used in the study for Vietnam and Table 10.1-1 shows the total area of each land-use. The total area, correction factor, and emission are calculated for each grid because a grid in GLCNMO was used as the unit for the spatial distribution analysis. Although this map shows the land-uses and tables for the areas outside of Vietnam, the total areas and emission factors by land-use are calculated only for the areas within Vietnam territory.



Land-use in 2003

GLCNMO (2008)

Model: Global Map-Global Land Cover (GLCNMO)
Source: Geographical Survey Institute, Chiba University and collaborating organizations., 2008
Year: 2003
Remark:

Data name: GLCNMO

Source: Geospatial Information Authority of Japan, Chiba University and collaborating organizations

Figure 10.1-1 Land-use map of Vietnam

Table 10.1-1 Area for each land-use classification in Vietnam

Unit: km^2

Code	Land-use identification	Area (km^2)	Proportion (%)
1	Broadleaf Evergreen Forest	40,699	12.3%
2	Broadleaf Deciduous Forest	11,183	3.4%
3	Needleleaf Evergreen Forest	26,993	8.2%
4	Needleleaf Deciduous Forest	27	0.0%
5	Mixed Forest	1,922	0.6%
6	Tree Open	77,388	23.5%
7	Shrub	16,861	5.1%
8	Herbaceous	14,450	4.4%
9	Herbaceous with Sparse Tree/Shrub	0	0.0%
10	Sparse vegetation	1,081	0.3%
11	Cropland	21,843	6.6%
12	Paddy field	36,558	11.1%
13	Cropland / Other Vegetation Mosaic	74,078	22.5%
14	Mangrove	1,327	0.4%
15	Wetland	0	0.0%
16	Bare area, consolidated（gravel, rock)	312	0.1%
17	Bare area, unconsolidated (sand)	0	0.0%
18	Urban	1,017	0.3%
19	Snow / Ice	0	0.0%
20	Water bodies	4,101	1.2%
	Total	329,840	100.0%

Source: Within GLCNMO's land-use data, the total areas of the area surrounded by national borders and coastlines in 2010 administrative boundary data by the Map Distribution Centre, MONRE, are calculated.

10.1.3 Setting of emission factors

As in BEIS and EMEP/EEA, the NMVOC emissions per unit area is calculated by multiplying "NMVOC emission per unit area by vegetation and land-use under the standard conditions (30°C, PAR=1000μmol/m^2/s)" and the "correction factor".

10.1.3.1 Emission per unit area by land-use under the standard conditions

Table 10.1-2 shows the total emission per unit area by land-use under the standard conditions (30°C,PAR=1000μmol/m^2/s).

In this table, BEIS's land-use classifications corresponding to GLCNMO's land-use classifications are selected and BEIS's emission factors by land-use are cited. Since MODIS is a sensor developed as AVHRR's succession, the land-use classifications by AVHRR were preferably chosen among BEIS's land-use classifications. In BEIS, there is no common "Mangrove" classification, and instead there are three refined classifications of "Avicennia (black mangrove)", "Laguncularia (white mangrove)" and "Rhizophora (red mangrove)". However, since the emission factors of these 3 classifications have the same values, the emission factors are used as is.

Table 10.1-2 Emission factors for each land-use classification

Unit: μg/m^2/h

GLCNMO		BEIS			
Code	Land-use identification	Land-use identification	Emission factor		
			Isoprene	Mono-terpene	Other NMVOC
1	Broadleaf Evergreen Forest	Hardwood forest (AVHRR, Guen)	8730.0	436.0	882.0
2	Broadleaf Deciduous Forest	Southeast/Western Deciduous Forest	10750.0	530.0	910.0
3	Needleleaf Evergreen Forest	Conifer forest (AVHRR, Guen)	1550.0	1564.0	1036.0
4	Needleleaf Deciduous Forest	Conifer forest (AVHRR, Guen)	1550.0	1564.0	1036.0
5	Mixed Forest	Mixed forest (AVHRR, Guen)	11450.0	1134.0	1140.0
6	Tree Open	Open forest	56.2	140.5	84.3
7	Shrub	Scrub	37.8	94.5	56.7
8	Herbaceous	Grass	56.2	140.5	84.3
9	Herbaceous with Sparse Tree/Shrub	Desert shrub (AVHRR, Guen)	65.0	94.5	56.7
10	Sparse vegetation	Barren	0.0	0.0	0.0
11	Cropland	Misc crops	7.6	19.0	11.4
12	Paddy field	Rice	102.0	255.0	153.0
13	Cropland / Other Vegetation Mosaic	Woodland/cropland (AVHRR, Guen)	2550.0	663.0	2053.0
14	Mangrove	Avicennia (black mangrove) Laguncularia (white mangrove) Rhizophora (red mangrove)	42.5	42.5	693.7
15	Wetland	Herbaceous Wetlands (AVHRR, Guen)	1050.0	660.0	770.0
16	Bare area, consolidated (gravel, rock)	Barren	0.0	0.0	0.0
17	Bare area, unconsolidated (sand)	Barren	0.0	0.0	0.0
18	Urban	BEIS2 other urban (assume 20% grass)	11.2	28.1	16.9
19	Snow / Ice	Snow	0.0	0.0	0.0
20	Water bodies	Water	0.0	0.0	0.0

Source: The land-use corresponding to GLCNMO (Geospatial Information Authority of Japan, Chiba University and collaborating organizations) are selected from BEIS (Biogenic Emissions Inventory System Version 2.3, US-EPA). The source of the values of the emission factors is BEIS.

10.1.3.2 Correction factor

As in the detailed method in EMEP/EEA and in BEIS, the correction factors are defined as below.[14]

1. Correction factor “γ” for Isoprene

Correction factor “γ” for Isoprene is calculated by the following equation:

$$\gamma = \mathrm{CLiso} \cdot \mathrm{CTiso} \qquad (10.1\text{-}1)$$

γ	Correction factor to multiply the emission factor
CLiso	Correction factor by light shown in the equation (10.1-2)
CTiso	Correction factor by temperature shown in equation (10.1-3)

$$C_{Liso} = \frac{\alpha \cdot C_{L1} \cdot L}{\sqrt{1+\alpha^2 L^2}} \qquad (10.1\text{-}2)$$

α	0.0027
C_{L1}	1.066
L	PAR flux (μmol m^{-2} s^{-1}) (hereinafter described)

$$C_{Tiso} = \frac{\exp(C_{T1}(T-T_S)/RT_ST)}{1+\exp(C_{T2}(T-T_M)/RT_ST)} \qquad (10.1\text{-}3)$$

C_{T1}	95000 (J mol^{-1})
C_{T2}	230000 (J mol^{-1})
R	Gas constant (8.314 J K^{-1} mol^{-1})
T_S	Standard temperature (303 K)
T_M	314 K
T	Leaf temperature (K) (hereinafter described)

2. Correction factor “γ” for monoterpen and other NMVOC

Correction factors “γ” for monoterpen and other NMVOC are calculated using the following equation.

$$\gamma = \exp(\beta \cdot (T - T_S)) \qquad (10.1\text{-}4)$$

β	0.09 K^{-1}
T_S	Standard temperature (303 K)
T	Leaf temperature (K) (hereinafter described)

---

[14] The simple method in EMEP/EEA uses correction factors by country described in EMEP/EEA. Since it is not simple to calculate correction factors by country in East Asia region, this guideline shows a method complying with the detailed method in EMEP/EEA.

3. PAR flux

Since a correction factor is not proportionate to PAR flux, the correction factor should be calculated from hourly measurement values and not from daily average values. However, if hourly distribution data of PAR flux is not available, the correction factor may be calculated from the total solar radiation amount measured by a meteorological observatory using the following equation.[15]

$$L = 90.4 \cdot \mathrm{Sun} \qquad (10.1\text{-}5)$$

Sun Total solar radiation amount (kWh/m^2/day)

4. Leaf Temperature

The leaf temperature is defined as the air temperature. Since a correction factor is not proportionate to the leaf temperature, the correction factor should be calculated from hourly measurement values. However, if hourly distribution data is not available, it may be calculated suing the monthly mean temperature data for descriptive purpose (EMEP/EEA, 2009).

10.1.4 Temporal change and spatial distribution

10.1.4.1 Temporal change

Since a correction factor is not proportionate to PAR flux, the correction factor should be calculated from hourly measurement values not from daily average values. However, if hourly change data is not available, 1 for daytime and 0 for nighttime are used for the correction by solar radiation amount and the monthly average temperature may be used for temperature (the detailed method in EMEP/EEA, 2009).

10.1.4.2 Spatial distribution

Emissions are calculated for each region using the land-use data used for the activity data, the solar radiation amount data, and temperature data of each region.

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[15] For the conversion of total insolation amount into the photon flux density, 4.57μmol/s/W (McCree, 1972) is used to calculate the constant, and for the rate of PAR flux, 47.5%, which is the mid-value of 45 to 50% shown in EMEP/EEA, 2009 is used.

Article 10.1-2 Data on solar radiation amount and leaf temperature used for the calculation of emissions from Vietnam

1) PAR flux

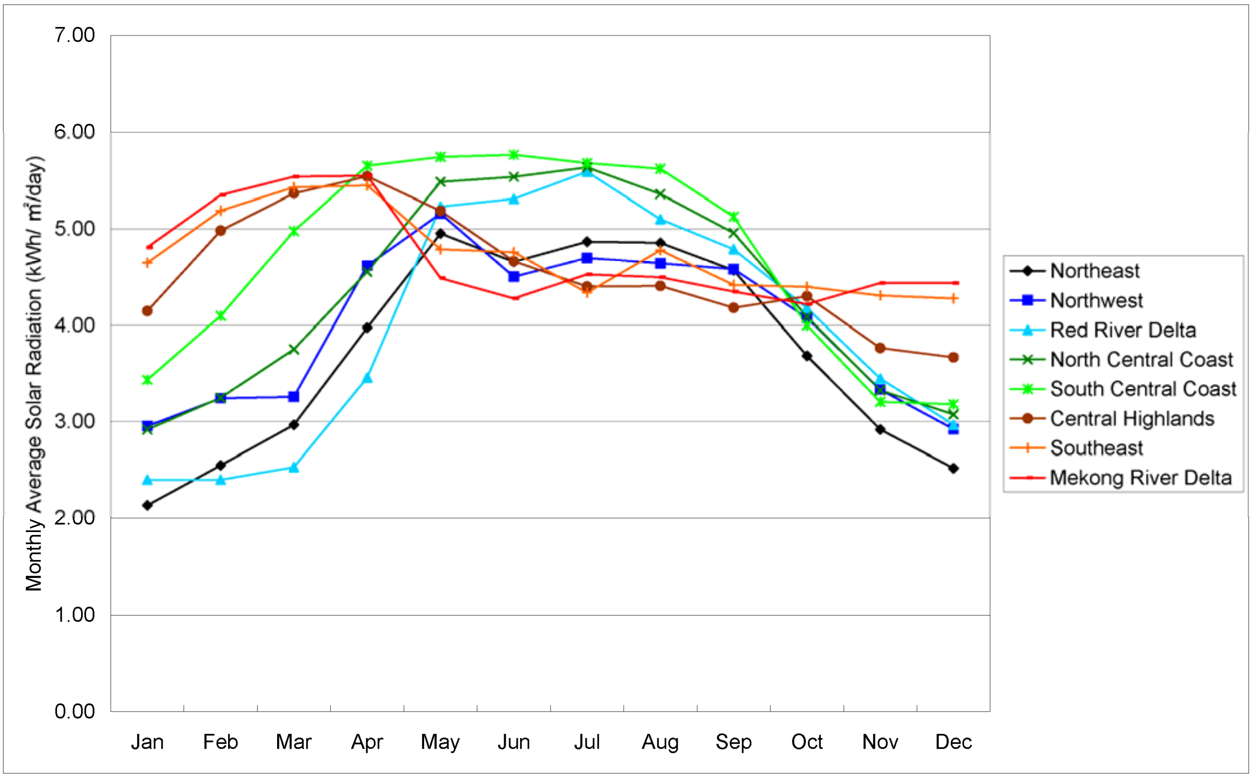
Table 10.1-3 and Figure 10.1-2 show the average solar radiation amounts by region in Vietnam.

Table 10.1-3 Monthly average solar radiation amount by region

Unit: kWh/m^2/day

Region	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Northeast	2.14	2.55	2.97	3.98	4.95	4.66	4.87	4.86	4.57	3.69	2.92	2.52
Northwest	2.96	3.25	3.26	4.62	5.16	4.51	4.70	4.65	4.59	4.08	3.34	2.93
Red River Delta	2.40	2.40	2.53	3.46	5.23	5.31	5.59	5.10	4.79	4.18	3.45	2.97
North Central Coast	2.92	3.25	3.75	4.56	5.49	5.54	5.64	5.36	4.96	4.09	3.33	3.08
South Central Coast	3.44	4.10	4.98	5.65	5.74	5.77	5.68	5.62	5.13	4.00	3.21	3.18
Central Highlands	4.15	4.98	5.37	5.54	5.19	4.67	4.40	4.41	4.18	4.30	3.77	3.67
Southeast	4.65	5.19	5.43	5.45	4.79	4.76	4.34	4.78	4.42	4.40	4.31	4.28
Mekong River Delta	4.81	5.35	5.54	5.55	4.49	4.28	4.53	4.50	4.35	4.22	4.44	4.44

Source: The table was prepared from the regional averages based on ”Investigation on the renewable energy use in Thailand, Indonesia, Malaysia, Philippines and Vietnam and the present and the future of the relevant policies, by New Energy and Industrial Technology Development Organization.”



Source: The table is prepared from the regional averages based on ”Investigation on the renewable energy use in Thailand, Indonesia, Malaysia, Philippines and Vietnam and the present and the future of the relevant policies, by New Energy and Industrial Technology Development Organization.”

Figure 10.1-2 Monthly average amount of solar radiation by region

2) Leaf temperature

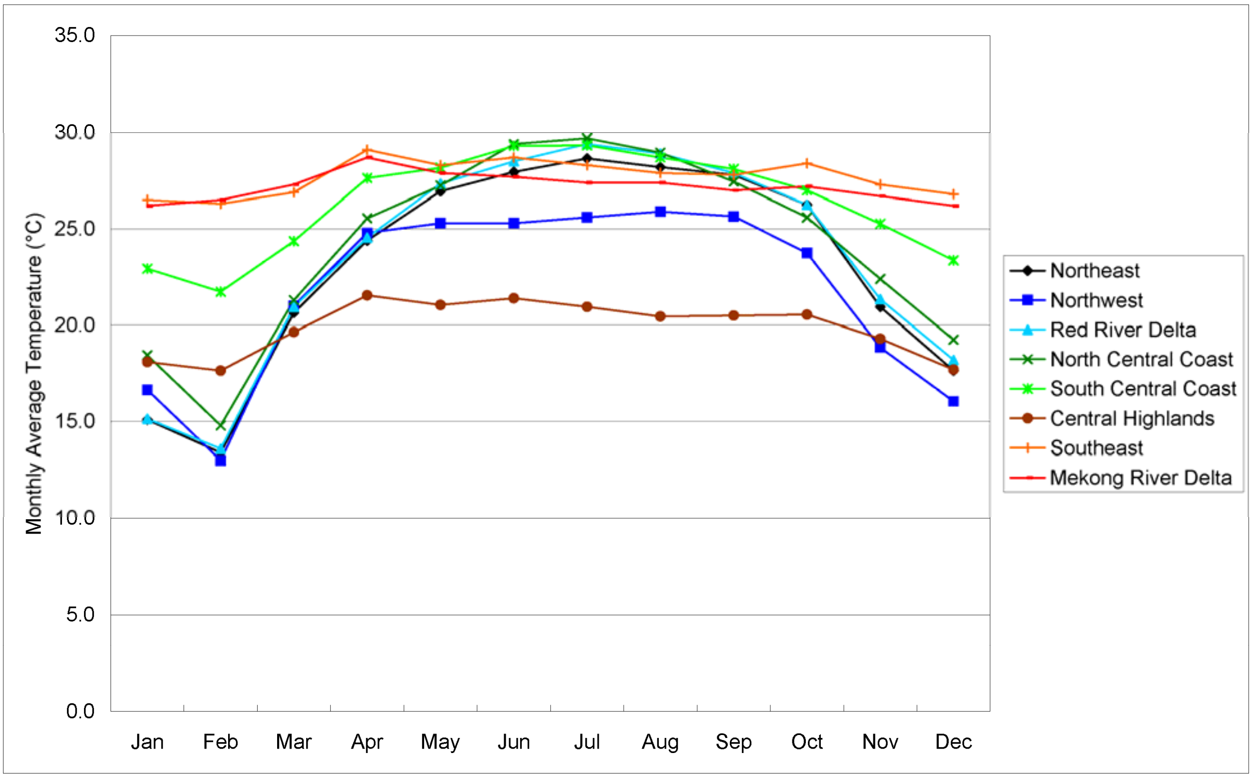
Table 10.1-4 and Figure 10.1-3 show the monthly average temperatures by region in Vietnam.

Table 10.1-4 Monthly average temperatures by region

Unit: °C

Region	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Northeast	15.1	13.4	20.7	24.4	27.0	28.0	28.7	28.2	27.8	26.3	21.0	17.7
Northwest	16.7	13.0	21.0	24.8	25.3	25.3	25.6	25.9	25.7	23.8	18.9	16.1
Red River Delta	15.2	13.6	21.0	24.6	27.4	28.5	29.4	28.9	27.9	26.3	21.4	18.2
North Central Coast	18.5	14.8	21.3	25.6	27.3	29.4	29.7	29.0	27.5	25.6	22.4	19.3
South Central Coast	22.9	21.7	24.4	27.6	28.2	29.3	29.3	28.7	28.1	27.0	25.3	23.4
Central Highlands	18.1	17.7	19.7	21.6	21.1	21.4	21.0	20.5	20.5	20.6	19.3	17.7
Southeast	26.5	26.3	26.9	29.1	28.3	28.7	28.3	27.9	27.8	28.4	27.3	26.8
Mekong River Delta	26.2	26.5	27.3	28.7	27.9	27.7	27.4	27.4	27.0	27.2	26.7	26.2

Source: The table is prepared based on the regional averages based on the monthly average temperatures of major cities from "Statistical Yearbook of Vietnam, 2008" (General Statistics Office of Vietnam)



Source: The table is prepared based on the regional averages based on the monthly average temperatures of major cities from "Statistical Yearbook of Vietnam, 2008" (General Statistics Office of Vietnam)

Figure 10.1-3 Monthly average temperatures by region

10.2 Estimating SOx emissions from volcanoes

10.2.1 Outline of emission estimation method

The target of air pollutant from volcanoes is only SO_2.

Estimation method of SOx emissions from volcanoes is based on EMEP/EEA Guidebook (11.A Volcanoes).

According to the study of Halmer et al., 2002[16], the SO_2 emissions from volcanoes globally account for 10 to 15% of the emissions from man-induced source. Also there are much accumulated data on the SO_2 emissions from volcanoes using Cospec (Correlation Spectrometer) and TOMS (Total Ozone Mapping Spectrometer). Because of information availability, above, SO_2 is discussed for air pollutant emissions from volcanoes.

SO_2 emissions from volcanoes can be classified into explosive emissions and non-explosive emissions. The latter includes continuous emissions from fumaroles and geysers, and is considered to be more important than the former. However, it is difficult to assess the latter. Here mainly explosive emissions are estimated for SO_2.

For volcanic eruptions, emissions from a volcano at a subduction zone (a boundary zone where a tectonic plate sink under another tectonic plate) may be 10 to 100 times less than that of a volcano at a zone other than a subduction zone.

Based on the data on SO_2 emissions from volcanic explosions measured in the past, the relation between the scale of volcanic explosions and SO_2 emissions was analyzed. The scales of explosions are indicated by VEI (Volcanic Explosive Index), and the information on VEI of individual volcanic explosion over the past 200 years is catalogued in the Smithsonian Global Volcanic Network.

The SO_2 emissions is to be calculated by searching the VEI of the volcanic explosions in the target year and then applying the SO_2 emission by zone and VEI.

10.2.2 Estimation of activity data and setting of emission factors

The scale of each volcanic explosion (VEI) is considered to be the activity data in this section; these values are catalogued at the Smithsonian Global Volcanic Network. (www.volcano.si.edu/gvp/) The scale of each volcanic explosion in the target year may be searched in this database.

Volcanic Sulfur Dioxide Index (VSI), which is corresponding to VEI, is summarized in Halmer et al., (2002).

SO_2 inventory can be developed through assessment of the information on the time, the location, the height of the volcanic smoke, and VEI for each volcanic explosion from the Smithsonian database and the information on SO_2 emissions from Table 10.2-1.

10.2.3 Temporal change and spatial distribution

The spatial distribution and the temporal change may be set based on the longitude and latitude of a volcanoes and the start and end time of the eruption from the Smithsonian database.

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[16] Halmer M. M., Schmincke H.-U. And Graf H.-F. (2002), ‘The annual volcanic gas into the atmosphere, in particular into the stratosphere: a global data set for the past 100 years’, Journal of Volcanology and Geothermal Research’

Table 10.2-1 Volcanic Explosive Index (VEI) and volcanic SO_2 emission index (VSI)

VSI (volcanic SO_2 emission index)	0	1	2	3	4	5	6	7	8
Subduction zone (thousand ton-SO_2)	< 1	1-8	8-60	60-800	200-2000	1000-16000	16000-120000	120000-1000000	> 1000000
Other zone (thousand ton-SO_2)	< 160	160 - 600	600 - 2000	2000 - 8000					
VEI (Volcanic Explosive Index)	0	1	2	3	4	5	6	7	8
Description	Non-explosive	Small	Moderate	Moderate	Large	Very large	Very Large	Very Large	Very Large
Height of volcanic smoke (km)	< 0.1	0.1 - 1	1 - 5	3 - 15	10 - 25	> 25	> 25	> 25	> 25
Volume of tephra*) (m^3) (Arc only)	$< 10^4$	10^4-10^6	10^6 - 10^7	10^7 - 10^8	10^8 - 10^9	10^9 - 10^{10}	10^{10} - 10^{11}	10^{11} - 10^{12}	10^{12} - 10^{13}

*) General term for pyroclastic material discharged from the crater during eruption

Source: Halmer et al., 2002

10.3 Estimating NH_3, NOx emissions from soils

The target air pollutants in the natural soil sub-sector are NH_3 and NOx.

This section deals with NH_3 and NOx emitted from natural soils, and NH_3 and NOx emitted due to N-species contained in livestock excreta and fertilizers applied to land are estimated in “Chapter 7 Agricultural activity.”

For estimation of the NH_3 emission, the method, which was used to improve the NH_3 inventory for the simulation of secondary generation of particulate matters, was selected.[17]

This report reviewed the existing papers and summarizes about NH_3 estimation methods and the emission factors.

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[17] An Improved Ammonia Inventory for the WRAP Domain, 2004, Mansell G.E. and Chitjian M.

For estimation of NOx emissions, the estimation method for NOx emissions from non-agricultural land in EMEP/EEA Guidebook is adopted.

In both NH_3 and NOx emission estimation methods, the emission factor by land-use is applied and the emissions may vary depending on the climate conditions.

Since the different reports and guidebooks were used as reference, there is no consistency between the estimation methods for NH_3 and NOx emissions.

10.3.1 Estimation of activity data and setting of emission factors

The emission factor is the emission per unit area by land use, and the activity data is the area for the land use.

1. NH_3

Table 10.3-1 shows the NH_3 emission factors by land-use.

These emission factors are to be adjusted according to the soil condition using the following adjustment equation (Potter et al., 2001[18]).

$$EF_{adj} = EF * (1-M)\left\{\frac{1}{\left[1+10^{\left(0.09018+2729.92/T_S-C*pH\right)}\right]}\right\} \cdots\cdots\cdots (10.3\text{-}1)$$

EF_{adj} : Adjusted Emission factor

EF : Emission factor (Table 10.3-1)

M : Soil moisture ratio

T_s : Soil temperature (K)

C : pH adjustment constant (= 1.3)

In a sample case in the United States, a database for soil pH, and the calculation results of a numerical weather model (MM5) are available for the soil moisture ratio and the soil temperature. The soil temperature may be obtained using atmosphere temperatures and the estimation equation in Table 10.3-2.

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[18] Potter, C., Krauter C., and Klooster S., 2001, 'Statewide Inventory Estimates of Ammonia Emissions from Native Soils and Chemical Fertilizers in California' Prepared for the California Air Resources Board. June 2001

Table 10.3-1 NH_3 Emission factor for each land-use classification

Land-use classification	Emission factor ($Kg\text{-}NH_3/km^2/year$)	Source
Water surface, snow and ice surface	0	Supposition
Urban area	10	Battye et al. (2003)1), Built-up
Barren lands	10	Battye et al. (2003)1), Barren Lands
Deciduous forest	174	The average value of Forests in Battye et al. (2003)1) and Oak Forest, Temperate Forest / Woodland / Shrub land in Chinkin et al. (2003)2)
Indeciduous forest	54	The average value of Forests in Battye et al. (2003)1) and Oak Forest, Temperate Forest in Chinkin et al. (2003)2) Chinkin et al. (2003)2)
Mix forest	114	The average value of deciduous forest and indeciduous forest
Shrub / grassland	400	Temperate Forest / Woodland / Shrub land in Chinkin et al. (2003)2) and Shrub land in Battye et al. (2003)1)
Fruit farm / vineyard	0	Estimated based on the manure applied
Grazing land	0	Estimated based on the manure applied and livestock excreta
Crop land	0	Estimated based on the manure applied
Fallow soil	205	The average value of Grasslands in Battye et al. (2003)1) and Barren Lands
Wetland	400	Temperate Forest / Woodland / Shrub land in Chinkin et al. (2003)2) and Shrub land in Battye et al. (2003)1)

1) Battye W., Aneja, V.P., and Roelle P.A., 2003, ‘Evaluation and Improvement of Ammonia Emission Inventories’, Atmospheric Environment, 37, p. 3873-3883

2) Chinkin L.R., Ryan P.A., and Coe D.L., 2003, ‘Recommended Improvements to the CMU Ammonia Emission Inventory Model for Use by LADCO”. Prepared Lake Michigan Air Directors Consortium.

2. NOx

In the simple method in EMEP/EEA Guidebook, the background NO emission factor in non-agricultural land is set as 0.1ng NO-N/m^2/second = 0.113kg NO/km^2/year. This can be used as the minimum value.

In this section, the detailed method is selected, but this detailed method is originally the method used in the version 2 of Biogenic Emissions Inventory System (BEIS-2). (Williams et al., 1992[19]) In this method, NO emission is estimated using the following equation.

$$F_{NO} = A * \exp(0.071 * T_S) \qquad \text{(10.3-2)}$$

F_{NO} : NO Emission factor (ng-N/m^2/s)
T_s : Soil temperature (°C)
A : Constant for each land-use from experiments (Table 10.3-2)

Table 10.3-2 Constants obtained from experiments (Novak and Pierce, 1993)

Land-use	Constant	Soil temperature estimation equation using air temperature T_s: Soil temperature (°C), T_a: Air temperature (°C)
Grassland/grazing land	0.9	$T_s = 0.67T_a + 8.8$
Woodland	0.07	$T_s = 0.84T_a + 3.6$
Marsh	0.004	$T_s = 0.92T_a + 4.4$

Note: Valid when $0 < T_s < 35$ (°C)

Source: Novak-J, Pierce-T., 1993, 'Natural Emissions of Oxidant Precursors', Water, Air, and Soil Pollution, 67, p. 57–77, 340, 342–352, 353

EMEP/EEA Guidebook states that when the soil temperature is 0 degree or lower the emission factor at the temperature of 0 degree should be applied. Therefore, when the temperature is 35 degree or higher the emission factor at the temperature of 35 degree might be recommended.

Also, emissions of NOx from grazing land can be estimated from this table, but the emissions from grazing land shall be estimated in the section for agricultural activity, and are not estimated here.

10.3.2 Temporal change and spatial distribution

1. NH_3

The spatial distribution is defined by the spatial distribution of a land-use classification.

The temporal change is defined by the temporal change of the soil moisture ratio and the soil temperature in the equation (10.3-1).

2. NOx

The spatial distribution is defined by the spatial distribution of a land-use classification.

The temporal change is defined by the temporal change of the soil temperature in the equation (10.3-2).

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[19] Williams-E, Guenther-A, Fehsenfeld-F., 1992, 'An Inventory of Nitric Oxide Emissions from Soils in the United States', Journal of Geophysical Research, 97, p. 7511–7519

11 Future tasks

11.1 Development of East Asia-specific emission factors

1) Necessity of the emission factor development

This guideline was created using GAP Forum Manual as its base and citing from EMEP/EEA Guidebook, IPCC Guideline, and USEPA's AP-42 as needed. However, the emission factors used in these manuals and guidelines have been developed based on the measurements mostly in Europe and the United States. These factors do not necessarily reflect the conditions of East Asia, and in some cases the application of this emission factor to East Asia is not appropriate. For example, NMVOC emissions from vegetation are assumed to be largely different depending on vegetation type, but there is only limited information available on the plants growing in East Asia. Also, some emission factors were adjusted for the application in East Asia, but there are only a limited number of the emission factors for specified air pollutants and sectors. In many cases there was no option but to use such emission factors. There is an example where an adjustment was made the emission factor: the total amount of N-species from livestock excreta was changed to that in East Asia for the emission factor for NH_3 from livestock excreta.

On the other hand, as described in Chapter 1, the emissions of air pollutants and GHGs in East Asia account for a large portion of the emissions globally and such trend will increase further due to the drastic economic grown in the region.

Therefore, the development of emission factors reflecting the conditions in East Asia and their utilization and dissemination in guidelines are important tasks. For example, there is a case in Bangkok, Thailand, where driving modes and emission factors for air pollutants and GHGs were developed with research cooperation from Japan (Article 11.1-1).

For a emission calculation using the simple method, it is a common practice to apply an emission factor to consolidated activity data, but in order to set an appropriate emission factor for the simple method the emission calculation based on a technology-base emission factor and the composition ratio of each technology will be required. For example, in the case of the NH_3 emission factor for input of fertilizers containing N-species, first, NH_3 emission are calculated using the total input of nitrogen for each fertilizer type and the emission factor for each fertilizer type. Then, the NH_3 emissions are divided by the total input of nitrogen fertilizers to create the simple emission factor for the total input of nitrogen fertilizers in the region. In addition to the fertilizer types, temperatures and the soil pH levels in the region may be taken into consideration to develop the emission factor. In the end, in order to obtain the emission factor to be used in the simple method, emission estimation using the detailed method will be required.

As described the above, what is important is to carry out measurements in East Asia, to calculate emissions using the emission factors based on such measurements and to develop the East Asia-specific emission factors. Through the development of such emission factors, emission estimations in East Asia become more refined.

2) Selection of emission factor for development

Upon the development of the emission factors, the emission factors subject to the development should be selected in advance. The selection should be based on the analysis of elements that influence the emission factors and on the attributable fraction of pollutant/sector emissions to which the emission factors will be applied.

Regarding the elements that influence the emission factors, for example, it is assumed that there will be no major error for the emission factor in manufacturing industry (combustion related) when the emission factors for the facility using the technology available in the country is used. Also, the judgment on whether the existing emission factors can be applied to may differ depending of the type of fuel. For example, it is assumed that there would be a higher chance of possible application of the existing emission factor for natural gas than for heavy oil, and for heavy oil than for coal. In the case of coal combustion facilities, emission factors for the same type of facilities may be largely different depending on the characteristics of coal and the combustion management of each facility.

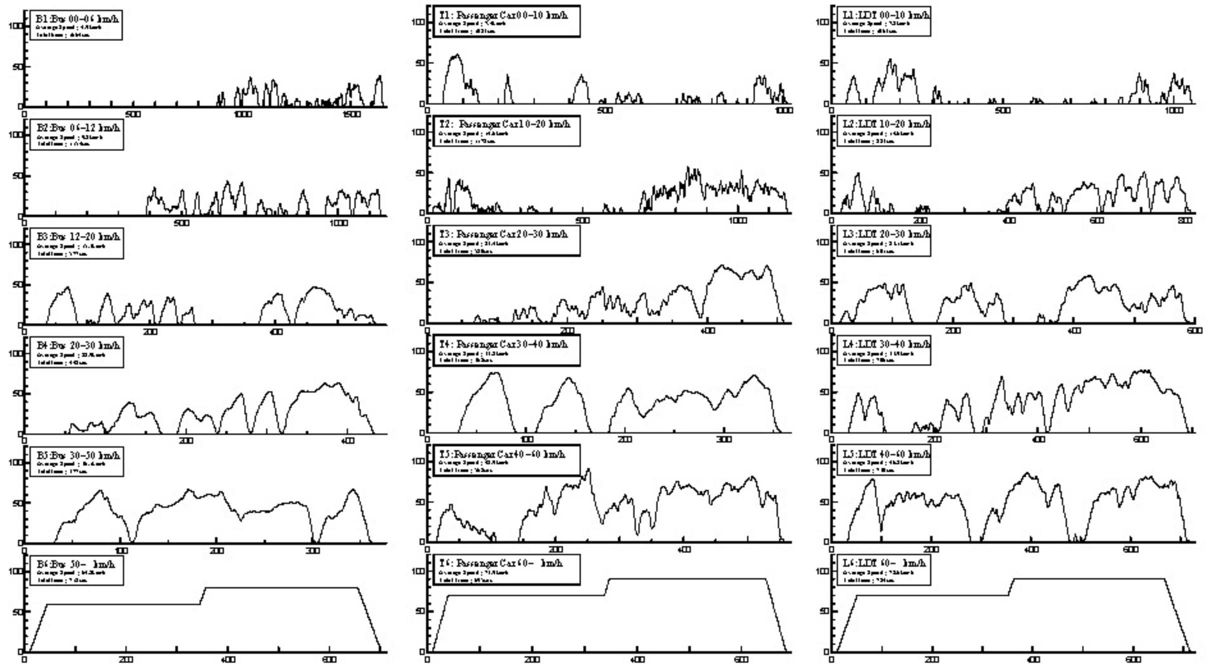
With regard to cars, it is assumed that the existing emission factor models can relatively be applied since cars manufactured in the developed countries are globally sold and used. However, there are cases where used-cars are employed and the travel distance of the cars are very long, and in some cases the exhaust-gas treatment equipment adopted in the developed countries are removed. Considering that the motorization in East Asia is rapidly expanding, the development of the region-specific emission factors is necessary.

With regard to the emission factors related to natural sources such as agriculture and vegetation, in general, it is assumed that the application of the emission factors measured under the conditions of soils, climate and weather in the temperature zone and subarctic zone is limited. In particular, for emission factors by plant type and crop type, it is very difficult to estimate when the emission factor of the subject country are not available.

From the above perspective, in addition to the assessment and compiling of the accuracy of the existing emission factors, it is a necessary attempt to compile the parameters such as countries that develop the inventory, facility conditions and natural conditions in order to evaluate the necessity of the emission factor development in a comprehensive manner.

Article 11.1-1 Development of driving modes and emission factors in Bangkok metropolitan area

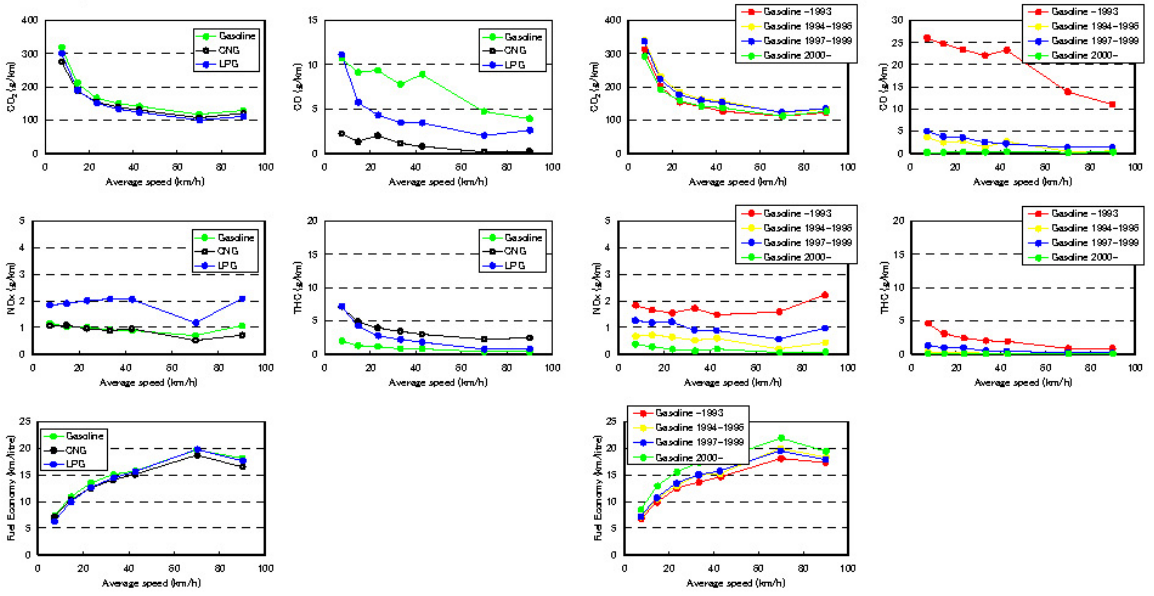
Under the Ministry of Land, Infrastructure, Transport and Tourism of Japan, the Japan Transport Cooperation Association developed the automobile driving modes and emission factors for air pollutants and CO_2 in the metropolitan area of Bangkok.



(Buses) (Passenger car) (Light Duty Truck)

Figure 11.1-1 Automobile driving mode in the metropolitan area of Bangkok

- Passenger car



(Passenger car by type of fuel) (Passenger car by engine age)

Figure 11.1-2 Emission factors for passenger car in the metropolitan area of Bangkok

Source: Estimation of Mobile Source CO_2 Emission in Bangkok Metropolitan Area, Thailand– Development of Driving Cycles and Emission Factor -, R. Matsumoto et al., BAQ 2004

11.2 Dissemination of the guidelines and refinement of the emission inventory

It can be said that the dissemination of guidelines and the refinement of emission inventories are deeply interrelated. To begin with, the development and dissemination of guidelines itself is not the purpose, but the final objective is to refine the emission inventories in East Asia as a result of the development and dissemination.

For those who have no experience in developing emission inventory, it is difficult to develop an inventory on their own after a guideline is handed to them. In order to develop the inventory in the target country and disseminate the guideline, Japan’s support to the target country is indispensable. As a ways of support, experts may be dispatched to the target county to develop the emission inventory and people in charge in the target country may be invited to Japan to attend seminars. It is effective to set up a online help desk for the inventory guideline in a website or through email.

In effort to make the guideline user-friendly, feedback from users in the target country is important. The guideline should be regularly updated based on such feedback. The update of the guideline is important considering other guidelines and manuals cited in this guideline will be updated. Users will trust and utilize the guideline that is updated as needed to include new information, which help to disseminate the guideline. The support for the target country to develop the inventory must be provided in order to disseminate the guideline when there are no international framework such as the Kyoto Protocol and the Convention of Long-Range Transboundary Air Pollution for IPCC Guidelines and EMEP/EEA Guidebook.

In order to refine emission inventory, not only the development of emission factors but also the improvement in assessment accuracy of activity data is required. In some countries, statistic data necessary for emission estimation may not be developed. Even if the statistic data is available, the accuracy of the statistic data may be problematic.

One approach to secure the accuracy and the development of statistic data as activity data is to actually develop emission inventory. If possible, the comparison of emission estimation results from calculations based on different activity data and by different methods is an effective way to check the accuracy. In addition, the comparison of estimation results of the country in different years and the comparison with estimation results of neighboring countries are useful for the accuracy check of the emission estimations as well.

In view of the development of activity data, the dissemination of this guideline, the comparison of the results of the emission inventory development utilizing this guideline, and the feedback from the comparison will facilitate to further refine the emission inventory.

Through the synergy of the three components: the update of the guideline; support for inventory development; development of East Asia-specific emission factors, the final objectives of the dissemination of the guideline and the refinement of the emission factors can be achieved. (Figure 11.2-1)

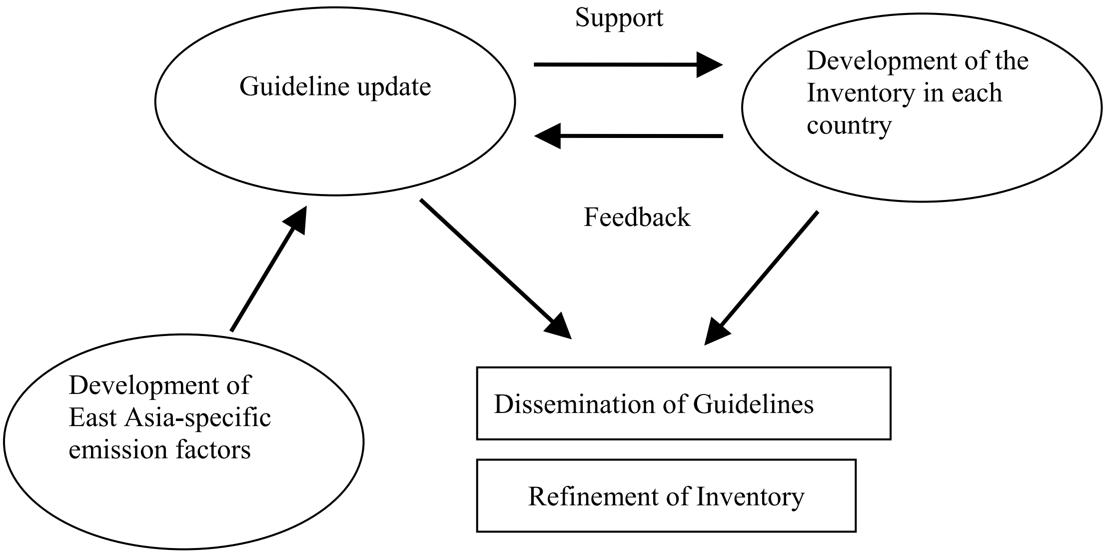


Figure 11.2-1 Dissemination of the guidelines and the refinement of the emission inventory

11.3 Improvement in usability

1. Development and distribution of spreadsheet

IPCC Guideline and others have spreadsheet attached, and users can calculate an emission inventory simply by inputting necessary data into the sheet. Considering user-friendliness that this spreadsheet can provide, it is desirable to develop a spreadsheet for this guideline as well.

However, the spreadsheet has a drawback that it may hinder the users from correctly understanding the calculation method. Also, there are users who don’t like to use a mechanical spreadsheet. The creation of the spreadsheet itself is not sufficient enough, but the spreadsheet should be incorporated into the dissemination activities such as the aforementioned support to develop the inventory or it should be treated as a tool to facilitate such activities.

On the other hand, the creation of spreadsheet provides another benefit of ensuring the necessary transparency: one of the requirements for the inventory is that other people should be able to see what kind of data an inventory was based on and how the inventory was developed. In other words, an inventory should be developed in a way that other people can trace back the inventory.

The more detailed an estimation method becomes, the more complicated it becomes to describe the data and calculation equations that were used in a report. If a spreadsheet is available for the report together with the data used, it would be easier to ensure the transparency of the processes.

Therefore the spreadsheet should be developed as a means to improve the user’s usability.

2. Check tree for main emission source and attributable fraction by pollutant and by sector

There are cases where no reliable initial inventory is available and there is no activity data or detailed breakdown. In such cases, a special investigation may be required in order to calculate the air pollutant emissions in a sector or sub-sector where the available information is limited. If the decision to implement such investigation can be made mechanically, that would reduce efforts for inventory development, in particular, efforts to collect data for the activity data.

To provide a specific image, it is to create a flow chart that can display the necessity of a calculation and an investigation at several phases by inputting basic information such as the existence of specified industry sectors, the total production, and the fuel types in manufacturing business.

But even for this approach, as in the aforementioned development of emission factors, for which the data on facility type, production technology and abatement technology are consolidated, it will require to accumulate sample cases of inventory development across multiple countries and regions.

After the calculation results for the emission inventory of each pollutant are accumulated and consolidated, various decisions can be made easily: whether emission estimation for each pollutant and each sector should be conducted after the identification of major emission sources based on the attributable fraction by pollutant and sector; and whether the simple method is to be applied or whether the detailed method is to be applied.

Providing such check tree for major emission source and the contribution ratio by pollutant and sector leads to improvement in the user's convenience.

11.4 Inventory development through the integrated procedure

Upon the development of this guideline, the objective was calculation of air pollutant and GHGs emissions based on the same activity data using a same calculation method.

However, for example, when there is inconsistency between the fuel consumption data, which is from questionnaire surveys conducted for the calculation of air pollutant emissions from LPS, and the existing statistic data, the fuel consumption of LPS is used on a priority basis in principle. On the other hand, according to the method in IPCC Guidelines, it is common practice to use fuel consumption in the existing data for the calculation of CO_2 emissions from a combustion system. If there are differences between the results of the questionnaire surveys and the statistic data on the fuel combustion even after the authenticity of both data is confirmed, it is preferable to add correction to the data; however, the decision is made on case by case basis.

Essentially, it is desirable to develop emission inventories for both air pollutants and GHGs based on the same activity data and by an integrated calculation method. Or, even when it is considered advisable to use different activity data due to different characteristics of air pollutants, the activity data should be adjusted to be equivalent.

For example, when the CO_2 emissions from cars is calculated using the fuel consumption as activity data and the NOx emissions from the cars is calculated using the total driving distance as the activity data, it is assumed that the difference between the fuel consumption used for the CO_2 emissions and the corresponding fuel consumption for NOx should be corrected; the fuel consumption for NOx can be estimated from the total driving distance and the fuel efficiency.

There is the concept of co-benefit which aims to simultaneously reduce both air pollutants and GHGs. With regard to the air pollution, it means to simultaneously reduce emissions of air pollutants and GHGs. In addition, this concept will let us discuss cost-effectiveness of measures and choose the most suitable measure after taking into account the emissions of both the air pollutants and GHGs. When such analysis and discussion is conducted, the emission inventory should be an emission inventory for which both air pollutants and GHGs are calculated in a integrated manner. In this sense, it is important to develop an emission inventory based on the method in which air pollutants and GHGs are treated in a integrated manner.

Appropriate design of the emission calculation method also makes it possible to calculate many types of air pollutant and GHG basically with the same activity data and a change in the emission factor only. By this, the coherence of the inventory over multiple years can be maintained and the transparency is also ensured.

11.5 Linkage with the simulation model

This guideline deals NMVOC as a matter subject to calculation, but the chemical composition of NMVOC is not covered. The resolution of NMVOC into chemical components is an operation that is positioned at the border between the development of an emission inventory and the simulation.

On the other hand, when an emission inventory is used as input data for a simulation model, the chemical composition of NMVOC might be required in some cases other than the temporal change and the spatial distribution. In the chemistry-transport model among simulation models, the generation of O_3 and particulate matters is predicted by solving the simplified equation for chemical reaction in the atmosphere. In these chemical equations, detailed chemical matters are classified into a several chemical substance groups for simplification and then calculations are conducted. Therefore, NMVOC for each sector and subsector is required to be broken down into chemical composition for input data of these models.

Although such chemical composition data is only available at a limited number of sources such as USEPA’s SPECIATE database and EMEP/EEA Guidebook, it is one of the remaining tasks to describe these matters in the guideline.